Canada's Independent Agri-Food "Think-Tank"

Agronomic, Economic and Environmental Impacts of the Commercial Cultivation of Glyphosate Tolerant Soybeans in Ontario

FINAL REPORT

Prepared for: Council for Biotechnology Information (Canada)

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Date: July 3, 2002

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1.0 Background

Glyphosate tolerant (GT) soybeans appear to be popular among many Ontario farmers. For example, Statistics Canada reports that 23% of the 2001 soybean acreage was planted to GT varieties, up from 18% in 2000. However, the environmental impact of GT seeds is perceived as controversial in the minds of some members of the public. This manifests itself in the form of public action on behalf of some activist groups, and a demand for products not containing GT soybeans. The apparent contradiction between producer preferences and public attitudes lies in a general lack of knowledge surrounding the environmental impact of GT soybeans. In this regard, the specific impact of GT soybeans in Ontario is unknown.

Two recent studies (Hin et al., and American Soybean Association) investigated the impacts of GT technology on soybean production in the United States. Similar studies have not been conducted that measure the agronomic, economic and environmental impacts of GT soybean technology in Canada. Based on the forgoing, an analogous study measuring these impacts in Ontario[1] agriculture is warranted.

1.1 Purpose and Objectives

The purpose of this study is to assess the agronomic, economic and environmental impacts of Glyphosate tolerant soybeans in Ontario by conducting similar analyses as Hin et al. and ASA, but using Ontario data. As such, the study will provide a measurement of the agronomic, economic and environmental impacts of GT soybean technology.

The principal objectives of the study are:

- To establish the significance of GT soybean technology in Ontario;
- To identify the differences between conventional and Glyphosate tolerant soybean growing systems;
- To determine producers' rationale for use of GT technology;
- To determine the impact of GT technology on:
    - tillage practices;
    - farm profitability;
    - ecosystem biodiversity.

[1] The impacts are being assessed from an Ontario perspective because Ontario represents 80% of the seeded area and production of soybeans in Canada.

1.2 Methods

Previous studies in the US have sought to measure the environmental impact of GT soybean technology. One of the first attempts to assess the impacts of GT technology was a joint study released in June of 2001 by Hin and Pak from the Centre for Agriculture and Environment, and Schenkelaars from the Schenkelaars Biotechnology Consultancy. The study investigated the agronomic and environmental impacts of GT soybeans in the United States. The authors collected observations on the agronomic and environmental impacts of GT-soybeans compared to those of conventional (CN) soybean varieties in the US. The study observed that GT soybean acreage in the US has expanded rapidly, with more than half of the soybean acres in 2000 planted to glyphosate tolerant varieties. They concluded that commercial cultivation of GT soybeans has resulted in an insignificant to a small yield increase, with little change in farm profits. Studies by Duffy and Ernst as an extension to the USDA Farm Costs and Returns Survey in Iowa, estimated the impact of GT soybeans in Iowa. The studies were conducted in 1998 and 2000. Their studies concluded that there was no significant difference in production costs or revenue between GT and conventional seed varieties. They also determined that 48% of producers with GT soybean acreage were making one or more cultivation passes, while 63% of producers with conventional soybean acreage were making one or more cultivation passes.

In November 2001, the American Soybean Association (ASA) released a study that assessed the environmental benefits of agricultural biotechnology. The purpose of the study was to estimate how tillage practices in the US have changed in the past five years, and to identify what factors brought about these changes. The key finding from the ASA research was that 63% of growers indicated that GT technology made it possible for them to adopt reduced tillage or increased crop residue soybean production techniques. Of this, 53% of the growers indicated that they were making fewer tillage passes in soybeans, 73% were leaving more crop residue on the soil surface and 48% had increased their no-till soybean acreage. However, the study was done without statistical tests of the significance of the responses. While the raw data indicate considerable adjustments, the sample represents less than one-half of one percent of the soybean acreage in the US. Therefore, variances within the sample are important in determining whether the changes are statistically significant.

Following the ASA study, the Conservation Technology Information Centre (CTIC) (Towery, 2001) released preliminary results[2] linking GT technology to conservation tillage and the resulting topsoil and fuel savings from a reduction in tillage passes. The results were obtained by taking the total no-till acreage from the ASA survey, multiplying

[2] The calculations in the noted paragraph were generated for the press release, i.e., there was no formal research or report based on the numbers. Since then, Dan Towery (CTIC) has conducted further research linking conservation tillage and GT technology with topsoil and fuel savings from reduced tillage practices in US soybeans. The research should be released publicly in the near future.

it by the average per acre fuel and topsoil savings relative to conventional tillage and adjusting the acreage by the percentage of GT soybeans produced using no-till practices provided by Monsanto. Thus, using the ASA survey results as a base, GT technology assisted producers in reducing tillage which saved an estimated 247 million tons of topsoil in 2000, and 234 million gallons of fuel in the US from the reduction in the number of passes of equipment (type of equipment not specified) over the field.

The difficulty with the approach in the ASA and Towery studies is that they make stringent assumptions on the relationship between GT seed and tillage practices. Implicitly, Towery assumes that GT seed *is the sole caus*e of the adoption of conservation tillage practices. However, some of these practices likely would have been adopted regardless of GT seed; the CTIC and ASA assume that all the no-till soybean acres would have otherwise been conventionally tilled. In addition, both the ASA survey results and the generated savings were not tested for statistical significance. This is important because the evidence presented from a survey is a sample rather than a population. Without statistical significance tests, and because of the assumption stated above about causality, it is difficult to determine the robustness of the fuel and topsoil savings.

The impact of GT soybeans in Iowa was considered in studies by Duffy and Ernst. The studies were conducted in 1998 and 2000 as an extension to the USDA Farm Costs and Returns Survey in Iowa. In the 1998 study, a survey of 800 Iowa farmers was conducted. The sample was statistically representative of Iowa crop farms.

The 1998 survey produced the following findings:

- 40% of the soybean acreage in the sample was planted to GT varieties.
- 53% of respondents that planted GT soybeans claimed that motivation for choosing GT varieties was increased yields due to improved weed control; 27% claimed reduced herbicide costs was their motivation, 12% stated that increased planting flexibility was their rationale, and 3% adopted GT seed because they felt it was a more environmentally friendly practice.
- The average yield for GT varieties was 49.26 bushels per acre; conventional seed varieties yielded 51.21 bushels per acre.
- Seed costs averaged $US 26.42 per acre for GT seed and $US 18.89 per acre for conventional seed.
- Because of lower herbicide costs, total cost per acre not including land and labour averaged $US 115.11 for GT soybeans, and $US 124.11 for the conventional soybeans.

- Total return averaged $US 144.50 per acre for GT soybeans and $US 145.75 per acre for conventional soybeans. The difference in total returns was not significantly different.

The 2000 survey included 172 Iowa soybean fields, and obtained the following results:

- 63% of the acreage in the sample was planted to GT varieties.
- The average yield of GT soybeans was 43.4 bushels per acre, compared with 45.0 bushels per acre for conventional varieties.
- Seed costs averaged $US 25.56 per acre for GT seed and $US 21.21 per acre for conventional seed.
- Herbicide costs averaged $US 19.98 per acre for GT soybeans and $US 26.15 per acre.
- There were an average of 1.55 sprayer passes for GT soybeans and 2.45 sprayer passes of conventional seeds.
- 48% of GT acreage had one or more cultivation passes; 63% of conventional soybean acreage had one or more cultivation passes.
- There was no significant difference in production costs between GT and conventional seed varieties.

The majority of the research by Hin *et al*, used secondary data or was literature based. However, they established relevant research categories, for example, agronomic differences between GT and CN, farm profitability and biodiversity. While observing the above caveats on the ASA study, its contribution is significant because it collected and analyzed primary producer data. It is thus a model for assessing producer use of GT soybeans technology in Ontario and for making comparisons between US and Ontario with respect to GT soybean use.

To achieve the specific objectives outlined in section 1.3, the following methods were applied. Based on the survey developed in the ASA study, a survey of Ontario soybean producers was developed with adjustments made to questions or sections of the survey to address the categories from the Hin *et al.* study. The survey measured Ontario producer's economic differences and perceptions related to GT technology (Appendix 1.0).

The main differences between the ASA study and this study were:

- Sample size
    - 325 Ontario soybean producers were surveyed, with no minimum soybean

acreage required to qualify as a participant. This sample represents three percent of the soybean acres in Ontario.
  - The ASA surveyed 457 producers with a minimum of 200 acres of soybeans. This sample, while larger than the sample in Ontario, represents 0.3%[3] of the soybean acres in the US, and also represents a much broader range of climatic conditions and soil types.
- Time period to compare changes in production practices
  - We asked producers to compare their production practices to the previous three years as we felt adoption of GT technology was slower in Ontario.
  - ASA compared producer production practices to the previous five years.
- Our survey accounts for sampling variance by testing the statistical significance of our results.

To enrich the results of the survey, additional methods were required to estimate the differences in farm profitability and the impacts of GT technology. With farm profitability we used OMAFRA soybean enterprise budgets (public budgets developed by crop extension people) and the agronomic profiles of GT and conventional soybean production systems obtained from a Canadian agribusiness firm.

In combination with our survey results, a literature review was completed to assess the potential impact of GT soybeans on biodiversity. The review focussed on impacts of GT soybeans on non-target organisms, and the development of resistant 'super weeds'.

1.3 Report Outline

To achieve the objectives outlined in section 1.3 the project has been separated into four sections. Section 2.0 provides background information on the soybean industry in Ontario and addresses the significance of GT technology within the Ontario soybean sector. Section 3.0 provides the background information on the agronomic practices used in the production of conventional and GT soybeans in Ontario. Section 4.0 discusses the producer survey and establishes the on-farm changes that can be attributed to the use of GT technology, and determines the producers' rationale for using GT technology. Finally, in Sections 5.0-8.0, we assess the impact of Glyphosate tolerant soybeans on tillage practices, farm profitability, and biodiversity in Ontario soybean production.

[3] The ASA survey had 457 respondents with an average of 554 acres = 253,178 acres. Total US acres in 2001 were 72.4 million. Therefore, the ASA survey represented approximately 0.3% of the US soybean acreage (253,178/72,400,300).

2.0 Significance of Glyphosate Tolerant Soybeans in Ontario

Section 2.0 provides background information on the soybean industry in Ontario and addresses the significance of GT technology within the Ontario soybean sector.

2.1 Soybean Production in Ontario

Soybean production in Ontario has grown rapidly throughout the 1980's and into the mid 1990's. Table 2.1 below illustrates that 1997 was the largest soybean production on record in Ontario. Since then the area planted and harvested has declined (Figure 2.1), while soybean yield has increased modestly (Figure 2.2), resulting in relatively constant production levels (Figure 2.3) (with the exception of 2001). It is clear that, overall, increased production in Ontario resulted from increased acreage, rather than increased yields. However, improvements in crop varieties have allowed soybean production to expand in virtually all significant agricultural regions of Ontario, without negatively affecting average yields. Expansion in soybean acreage has been particularly evident in Central and Eastern Ontario. This is presented in Table 2.2. From 1985 to 2000, soybean acreage increased by 300% in Central Ontario and by almost 800% in the Eastern region. Even in the last five years these areas have continued the growth pattern with a 32% increase in soybean area in Central Ontario and almost 85% in Eastern Ontario.

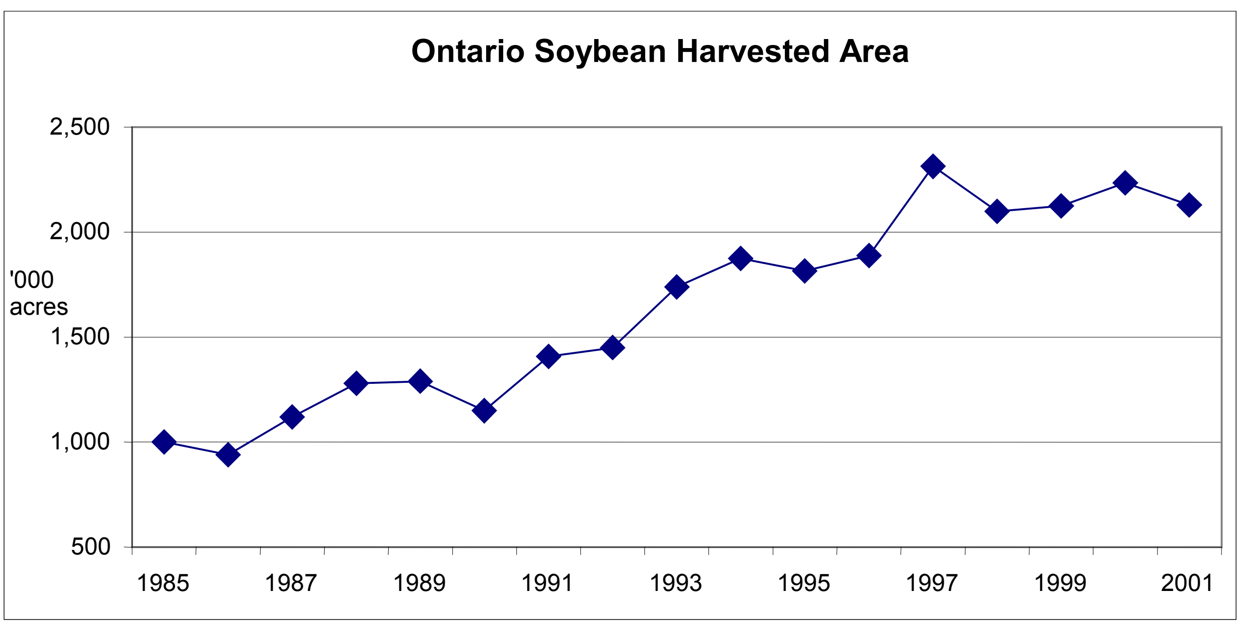
An important thing to note about the 2001 crop year was that soybean yields were the lowest they have been since 1963, and well below the ten-year average of 38.8 bu/acre. Dry growing conditions throughout the summer, a heavy aphid infestation, and wet harvest were the reasons cited for the drop in yields (Statistics Canada, 2001). Total Ontario soybean production in 2001 was 1.224 million tonnes, with 284.6 thousand tonnes of GT soybeans and 940.1 thousand tonnes of conventional soybeans.

Table 2.1 Ontario Soybean[1] Statistics, 1985-2001

Year	Harvested Area ('000 Acres)	Yield (bu/acre)	Production (tonnes)
1985	1,000	37	1,012,000
1986	940	37	949,800
1987	1,119	42	1,251,900
1988	1,279	33	1,124,000
1989	1,289	34	1,175,700
1990	1,150	39	1,211,100
1991	1,408	36	1,388,000
1992	1,449	34	1,360,800
1993	1,739	39	1,823,400
1994	1,874	40	2,068,400
1995	1,814	42	2,041,200
1996	1,920	37	1,933,061
1997	2,320	38	2,398,912
1998	2,100	41	2,342,857
1999	2,123	40.5	2,341,837
2000	2,235	38	2,313,300
2001*	2,130	21	1,224,700

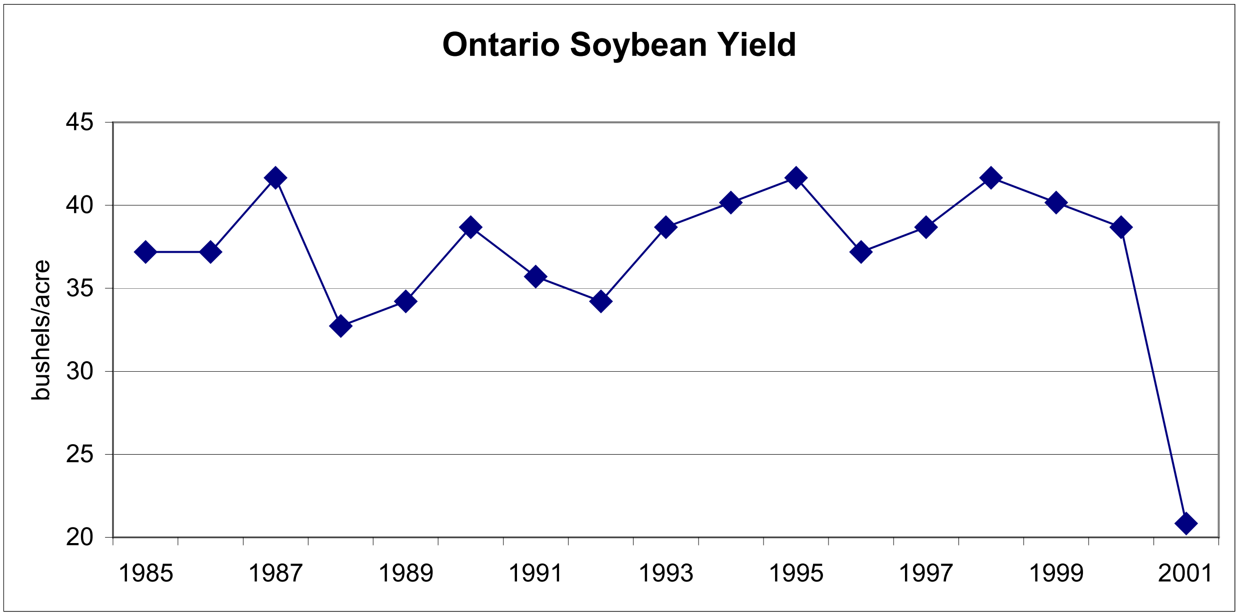
[1]These values do not distinguish between conventional and GT soybeans.
*Estimates. Source: Statistics Canada

Figure 2.1



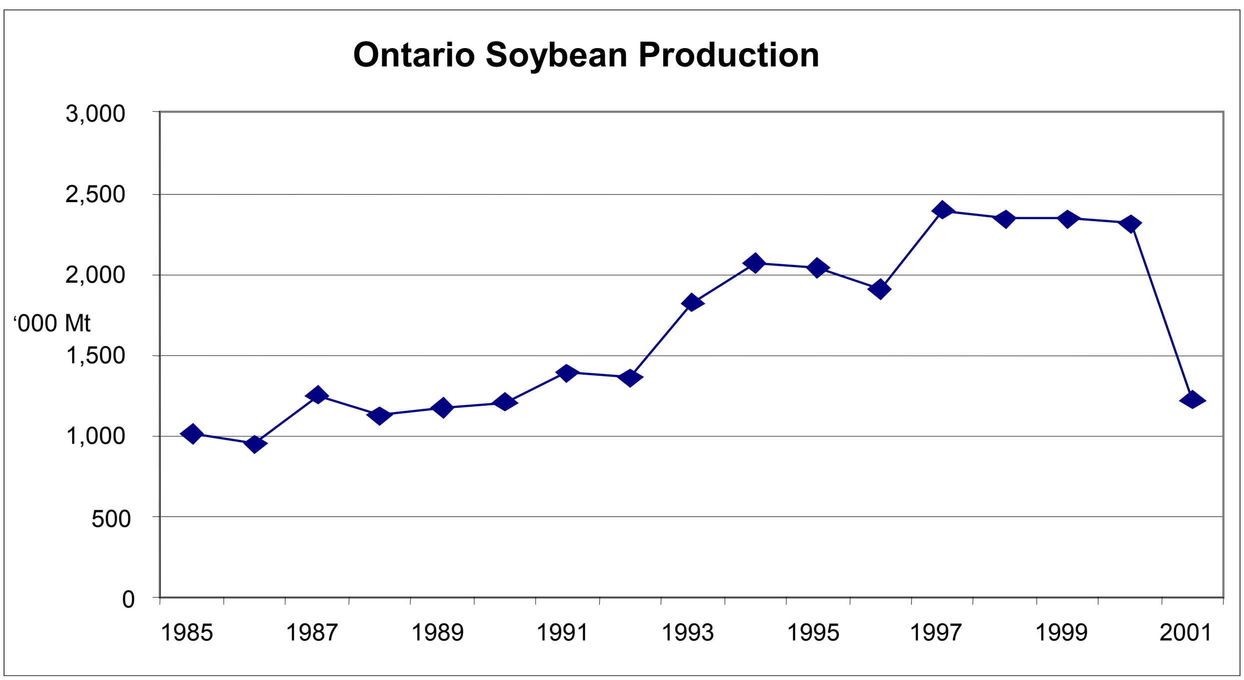
Source: Statistics Canada

Figure 2.2



Source: Statistics Canada

Figure 2.3



Source: Statistics Canada

Table 2.2 Regional Distribution of Soybean Area (Acres) and Percentage Changes

	Southern Ontario	Western Ontario	Central Ontario	Eastern Ontario	Northern Ontario
	('000 Acres)				
1985	874	117	38.5	20.5	NA
1986	791.5	105.5	28.6	14	0.133
1987	936.5	127	38	18.5	NA
1988	1,012.5	192.5	48.5	26.5	NA
1989	1,027	185.5	50.1	27.4	NA
1990	935.8	158.8	48	27.4	NA
1991	1,057.5	249.3	67.6	34.5	0.283
1992	1,085	300.5	77.6	36.9	NA
1993	1,205.5	350.8	95	48.7	NA
1994	1,261	431	111.3	71.7	NA
1995	1,248	383	114.7	74.3	NA
1996	1,223.7	479	118.2	99	0.1
1997	1,543	524	137	115.8	0.2
1998	1,253	559.1	141	146.3	0.6
1999	1,270	546	145.5	162.9	0.6
2000	1,330	577	156	183	4
%Δ 1985-2000	+ 52.2	+ 393.2	+ 305.2	+ 792.7	NA
%Δ 1990-2000	+ 42.1	+ 263.4	+ 225	+ 567.9	NA
%Δ 1996-2000	+ 8.7	+ 20.5	+ 32.0	+ 84.8	+ 3900

NA – Not Available
Source: OMAFRA Statistics

2.2 Significance of Glyphosate Tolerant Soybeans in Ontario

The collection of data to determine the significance of Glyphosate tolerant soybeans in the Ontario soybean sector is still relatively new. Data distinguishing between Glyphosate tolerant and conventional soybean acreage, yield, and production was collected for the first time by Statistics Canada in 2000 (Table 2.3).

Table 2.3 Glyphosate Tolerant and Conventional Soybean Production in Ontario, 2001 and 2000

	Conventional		Glyphosate Tolerant	
	2001	**2000**	**2001**	**2000**
Total Seeded Area (acres)	1655	1845	495	405
Total Harvested Area (acres)	1650	1835	480	400
Yield (bu/acre)	20.9	37.9	21.8	38.8
Total Production (tonnes)	940.1	1890.6	284.6	422.7
Ratio of GT Seeded Area to Total Seeded Area (%)			23%	18%
Difference GT Yield – Conventional Yield (bu/acre)			0.9	0.9

Source: Agriculture Division, Statistics Canada, 2001

The data in table 2.3 show that GT seed represented 18% of total soybean area in 2000 and increased to 23% in 2001. In both years, average yields of GT soybeans were 0.9 bu/acre higher than conventional soybeans, although it should be underlined that all yields were very low in 2001, as explained in section 2.1.

3.0 Agronomic Practices Used in the Production of Conventional and Glyphosate Tolerant Soybeans

In section 3.0 we compare the agronomic differences in the production of conventional (CN) and glyphosate tolerant (GT) soybean growing systems. Specific attention is paid to no-till and conventional tillage.

3.1 Comparison of Agronomic Practices Used in the Production of Conventional and Glyphosate Tolerant Soybeans

CN and GT soybean production have some differences in equipment, herbicides, herbicide rates, timing of operations, and frequency of operations. These vary according to the tillage system applied.

Conventional Tillage System

Under conventional tillage practices, the soil is moldboard ploughed either in the fall or in the early spring prior to planting. It must then be tilled one to three times to provide a suitable seedbed, typically using a tandem disk and/or field cultivator. Spring tillage practices vary by soil condition, however, it is typical for moldboard ploughing to be followed by disking and then cultivating. Herbicides can be applied pre-plant soil incorporated, pre-emergent, or post emergent. If pre-plant incorporated herbicides are applied in CN production, application occurs immediately prior to final cultivation using herbicides that are soil incorporated such as ethafluralin, and trifluralin. Alternatively, pre-emergent herbicides are applied to the surface of the soil immediately prior to or shortly after planting. These include glyphosate, imazethapyr, metalachlor or metribuzin.

No- till System

Under a no-till system, producers do not engage in any kind of tillage prior to planting. It is common for producers to do a pre-seed burndown with glyphosate at a rate of 1 to 1.5 litres/acre. The glyphosate may be tank mixed with another herbicide, most commonly imazethapyr, metalachlor, or metribuzin, depending on weed pressure. Fields to be planted under a no-till system with GT soybeans are most often sprayed with glyphosate prior to seeding, and are not likely to be sprayed with any other herbicide.

Planting

Most soybeans in Ontario are solid seeded (7 inch rows), with the remainder seeded in 15 inch or 30 inch rows. In conventional soybeans, herbicide is applied to those acres or fields that did not receive a pre-emergent herbicide application. Acres that did receive an application prior to seeding may require a second application, depending on weed pressure. The post-emergent herbicides that may be used include *imazethapyr*, *bentazon*, *quiaziflop*, *sethoxydim*, *fomesafen*, *cloransulam*, *thifensulfuron* and *chlorimuron*.

GT soybeans receive one or two applications of glyphosate at a rate of 1 litre/acre, depending on weed pressure, weather and timing of the applications. Some producers may also use another post-emergent herbicide that they would normally use in a conventional soybean program, such as imazethapyr, if they feel the weed pressure or type of weeds calls for it.

In-crop tillage does not occur in solid-seeded stands of either conventional or glyphosate tolerant soybeans, and only rarely in stands grown in 30 inch rows.

Herbicides and desiccants may also be applied just prior to harvest and/or post-harvest, however the decisions to make these applications are based primarily on weed pressure, weather and crop rotation concerns. The type of soybean, i.e. GT or CN, influences the actual herbicide that is used, but it is most likely that glyphosate would be used in both systems.

The greatest difference in the agronomy of CN and GT soybeans is that herbicides are applied both prior to seeding and after the crop has emerged with CN soybeans.

4.0 On-Farm Changes Attributed to Glyphosate Tolerant Technology

Section 4.0 describes the results that were obtained from the survey sample and determines the on-farm changes in production practices that can be attributed to GT technology, and producers' rationale for using GT technology in Ontario soybean production.

4.1 Survey of Ontario Soybean Producers

The data to validate on-farm changes and producers' rationale for using the technology was collected through a survey of soybean growers in Ontario. The five main parts of the survey include: the profile of Ontario soybean producers, tillage practices, herbicide use, farm profitability and the farmers' perceptions about GT soybeans.

The information compiled for this component of the analysis was collected through interviews with Ontario soybean producers using a structured survey[4]. A producer database was provided by a co-operating Canadian agribusiness firm that contained the contact information for approximately 8,000 soybean producers in Ontario. Random samples[5] of 325[6] (including six pilot[7] surveys) Ontario soybean growers were surveyed by telephone.

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[4] See Appendix 1.0 for the Producer Survey.

[5] A formula was developed in the Excel database to randomly select 600 producers of 8,000 available names. A total of 1,900 names (3 sets of 600 plus 100 names from the Ontario Soybean Growers) were provided to Leads Phone Results for calling.

[6] The sample used in the survey is statistically representative of Ontario soybean growers. Based on our sample of 325 soybean producers, we are able to detect differences of less than 2 acres per farm, 95% of the time. The following formula was used to determine the statistical power of an estimate of soybean acreage per farm:

$$z\alpha/2 = \sqrt{(B^2 n/\sigma^2)}$$

Where:

n	Sample size.
$z\alpha/2$	Critical Z statistic value
B	Detectible difference in soybean acreage per farm
σ	Population standard deviation. In this case we calculated the standard deviation using the average acreage per soybean grower from 1987-2000.

Using values for the above parameters from the survey, we obtained a Z statistic value >2.0, which implies a statistical accuracy of greater than 95%.

[7] A pilot survey was administered throughout the last three weeks of January 2002 to pre-test the survey instrument. Random samples of 15 Ontario producers were contacted requesting participation for the pilot survey. Six producers agreed to participate. The purpose of the pilot survey was to identify any errors within the survey questions, and to determine if all necessary data could be obtained from the questions as presented.

The producer interviews were conducted in two stages:

I. Selected producers were called and informed of the objectives of the study, and were asked if they would be willing to participate by providing information through an administered questionnaire.
II. If the producer indicated interest in participating, the survey was faxed or e-mailed and a time was arranged to conduct the interview by phone. This allowed the survey respondents time to organize their production information.

The survey (see Appendix 1.0) was divided into five sections to gather the following information and data:

Section 1 Profile of Ontario Producers
- Type of farm (livestock, crops, mixed) and size of farm (acreage, livestock number).
- Total soybean acreage and acreage planted to GT soybeans in the last two crop years.
- Yields for conventional and GT soybeans in the last two years.

Section 2 Tillage Practices
- Current tillage practices – has method changed as a result of GT soybeans?

Section 3 Herbicide Use
- Changes in chemical use (indicate the chemicals that are no longer required)
- Chemical application rates for both conventional soybeans and GT soybeans

Section 4 Profile of Farm Profitability
- Whether GT soybean production has resulted in a change in per acre profit, and if so, why and by what percentage.

Section 5 Farmers' Perceptions about Roundup Ready Soybeans
- Perceived environmental benefits
- Rationale for use – why producers begin to use, continue to use and stop using GT technology.

4.2 Profile of Ontario Soybean Producers

In the first section of the survey the collection of data was used to determine relative farm size, acreage devoted to conventional (CN) and glyphosate tolerant (GT) soybeans, and whether there was livestock production.

The survey represents 174,296 acres (all crops). Of this, the total 2001 soybean acreage was 71,258, 28% of which were seeded to glyphosate tolerant varieties

(20,153 acres) (Table 4.1). The proportion of total soybean acreage represented by GT seedings in this survey is similar to the 23% GT proportion found by Statistics Canada in 2001 (Table 4.1). Acreage represented by the survey in 2000 is also identified in Table 4.1.

Of the total soybean acres grown in Ontario in 2001, the survey represents approximately 3%. Of the total GT soybean acres grown in Ontario in 2001, the survey represents 4%.

Fifty percent of the survey respondents were livestock producers. The majority of the livestock production was beef (steers, cow-calf), followed by hogs and dairy. Of those survey respondents growing GT soybeans, 53% also produce livestock. In this respect, our survey population is similar to the Statistics Canada data. In their survey, they determined that 41% of the producers growing GT soybeans were also livestock producers (Hategekimana, 2001).

Table 4.1 Survey Respondent Acreage Devoted to Conventional and Glyphosate Tolerant Soybeans Compared to Total Ontario Soybean Acreage in 2001 and 2000

	2001 Survey Acreage	% Distribution	ON Soybean Acreage (‘000)*	% Distribution	**2000** Survey Acreage	% Distribution	ON Soybean Acreage (‘000)*	% Distribution
Conventional Soybeans	51,105	72	1,650	77	53,815	82	1,850	82
Glyphosate Tolerant Soybeans	20,153	28	480	23	12,214	18	400	18
TOTAL	71,258		2,130		66,029		2,235	

* Source: Agricultural Division, Statistics Canada

4.3 Tillage Practices

The purpose of the tillage section in the survey was to determine the acreage distribution of soybeans by tillage practice. Producers were asked to identify the number of acres in no-till (NT), reduced tillage (RT) and/or conventional tillage (CT) for both varieties of soybeans. In addition, producers were asked how many tillage passes they were making on their soybean fields in a given year, how their tillage practices had changed in the last three years, and to identify what factors had impacted their decision to practice a no-till or reduced tillage scheme.

In question 4a) of the survey (Appendix 1.0), respondents were asked to identify the total number of CN and GT soybean acres that were produced using no-till, reduced tillage or conventional tillage in 2001 and 2000 using the following definitions as a guideline:

No-till/strip-till[1] - The soil is left undisturbed from harvest to planting except for strips up to 1/3 of the row width (strips may involve only residue disturbance or may include soil disturbance). Planting or drilling is accomplished using disk openers, coulters, row cleaners, in-row chisels or roto-tillers. Weed control is accomplished primarily with crop protection products. Cultivation may be used for emergency weed control. Other common terms used to describe No-till include direct seeding, slot planting, zero-till, row-till, and slot-till.

Reduced tillage (15-30% residue) - Full-width tillage which involves one or more tillage trips which disturbs all of the soil surface and is performed prior to and/or during planting. There is 15-30% residue cover after planting or 500 to 1,000 pounds per acre of small grain residue equivalent throughout the critical wind erosion period. Weed control is accomplished with crop protection products and/or row cultivation.

Conventional tillage or intensive-tillage - Full width tillage that disturbs all of the soil surface and is performed prior to and/or during planting. There is less than 15 percent residue cover after planting, or less than 500 pounds per acre of small grain residue equivalent throughout the critical wind erosion period. Generally involves plowing or intensive (numerous) tillage trips. Weed control is accomplished with crop protection products and/or row cultivation.

The results are presented in Table 4.2 below (also refer to Figure 4.1 and 4.2). The majority of conventional soybean production in both 2001 (62%) and 2000 (56%) used no-till practices. Interestingly, GT soybeans had almost the same proportion of no-till acres in both years (61% in 2001 and 55% in 2000).

[1] Source of tillage definitions: CTIC, http://www.ctic.purdue.edu/ctic/#

Table 4.2 Distribution of Acreage by Tillage Practice for Survey Respondents Growing Conventional and Glyphosate Tolerant Soybeans in Ontario in 2001 and 2000

	CN Soybeans (acres)		GT Soybeans (acres)	
	2001	2000	2001	2000
No Tillage	31,450 (62%)	30,324 (56%)	12,360 (61%)	6,616 (55%)
Reduced Tillage	6,257 (12%)	7,826 (15%)	3,179 (16%)	2,230 (18%)
Conventional Tillage	12,934 (26%)	15,771 (29%)	4,554 (23%)	3,258 (27%)
Total Acres	51,105	53,815	20,153	12,214

Note that the numbers do not add up to the total acreage, as some producers were unable to provide the information.

According to industry experts (Vermey, 2002), 60% of soybeans grown in Ontario use conservation tillage. It is important to note that this value does not distinguish between no-till and reduced tillage or CN and GT. Therefore, our survey sample of 55-62% is in line with, and helps confirm, the estimated Ontario average. Also, the data suggest that the trend toward no-till continued in 2001 since the percentages of both CN and GT soybeans that were produced with no-till increased relative to 2000.

Figure 4.1 Distribution of Acreage by Tillage Practice for Survey Respondents Growing Conventional Soybeans in Ontario in 2001 and 2000

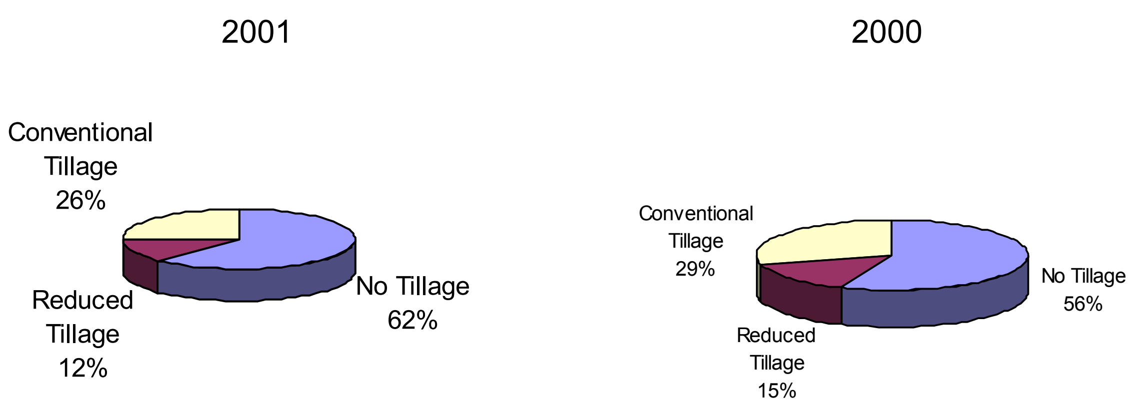
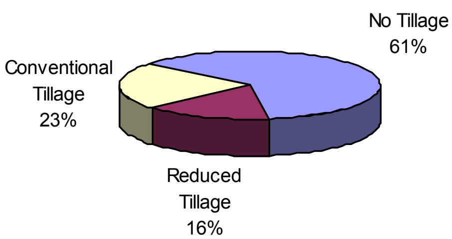
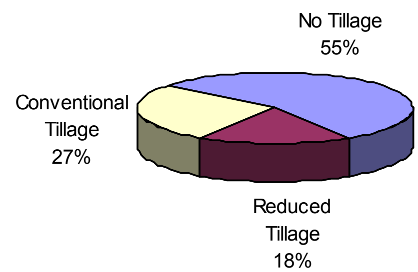


Figure 4.2 Distribution of Acreage by Tillage Practice for Survey Respondents Growing Glyphosate Tolerant Soybeans in Ontario in 2001 and 2000

2001



2000



Producers were asked how many passes they had made using the following equipment:

- moldboard plough
- chisel plough
- disk
- field cultivator
- row cultivator
- sprayer.

When analyzing the data describing the number of passes made on the soybean field, it was necessary to make the following assumptions:
- Under a no-till system producers do not engage in any kind of pre-plant tillage,
- A reduced tillage system has no use of a moldboard plough, but may include passes with a chisel plough (leaves more crop residue)
- Under a conventional tillage system, any number of tillage passes can occur.

The results from the survey are presented in Table 4.3. They show that, based on 2001 data, there is a statistically significant decline in the number of moldboard plough and field cultivator passes when producing glyphosate tolerant soybeans. What this tells us is that there is a statistically significant difference between GT and CN soybeans when it comes to moldboard plough and field cultivator use. The remaining chisel plough, disc, row cultivator and sprayer were not statistically different.

Table 4.3 Percentage Difference in the Number of Passes Made on Glyphosate Tolerant Soybeans Relative to Conventional Soybeans in 2000 and 2001

	Glyphosate Tolerant Soybeans	
	2001	**2000**
Moldboard Plough	-31%*	-30%**
Chisel Plough	-21%	+7%
Disk	+10%	-3%
Field Cultivator	-23%*	-9%
Row Cultivator	-44%	-62%**
Sprayer	+16%	+15%

*statistically different at the 95% confidence level
** statistically different at the 90% confidence level

To put the decline in moldboard plough and field cultivator use in context, we compared them on the basis of acreage. To do so, the total number of acres on which the tillage operation occurred was compared for CN and GT soybeans. This required multiplying the number of field passes (in 2001) for that operation by the total acreage for GT and CN soybeans. This gave the total acre·passes for each seed type. However, our survey sample contained proportionally more CN acreage (GT acreage- 20,153 acres; CN acreage- 51,105 acres). GT acreage was adjusted to put GT and CN acreage on a basis in which they could be compared[2]. To do so, the GT acreage was multiplied by the factor 51,105/20,153 to remove the initial acreage discrepancy.

Comparing the CN and GT acreage, we found that, relative to CN acreage, 53% fewer GT soybean acres had been moldboard ploughed and 44% fewer acres had been passed through with a field cultivator. When tested, these values were statistically significant at the 95% confidence level. This confirms that GT soybean producers are making less use of the moldboard plough and field cultivator than CN soybean producers.

These results raise an apparent contradiction, however. How is it that GT producers are making less use of the moldboard plough and field cultivator, but the distribution of no-till, reduced tillage and conventional tillage is relatively the same for CN and GT soybeans? This occurs because of our definition of conventional, reduced tillage and no-till (above). Conventional tillage does not imply they are using a moldboard plough, i.e., producers may have classified themselves as using conventional tillage but do not use a moldboard plough. Therefore, it is possible to have a significant reduction in the use of a particular piece of equipment, but observe no significant difference in acreage by tillage category.

When asked if they were making fewer tillage passes on their conventional soybean

[2] It is important to note that, had this adjustment not been made, it would have been far easier to observe a lower acreage with a moldboard plough or field cultivator pass with GT seed

acreage compared with three years ago, 57% of the CN respondents answered in the affirmative. When the GT producers were asked the same question, 52% responded that they were making fewer passes. On average, producers using GT soybean seed had 1.7 fewer field passes than three years ago (when tested, 1.7 was significantly different than zero). 70% of CN producers indicated that they were leaving more crop residue than three years earlier, while 64% of the GT producers said they were leaving more crop residue. Finally, 40% of CN producers said they had more no-till soybean acres now than they did 3 years ago, while 35% of the GT producers said they had more no-till acres. Respondents were asked whether the following influenced their decision to adopt no-till or reduced tillage:

- Improvements in reduced tillage equipment or no-till planters and drills
- Improvements in post emergent crop herbicides
- Introduction of GT technology
- Less time required/spent in the field
- Cost /availability of burndown herbicides
- Other reason

When the producers were asked if improvements in tillage equipment had an impact on their adoption of reduced or no-till, 50% of the GT producers responded in the affirmative. When asked about the improvement of post emergent crop herbicides, 46% indicated yes; the introduction of GT soybeans – 31% said yes; less time required and/or spent in the field - 65% said yes; cost of burn down herbicides – 48% said yes; and 42% of the respondents indicated that the availability of burndown herbicides had impacted their adoption of reduced or no-till soybeans in the last three years.

The results in Table 4.4 indicate that less time required in the field is the most important reason for producers to adopt reduced or no-till technology for soybeans. When asked to rank the criteria using a scale of 1-3 (1 having the greatest impact), 33% and 26% of the respondents said less time required and/or spent in the field is the most or second most important factor. The cost of burndown herbicides was ranked third by 22% of the respondents. Interestingly, producers did not perceive that the introduction of GT soybeans was a significant factor in the decision to adopt no-till or reduced tillage practices.

Table 4.4 Criteria Ranked Using a Scale of 1-3 (1 greatest impact) to Determine Reasons for Adoption of Reduced Tillage or No-till in Soybeans Within the Last Three Years

	Ranking					
Question	**1**		**2**		**3**	
Improved tillage equipment	65	27%	35	17%	32	18%
Improved post emergent herbicides	24	10%	49	24%	20	11%
Intro of GT soybeans	30	12%	14	7%	26	15%
Less time in field	**81**	**33%**	**54**	**26%**	34	20%
Cost of burndown herbicides	20	8%	34	16%	**38**	**22%**
Avail of burndown herbicides	16	7%	19	9%	23	13%
Other	8	3%	2	1%	1	1%
Total Respondents	**244**		**207**		**174**	

Note that there are a declining number of respondents as they could only rank those that were identified as having had an impact (i.e. answered yes).

Only those producers who were not growing GT soybeans were asked to complete question seven. The purpose of the question was to determine if the producers had considered trying GT soybeans, and to identify what factors or obstacles had prevented them from trying GT soybeans in the past.

In the survey, 184 of the respondents were not growing GT soybeans, of these 65% indicated they had considered trying GT soybeans. When asked what factors or obstacles had prevented them from trying GT soybeans, 50% indicated it was the technology fee, 33% indicated crop yields, 7% cost of weed control, 8% seed availability, 4% said they didn't know, and 18% stated it was a reason other than those identified above. Note that the sum of the percentages does not equate to 100 as producers could select more than one reason as being an obstacle.

When asked to rank the reasons using a scale of 1-3 (one being the greatest obstacle), 49% of the respondents indicated 'some other reason' was the greatest factor or obstacle (Table 4.5). What is interesting is that of the people who identified 'other', 41% indicated it was identity preservation that prevented them from trying GT soybeans. The technology fee was ranked in the second position with 39%, and crop yield was ranked in the third position with 41%. Putting the responses together from these two questions suggests that economics and risk are the fundamental reasons for not adopting GT soybeans. Perceived higher cost associated with the seed and weed control and the potential risk of not achieving offsetting higher yields (despite the fact that actual yields are higher) appears to be one set of issues. At the same time, a fairly large proportion of Ontario growers have contracts to grow identity preserved products. These products are generally not based on GT seed and they pay a premium over the "commodity" price. Hence these producers perceive that they can earn more financial contribution by using CN seeds.

Table 4.5 Criteria Ranked Using a Scale of 1-3 (1 greatest obstacle) to Determine Factors or Obstacles Preventing Producers from Growing Glyphosate Tolerant Soybeans

	Ranking					
Question	**1**		2		3	
Technology Fee	54	32%	**29**	**39%**	4	15%
Crop Yields	18	11%	26	35%	**11**	**41%**
Cost of Weed Control	5	3%	2	3%	5	19%
Seed Availability	2	1%	6	8%	3	11%
Don't Know	7	4%	0	0%	0	0%
Other	**82**	**49%**	11	15%	4	15%
Total Respondents	**168**		**74**		**27**	

Note that there are a declining number of respondents as they could only rank those that were identified as being a factor or obstacle (i.e. answered yes).

4.4 Profile of Farm Profitability

The purpose of profiling farm profitability in the survey was to obtain operating expense, revenue and gross farm income data as a means to provide the verification for differences in production practices or dollar savings between production techniques. Survey respondents were asked to indicate their operating expenses for CN and GT soybeans in 2001 and 2000. Unfortunately, 24% of our survey respondents were unable or unwilling to provide *any* information regarding their operating expenses for either variety of soybeans. In addition, the producers who did provide information had incomplete operating expense data, or they combined categories in such a way that it was very difficult to obtain any meaningful responses. Thus, direct collection of reliable revenue and expense was impossible.

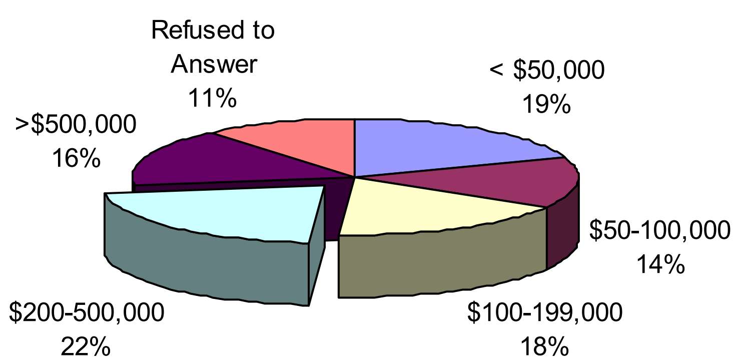
Producers were asked to provide their average yield and the price they received in 2001 and 2000 for their CN and GT soybeans. Table 4.6 below indicates the average yield, price and revenue for each variety in the corresponding year. What is interesting is that in 2001, despite the lower price received for GT soybeans, the higher yield resulted in $3.49/acre higher revenue. However, this was not statistically different at a 95% confidence level. This means that there was no statistically significant difference in average yield and average price between conventional and glyphosate tolerant soybeans and hence no difference in revenue in both crop years.

Table 4.6 Average Yield, Price and Revenue Data from Survey Respondents Growing Conventional and Glyphosate Tolerant Soybeans

	CN Soybeans	GT Soybeans	Difference
2001			
Yield (bu/acre)	22.4	23.1	(0.4)
Price ($/bu)	7.30	7.22	0.08
Revenue ($/acre)	163.55	167.04	(3.49)
2000			
Yield (bu/acre)	41.1	41.6	(0.5)
Price ($/bu)	7.68	7.40	0.28
Revenue ($/acre)	315.60	308.09	7.5

Producers were asked to select their appropriate gross farm income category for the 2001 and 2000 crop years. In Figure 4.3 below, the dislodged piece of the pie represents the bulk of the survey sample (22%), which fell in the second largest income category ($200-500,000). The top two income categories represented 38% of our survey sample.

Figure 4.3 Survey Respondents Total Gross Farm Income in 2001 and 2000



Using a combination of gross farm income data, GT production data, and tillage practices, we were able to verify several differences in production practices as a result of farm size (income). Table 4.7 provides a summary of the results. Within the highest two income categories (> $200,000 in sales), 31% of producers used a combination of both GT seed and no-till practices. This was the highest incidence of both GT and no-till (NT) practices among the income groups. In the lowest two income groups, 46% used conventional seed in combination with conventional tillage (CT). This was the highest incidence of both conventional seed and conventional tillage among income groups.

Other points for discussion:

- Producers in each sales category used a variety of tillage methods and seed types- this is why the percentages by seed and tillage methods exceed 100
- In the highest two income categories, most of the producers used no-till systems
- In the lowest two income categories, most of the producers were using conventional tillage systems

Because greater than 60% of the acreage practiced no-till, the larger sales groups farmed the majority of the acreage in the survey.

Table 4.7 Distribution of Soybean Variety and Tillage Practice by Gross Farm Income, 2001

	$0 – 100,000	$100,000 – 199,999	>$200,000	Total % of Sample
# Of Respondents in Income Category	109	57	123	
GT + NT	16%	23%	31%	21%
GT + CT	21%	14%	13%	14%
CN + NT	26%	54%	56%	39%
CN + CT	46%	39%	34%	35%

4.5 Farmers' Perceptions about Glyphosate Tolerant Soybeans

The purpose of the final section of the survey was to identify producers' perceptions about glyphosate tolerant soybeans. Each producer was given a series of statements[3] about 'Roundup Ready Technology' and then asked to rank them from 1 - strongly disagree to 5 – strongly agree. Thus, an average score >3.0 indicates that a majority of producers agreed with the statement.

Table 4.8 below provides the distribution of survey respondents who answered the questions in each of the categories. The final column of the table is the calculated average of all the survey respondents' answers. For example, the first statement,

[3] The twelve statements from question 12 can be viewed in Appendix 1.0.

"Roundup Ready soybeans save labour," had 26% of the total survey respondents who agree (4) and 33% who strongly agreed (5). The average was 3.58, which confirms that more producers were on the 'agree side' regarding the statement.

It is clear that the majority of the statements rendered an agree response. The top three statements that producers agreement with (highest average) were, GT technology save labour, GT technology save fuel, and lower herbicide costs are a reason farmers adopt GT technology.

There were four statements that more people disagreed with. The four contentious questions were; Roundup Ready soybeans increase biodiversity – average 2.8; seed technology has made no-till and reduced tillage soybeans feasible in my operation – average 2.81 and 2.71 respectively and; I believe that the overall profit per acre of Roundup Ready soybeans is greater than the overall profit on conventional soybeans – average 2.54, with 27% of the survey respondents 'strongly disagreeing' with the statement.

The statements that we felt had the most interesting results have been depicted in graph form in Figure 4.4.

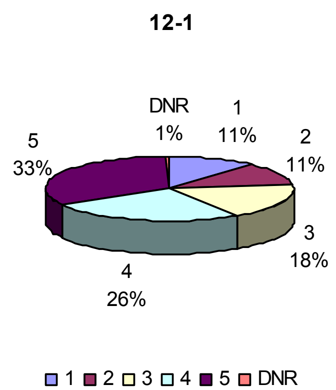
Table 4.8 Farmers' Perceptions Regarding Glyphosate Tolerant Soybeans

	%DNR*	%1	%2	%3	%4	%5	Avg
GT soybeans save labour	1%	11%	11%	18%	26%	33%	3.58
GT soybeans save fuel	0%	13%	14%	24%	23%	26%	3.37
GT soybeans reduce biodiversity	2%	6%	10%	58%	16%	8%	3.11
GT soybeans increase biodiversity	2%	10%	15%	59%	10%	3%	2.80
GT soybeans made adoption of reduced tillage possible in my area	2%	10%	16%	21%	35%	16%	3.31
GT soybeans made adoption of NT possible in my area	0%	13%	17%	23%	30%	17%	3.23
Seed technology has made NT soybeans feasible in my operation	0%	27%	13%	28%	18%	14%	2.81
Seed technology has made reduced tillage soybeans feasible in my operation	1%	26%	15%	29%	22%	8%	2.71
Lower herb costs are a reason farmers adopt GT soybeans	1%	10%	9%	20%	33%	27%	3.58
Env benefits from reduced pesticide use are a reason farmers adopt GT soybeans	1%	11%	14%	27%	29%	18%	3.29
The Env has been improved as a result of the use of GT soybeans on my farm	11%	16%	10%	33%	19%	12%	3.01
Overall profit/acre of GT soybeans is greater than conventional soybeans	1%	27%	20%	32%	12%	8%	2.54

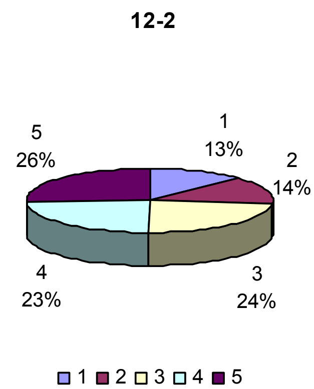
* DNR – Did not respond

Figure 4.4 Farmers' Perceptions Regarding Glyphosate Tolerant Soybeans

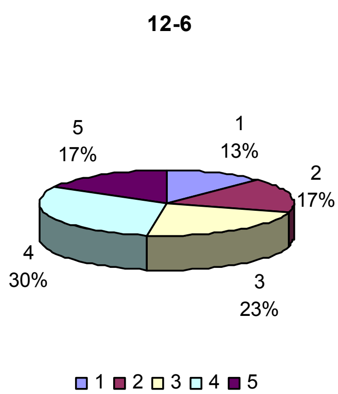
RR soybeans save labour.



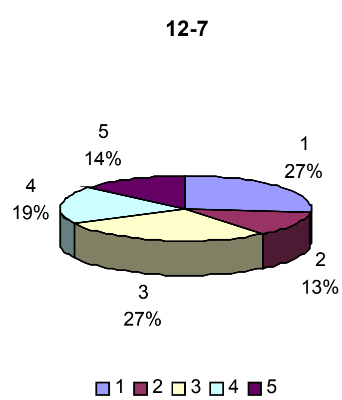
RR soybeans save fuel.



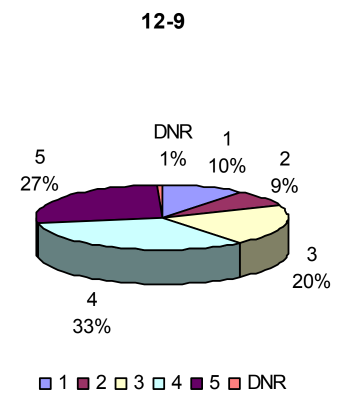
GT has made it possible for more growers in my area to adopt no tillage practices



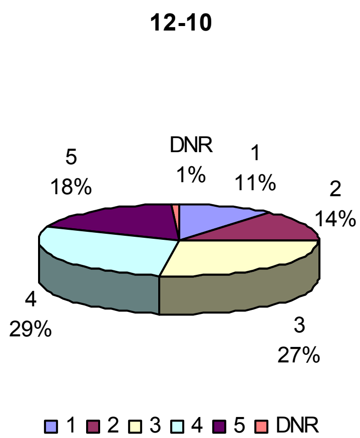
Seed technology has made no-till soybeans feasible in my operation.



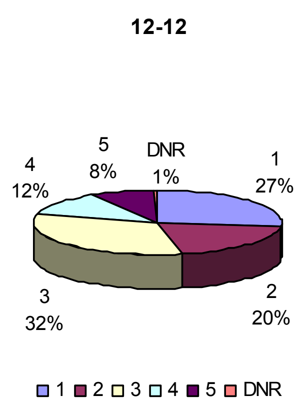
Lower herbicide costs are a reason farmers adopt RR soybeans.



Environmental benefits associated with reduced pesticide use are a reason farmers adopt RR soybeans.



I believe that the overall profit per acre of RR soybeans is greater than the overall profit on conventional soybeans



5.0 Tillage Practices

In this and the following two sections we assess the impact of glyphosate tolerant soybeans in Ontario soybean production. More specifically, we investigate the impact on tillage practices, farm profitability and biodiversity. Where possible, information from the research literature is combined with our survey results.

Conservation tillage is any tillage planting system that leaves at least 30% of the field surface covered with crop residue after planting is completed, and it involves reduced or minimum tillage. One of the anticipated impacts of GT technology was a reduction in the number of tillage passes over a field.

We analyzed the nature and significance of this potential for alternative tillage practices by addressing the following issues:

- Comparison of conservation and conventional tillage
- Discussion of how GT technology impacts decisions to use conservation tillage
- Evidence on actual changes in tillage practices from the survey
- Environmental impact of conservation tillage and the role of GT technology

5.1 Expected and Actual Impacts of GT Technology on Tillage Practices

Throughout the study, conservation tillage includes both no-till and reduced tillage. In the survey, we used the following assumptions:

- under a no-till system producers do not engage in any kind of pre-plant tillage,
- a reduced tillage system does not use a moldboard plough, but may include passes with a chisel plough (leaves more crop residue),
- under a conventional tillage system, any number of tillage passes can occur.

The complete definitions for no-till, reduced tillage and conventional tillage are described above in section 4.2.2.

The American Soybean Association study (ASA, 2001) found that soybean growers increased the amount of reduced tillage farming by 53% after 1996. The reason attributed for this increase was the use of glyphosate tolerant soybean technology.

The ASA study reported that:

- 53% of soybean growers are making fewer tillage passes since 1996.
- 73% of soybean growers now leave more crop residue on their fields compared to 1996.
- 54% of farmers credited glyphosate tolerant soybeans as the factor that had the greatest impact on their adoption of reduced or no-tillage systems.

In our study of 325 Ontario soybean growers we found:

- 57% of CN and 52% of GT soybean growers made fewer tillage passes than they did three years earlier.

- On average, producers using GT soybean seed had 1.7 fewer field passes than three years earlier.
- 70% of CN and 64% of GT soybean growers now leave more crop residue on their fields compared with three years ago.
- Less time required and/or spent in the field was the most important reason for producers to adopt reduced or no-till technology for soybeans. Interestingly, producers did not perceive that the introduction of GT soybeans was a significant factor in the decision to adopt no-till or reduced till practices.

The problem with comparing the results from the ASA study with our results is that ASA assumes that GT seed *caused* adoption of conservation tillage practices. However, some of these practices likely would have been adopted regardless of GT seed, as is clear from the Ontario data. In addition, the ASA survey results were not tested for statistical significance. The purpose of statistical testing is to estimate whether a sample represents a population. If it does not, then the conclusions from the sample cannot be used to represent the population. This is especially true when the sample is an extremely small portion of the total.

Having said that, if we compare the results from our study to ASA, our results are similar in most respects. The proportion of acres that are grown with no-till in Ontario is actually higher than in the US sample, while the total of no-till and reduced tillage is very similar. In both cases, there was a decrease in the number of passes made and an increase in the amount of crop residue left in the fields. In the Ontario case, these differences are statistically significant.

However, the most noticeable differences are that GT soybeans represent about 10% less of the total acreage in Ontario, and the reason stated by producers for their adoption of no-till or reduced tillage. The most obvious reason for the lower adoption in Ontario is the much greater opportunity producers have had for contracts that pay a premium for (in many cases) identity preserved, non-GT soybeans. The ASA study links no-till directly to GT soybeans by assumption, whereas our survey finds the reason to be less time required and/or spent in the field. The Ontario industry demonstrates that no-till is gaining prominence because it makes good business sense, and because a number of innovations make it even more sensible, including better tillage machinery, evolution of herbicides, as well as GT seed.

In actual practice, the relationship between GT and reduced tillage is very nearly the same in Ontario as in the ASA study. In addition, it is clear that, in practice, producers who use GT seed in Ontario make fewer passes over the field, and they make them without the equipment that is the most expensive to operate: the plough and the field cultivator. The real difference is in producers' perceptions. In Ontario, since many producers were already moving to no-till and since many have IP contracts that require conventional seed, then it is not surprising that they do not see GT as a pre-requisite for moving to no-till. On the other hand, the fact that producers make fewer field passes over the field with GT seed indicates that they have lower fuel costs.

One of the most widely circulated references to the fuel savings associated with no-till practices comes from a 1997 study by the Center for Agricultural and Rural Development. This study estimated that no-till reduces farm diesel use by 3.5 gallons (15.9 litres) per acre, and machinery wear is reduced by US$5 per acre over conventional tillage. Mitchell (1997) estimated the overall cost savings associated with no-till practices to be 10 to 20% relative to conventional tillage. The American Soybean Association and the Conservation Technology Information Centre[4] estimated that reduced tillage practices in soybeans saved 247 million tons of topsoil in 2000, in addition to saving farmers 234 million gallons of fuel as a direct result of reduced equipment use. Once again, we reiterate that caution must be used when referring to or comparing these numbers. Specifically, the CTIC and ASA assume that all the no-till soybean acres would have otherwise been conventionally tilled, i.e., the assumption does not allow for reduced tillage or the use of other equipment. In addition, the generated savings were not tested for statistical significance.

The results of our survey indicate that there is a statistically significant decline in the number of moldboard plough and field cultivator passes when producing glyphosate tolerant soybeans (compared to CN soybeans). Our study attempted to go beyond the ASA study and estimate from farmers' data what the cost and fuel savings might be. However, due to the difficulties with operating expense data, we can only project inferences about savings in fuel and topsoil. At the same time, the 31% reduction in the number of tillage passes being made with a moldboard plough and a field cultivator (23%) (2001) or row cultivator (62%) (2000) in GT soybeans relative to conventional soybeans very clearly translates into reduced costs for producers. The costs that are directly affected by fewer tillage passes include fuel, machinery wear, and labour. There can be no doubt that there is a savings. It is not possible from the survey to estimate exactly how much this is.

Although we know the reduction in moldboard passes using GT seed, there are difficulties making inferences on the associated savings in fuel and topsoil. The problem stems from the lack of statistically significant differences from the survey data:

- We know that there are significantly fewer moldboard plough passes in GT soybeans than CN soybeans, however:
- We do not know what alternative equipment the producer may be using, if any, at a statistically significant level. For example, the producer may have 'parked' his moldboard plough; however, he may now be making passes with a disk in place of the plough.
- Therefore, outside of assuming there is a direct movement from the moldboard plough to no-till, it is impossible to calculate the savings associated with a reduction

[4] We are waiting for a research report regarding fuel and topsoil saving from Dan Towery at the Conservation Technoy Information Center. The report is expected to be released shortly.

in passes without knowing the number of passes with alternative equipment. Although we attempted to estimate the number of passes with other farm equipment, the data was not sufficient to draw conclusions.

What we could determine about GT soybean growers and no-till production in Ontario is that within the highest two income categories (> $200,000 in sales), 31% of producers used a combination of both GT seed and no-till practices (Table 4.8). This was the highest incidence of both GT and no-till practices among the income groups. In the lowest two income categories, most of the producers were using conventional tillage. What this means is that larger soybean farmers in Ontario tend to use GT and no-till practices. Smaller farms tend to use conventional tillage and tend not to adopt GT seed.

5.2 Environmental Impact of Conservation Tillage and the Role of GT Technology

Environmental benefits of conservation tillage include the building of new topsoil (increased organic matter) from unharvested crop stalks and leaves (crop residue) left on the soil after planting. Crop residue also protects soil from wind and water erosion (ARS, 2001 and CTIC website). The other key environmental benefit from conservation tillage, specifically no-till, is the trapping of atmospheric carbon. Conventional tillage releases carbon into the atmosphere in sudden rushes of CO_2 as the soil is opened up by ploughing. Carbon dioxide is one of the greenhouse gases that may be causing global warming. By trapping carbon in the soil there are both economic and environmental benefits. For example, there is more carbon available to build organic matter (carbon accounts for about half of organic matter in soil (CTIC website)) leading to better yields with less chemical use. Because carbon and crop residue utilize nutrients, there is a reduction of soil and chemicals moving into waterways (residue can cut chemical runoff rates in half (ARS, 2001 and CTIC Website)). Additionally, microbes that live in carbon-rich soils can degrade pesticides helping to protect groundwater quality.

Other environmental benefits of conservation tillage include:

- Improvements in soil tilth – continuous no-till systems increase soil particle aggregation (small soil clumps) making it easier for plants to establish roots. Improved soil tilth can also minimize compaction. Of course reduced tillage also reduces compaction (CTIC website).
- Keeping crop residue on the surface traps water in the soil by providing shade. The shade reduces water evaporation. In addition, residue acts as tiny dams slowing runoff and increasing the opportunity for water to soak into the soil (CTIC website).
- Crop residues provide shelter and food for wildlife, e.g., game birds and small animals (CTIC website).

Our survey demonstrates that no-till was the dominant system under either conventional or GT seed systems. However, farmers using GT seed made significantly less use of implements recognized as causes of soil erosion. In particular, farmers using GT soybean seed made less use of the moldboard plough, which is associated with higher levels of erosion, greater release of carbon, and higher fuel use.

Putting the conclusions from this and the foregoing sections together, it is clear that farmers in higher income categories in Ontario tend to use more GT soybeans, tend to use better conservation tillage practices, and have a more positive impact on the environment with respect to the factors addressed in this study.

6.0 Farm Profitability

The Hin *et al.* study concluded that commercial cultivation of GT soybeans has resulted in an insignificant to a small yield increase, with little change in farm profits. Using OMAFRA soybean enterprise budgets and the agronomic profiles of GT and conventional soybean production systems, the impacts of GT technology on farm gross margins relative to conventional soybean production in Ontario were estimated. The simulation of profitability included the following data:

- Retail prices of relevant agricultural chemical products
- GT seed technology fee
- Changes in field operations (and the resulting changes to costs, e.g. fuel use)
- Changes in yields

6.1 Ontario Production Costs – Conventional and Glyphosate Tolerant Soybeans

Ontario production costs for conventional seed soybeans in a conventional tillage system are presented in Table 6.1 below as estimated by OMAFRA. It should be noted that this budget has high variable (operating) costs, but low fixed costs. This is because land costs are omitted from the OMAFRA budgets. Land costs have been omitted because cash land rents and acquisition prices vary widely across regions of Ontario according to land quality and location.

The operating expenses for a GT production system are also shown in Table 6.1. The only categories where operating expenses differ from conventional soybean production are seed, herbicide and average yield. We have assumed that all other expenses would be the same, as GT soybean production on its own does not materially change these expenses[5]. With regard to the seed expense, the technology fee associated with GT soybean seed is now included in the seed price, i.e., it is not a separate item, but it does still raise the price relative to CN soybean seed. The herbicide cost under GT production is for an application of glyphosate in-crop and does not include a pre-seed application of glyphosate or any other herbicide. The per acre cost of glyphosate is significantly lower than the herbicides (pre and post emergent) it is replacing in conventional systems. Consequently, the overall herbicide cost is lower for GT soybeans than conventional soybeans. GT budget figures, including average yield, are First Line Seed estimates (Rickard, 2002).

Comparing total variable operating expenses in Table 6.1 shows the costs for conventional soybeans are $20.00 per acre higher than for GT soybeans. As discussed above, this difference arises from higher herbicide costs that more than offset lower seed costs for conventional soybeans. Herbicide use varies by producer due to differences in types of weeds present, weed pressure, the variety of herbicides available, cost differences in herbicides and personal producer preference. This is true

[5] In fact, this assumption is conservative because it is anticipated (and the survey indicates) that there are fewer passes over the field using GT seed.

not only in conventional soybeans, but also to some degree in GT soybeans. In the latter case, some producers may elect to do a pre seed burndown, or use a soil applied herbicide in addition to the post-emergent application of glyphosate. However, even at the full label rate, a pre-seed glyphosate application would still leave the GT soybeans with a profitability advantage over conventional soybeans.

Table 6.1 Ontario Soybean Production Costs - Conventional and Roundup Ready (Conventional Tillage), 2001

		$/Acre	
Variable Costs:		Conventional	Glyphosate Tolerant
Seed		35.00	48.00
Seed Treatment		4.91	4.91
Fertilizer		13.20	13.20
Herbicide			
Annual Grasses		18.00	0
Broadleaf Herbicides		24.00	0
Other Herbicides		0	9.79
Insecticides		0	0
Fungicides		0	0
Crop Insurance		8.50	8.50
Custom Work #1	Combine	30.00	30.00
#2	Fertilizer Spread	7.00	7.00
Trucking		6.21	6.21
Marketing Fees		0.72	0.72
Fuel		16.20	16.20
Mach. Repair & Maint.		16.00	16.00
Bldg. Repair & Maint.		3.00	3.00
Rent and Labour		16.00	16.00
General Variable Costs		15.00	15.00
Operating Interest		8.27	8.27
		-------	-------
Total Variable Costs		222.01	202.80
Fixed Costs:		$/Acre	$/Acre
Depreciation		24.00	24.00
Interest on Term Loans		14.00	14.00
Long-term Leases		0.00	0.00
General Fixed Costs		10.00	10.00
		-------	-------

Total Fixed Costs	48.00	48.00
Total Cost	270.01	250.80
Yield (bu/acre)	38	39
Total Cost/bushel	**7.11**	**6.43**

Source: Conventional - OMAFRA, 2000 and Glyphosate Tolerant – Rickard, 2002

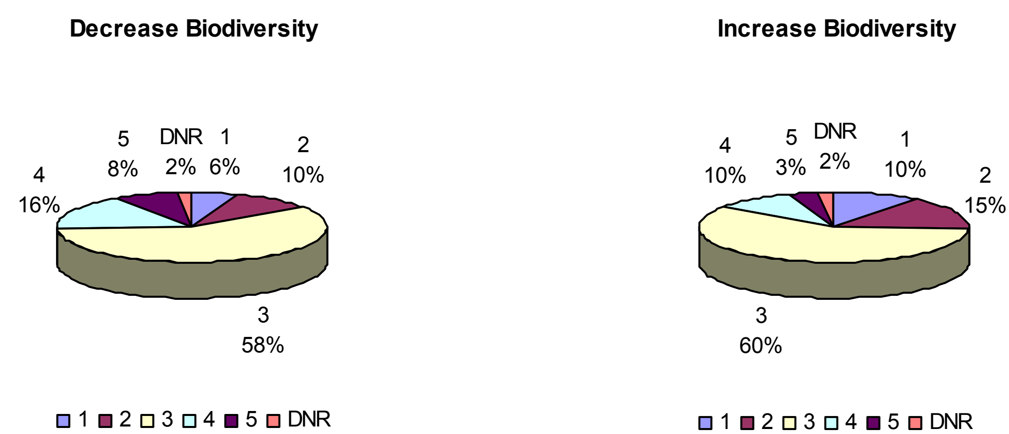
6.2 Farm Profitability Survey Results

Survey respondents were asked to provide their operating expenses for CN and GT soybeans in 2001 and 2000. As indicated above, 24% of our survey respondents were not able to provide *any* information regarding their operating expenses for either type of soybean production system, and the producers that did provide information had incomplete operating expense data. Thus, the survey did not provide reliable revenue and expense data. There was no significant difference in revenue between GT and CN soybeans in either 2001 or 2000 based on the results of the survey. However, the estimates in the previous table suggest that if the price is the same for both types of soybeans, then GT soybeans have a cost advantage of almost $.70 per bushel.

7.0 Biodiversity

The impacts of GT technology on biodiversity relate to the impact on non-target organisms (plant and animal), and the evolution of these organisms to GT technology. Producers' perceptions of changes to biodiversity were documented in the survey. When asked if Glyphosate tolerant soybeans reduced or increased biodiversity[6], the majority of the producers (58% and 60% respectively) responded that they didn't strongly agree or disagree with the statement (Figure 8.1). This may have been a result of the lack of understanding of the term biodiversity.

Figure 7.1 Producers Perception Regarding the Impact of Glyphosate Tolerant Soybeans on Biodiversity



DNR – Did not respond

True impacts to biodiversity are difficult to assess and identify from a small sample of producer 'opinions'. As such, a literature review was required to assess the potential impact of GT soybeans on biodiversity. Specific attention was given to newer studies (i.e., after 2000) and Canadian studies. The review attempted to look at the affects of GT soybeans on non-target organisms, and the development of resistant 'super weeds'.

According to Hin et al. (2001), associated biodiversity is the number of species in an agro-ecosystem with no direct relation to the agricultural production, for example birds, flora and fauna in borders of a field.

Throughout the literature the greatest concern of genetically modified crops is the potential environmental harm if these organisms escape or are released into the environment. Through this escape there may be direct or indirect impacts on various levels of the environment. Some of the impacts from the introduction of genetically

[6] The following definition of biodiversity was provided on the survey questionnaire, "Biodiversity refers to the variety and variability of living organisms (flora and fauna) within the ecological complexes in which they occur."

modified crops may include:

- Depending on the number of varieties of a crop species into which the genetic modification has been bred, there may be impacts on the genetic diversity of non-target plants, animals, and microbial organisms.
- GM crop may change interactions with other species, for example, increased toxicity of the GM crop to pollinating insects in the agro-ecosystem
- The GM crop itself could become a problematic weed in a subsequent crop
- Changed weed control strategies from changes in agricultural practices due to use of the GM crop might have positive or negative impacts on non-target flora and fauna species
- Introgression of the genetic modification from GM crop into (related) wild species could result in the establishment of the novel genetic trait in the wild species – increasing the potential for natural ecosystem disruption.
- GM crop itself may invade natural habitats, for example, GM crop may have increased competitiveness compared to wild flora.

Source: Hin et al, 2001 and Wolfenbarger and Pheifer, 2000

Unfortunately there are currently no published studies that have examined whether introgression has occurred in GT soybeans, or studies that have examined the interactions with other species in the agro-ecosystem from the production of GT soybeans compared to CN soybeans. Thus, the potential ecological consequence that may be occurring in natural populations remains unknown.

8.0 Summary and Conclusions

The purpose of this study was to determine the agronomic, economic and environmental impacts of producing Glyphosate Tolerant (GT) soybeans in Ontario, and to compare the results with a similar study that was carried out in the United States (American Soybean Association (ASA)). The objectives of the study were:

- To establish the significance of GT soybean technology in Ontario;
- To identify the differences between conventional (CN) and Glyphosate tolerant soybean growing systems;
- To determine producers' rationale for use of GT technology; and
- To determine the impact of GT technology on:
  - tillage practices;
  - farm profitability;
  - ecosystem biodiversity.

To attain these objectives, a questionnaire was designed, following the model of the survey used by the ASA. It was applied to a sample of 325 randomly selected soybean growers in Ontario. The sample represents three percent of total soybean acreage in the province. The survey measures producers' economic differences and perceptions related to GT technology. The survey database included both producers that had and had not adopted GT technology. In addition, previous and related research was consulted to provide a full analysis of GT impacts. Standard t-tests were used to determine the statistical significance of the responses. This was not done in the ASA study. Therefore, it is not possible to know whether their results are representative of the US population.

8.1 Conclusions

The picture that arises from both the survey and from background information on the soybean industry is one of considerable complexity, especially relative to the US. Unlike the US, Ontario producers have not been able to operate during the past six years with a government program that guarantees a price no lower that US$5.26 per bushel for "commodity" soybeans. Given that USDA estimates of direct producer costs are far less than $5.26, US producers respond to the government incentive rationally by adopting a minimum cost strategy.

Partly as a result of the US program, Ontario producers have not enjoyed the same level of returns for commodity soybeans. In fact, the average prices received by Ontario farmers for many Ontario producers have had a considerable opportunity to produce soybeans under contract for specific end user markets. Many of these contracts require protocols for identity preservation and, many of these protocols specify varieties that are not genetically engineered. Hence, the economic incentive for their adoption has been somewhat different than in the US. In addition, it is very clear that Ontario producers moved rapidly to no-till or reduced tillage practices during the past few years. This is most likely because reduced tillage practices make good sense from both an economic and a stewardship perspective. Moreover, GT seed was finally approved for use three years later in Canada than in the US, and the major crushers in Ontario were reluctant to accept them in the first year. Hence the market environment in Ontario has been far different than in the US.

Despite all the foregoing, in moving toward reduced tillage, it would appear that GT soybean technology is viewed by Ontario farmers as one of the tools in the kit bag that help achieve no - or reduced tillage. In other words, the flow of causality is not "now that we have GT soybean seed, we can move to no-till". Rather, it is "we want to move to no-till, and one of the tools that will help us do that is GT soybeans, unless the economic incentives (through an IP program) are greater to get there with CN seed".

The Significance of GT Soybean Technology in Ontario

Despite the foregoing, the survey confirms that about 30% of the soybean area in Ontario was planted to GT soybeans in 2001. Therefore, it is clear the adoption of GT varieties is extremely significant, and that it is particularly significant among larger producers. Because IP contracts have a substantial role in Ontario, some producers use both GT and CN seed as part of their production program.

Ontario contrasts to the ASA data for the US. ASA found that a higher proportion of US soybean acres were using GT varieties. Again, we believe this difference arises mainly because Ontario producers have had opportunities to contract the production of non-GT varieties, often at substantial price premiums to commodity soybeans. In fact, producers often cited their contract obligations in the survey for this project as the major reason they did not adopt GT seed.

Conversely, since the 1996 FAIR Act in the US, US producers have been guaranteed US$5.26 per bu for soybeans, thereby increasing their production and driving down prices in the world market. Canadian growers needed to find alternatives that would increase their revenue; hence the higher likelihood of contracts to grow non-genetically engineered soybeans in Ontario. The price support system in the US gave US growers an incentive to grow beans at as low a cost as possible. Therefore, the promise offered by GT to help reduce cost and/or increase yield makes sense in the economic climate created by the FAIR act, while searching for ways to enhance revenue per bushel or acre makes sense in the Ontario market.

Differences between conventional and glyphosate tolerant soybean growing systems in Ontario

Section 3.0 of this report presents the differences in production systems between GT and CN seed. The differences are mainly in the application of herbicides and in the machinery used.

Producers' rationale for use of GT technology

Unlike the ASA study, Ontario producers did not associate their adoption of GT soybeans as a major cause of their movement to no-till. The major specific reasons for the move to no-till are reduction of time in the field, and the improvement of tillage equipment and herbicide technology. These results seem entirely logical given that GT seed was approved in Canada much later than the US – after the other elements of the technology package had been improved. It is also consistent with the fact that roughly the same proportion of GT and CN soybeans are grown with no-till, and with the fact that many Ontario producers have tapped into the IP market, which is predominantly not genetically engineered.

On the other hand, those who use GT technology are making 1.7 fewer passes across their fields than they did three years ago. This, plus the fact that larger operators tend to use both GT and no-till indicates that while GT may not be the most important reason Ontario farmers adopt no-till, it is an important factor in actual practice. This is underlined by the fact that GT adoption continues to grow, as does no-till.

Two additional aspects of why farmers adopt GT arise from the information from those who have not done so. As indicated above, the most frequently cited reason for not adapting it was "other", and where that was specified, the bulk cited their commitments regarding IP contracts. Hence, as we discussed above, it's a matter of higher revenue available from contracts.

The second aspect is that the next most frequently cited reasons for not adopting GT were the technology fee and concerns about yields. In other words, people did not adopt because of their perceptions about cost and risk. Turning this around implies that those who did adopt either perceive that contracts for IP, non genetically engineered soybeans were not profitable, or that they perceive that GT technology will lower their overall costs, and/or increase their yields, and/or reduce risk. In this latter regard, these results are very similar to Duffy and Ernst for growers in Iowa in 1998 and 2000.

The impact of GT technology on tillage practices

In one sense, tillage practices are quite similar for GT and CN seed because roughly 60% of acreage is planted with no-till or reduced tillage practices for both types of seed. This is a higher proportion than the ASA study found.

Farmers using GT seed made, on average, 1.7 fewer passes over their fields (when tested, 1.7 was significantly different than zero). In addition, farmers using GT seed made significantly less use of implements recognized as causes of soil erosion. In particular, farmers using GT soybean seed made less use of the moldboard plough, which is associated with higher levels of erosion, greater release of carbon, and higher fuel use.

Producers who use GT technology are also leaving more plant residue on the ground, which is an advantage to the environment. Finally, a strong majority of the respondents agree that GT technology is assisting in the adoption of reduced tillage practices in their areas.[7]

One very significant relationship in the survey is that between farm size, adoption of GT seed, and tillage practices. The highest incidence of GT seed and no-till production in Ontario is in the highest two income categories (> $200,000 in sales). In the lowest two income categories, most of the producers use conventional tillage. It is clear that larger farms in Ontario tend to use more GT soybeans, tend to use better conservation tillage practices, tend to leave more crop residue on the land, and therefore, tend to have a more positive impact on the environment, with respect to the factors addressed in this study. This is opposite to what some people in the popular media would have people believe.

The impact of GT technology on farm profitability

The aggregate data from the study do not give an overall indication of the effect of GT on profits. This is in part because respondents did not know their costs or do not keep records in a way that allowed them to answer the questions in a standardized way. To do this properly likely requires the development of a standardized profit model as the basis for a survey that is done in person and on site.

It is interesting to note that Duffy and Ernst were also unable to conclude anything about the impact of GT on profitability. The ASA study does not address the issue in their study.

On the other hand, when producers were asked about their perceptions about GT technology, the top three statements that producers agree with (highest averages) were: GT technology saves labour, GT technology saves fuel, and lower herbicide costs are a reason farmers adopt GT technology. When one puts together a budget, as we did in section 6.0, it is easy to show any or all of these effects. In practice, the effects depend on the farmer, the location and climate in a particular year.

Producers' perceptions about the impact of GT technology on ecosystem bio-diversity.

Ontario producers were split on whether GT technology has a positive or negative impact on biodiversity. Overall, slightly more said it reduces bio-diversity than said it increases it.

[7] A majority also said that it is not helping with reduced tillage on their farms. But since the majority are not using it, this is a tautology.

8.2 Implications Of The Research

Glyphosate tolerant seed technology for soybeans is a rapidly growing part of the arsenal of management tools for Ontario farmers. The market environment is different in Ontario for two reasons. The first is that Ontario farmers are not able to access US subsidies, and are disadvantaged by the market impact of those subsidies. Therefore, Ontario farmers, and their suppliers and customers, pursue specialty premium markets that, to date, do not generally include GT seed. Second, Canadian regulators held up the registration of GT for three years after it was registered in the US, and Canadian crushers were initially sceptical about them, thereby hindering its adoption.

Despite all the foregoing, this study shows that:

- 30% of the soybean acreage in Ontario was planted to GT seed last year, and that the proportion grew from the year before.
- Producers who use GT make 1.7 fewer field passes than they did three years ago.
- Farmers made less use of the moldboard plough on GT acreage than conventional soybean acreage. The moldboard plough is associated with higher levels of erosion, greater release of carbon, and higher fuel use.
- Producers tend to view, and often use, GT as an important tool in moving to no-till practices, which has environmental benefits.
- There is a positive correlation between size of operation, the adoption of GT technology, and no-till practices.
- Ontario producers believe that GT technology reduces costs of fuel, herbicides and labour. The first and third also implies lower machinery costs. The magnitude of the savings is specific to the operation.

The foregoing implies that GT technology is likely to continue to grow as part of the management tool kit in Ontario. What will determine the extent of growth in its adoption are the economic benefits of the technology. In the case of no-till or reduced tillage practices, they make good sense from both an economic and environmental perspective and it is clear that GT will continue to grow as a result of its positive relationship to them.

What is also true is that, with the passage of the 2002 US Farm Act, economic pressure will continue to be substantial on Ontario soybean growers. They will search for any technology or product that will give them an edge. This too will contribute to the continued adoption of GT technology. At the same time, GT will need to deliver economic benefits commensurate with those of the specialty products that will continue to be introduced over the next few years.

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Appendix 1.0 – Producer Survey

Agronomic, Economic and Environmental Impacts of the Commercial Cultivation of Glyphosate Tolerant Soybeans in Ontario:
A SURVEY

Introduction to the Survey
The George Morris Centre is conducting a producer survey to help determine the benefits of Roundup Ready (RR) technology in the Ontario soybean industry.

This survey is designed to help us understand how Roundup Ready technology is affecting your production practices. You can be assured that all information collected will be held in confidence. When the survey form is completed, you will be identified by a number. No one other than our research staff will see the individual survey forms.

Survey Instructions
A member of our research team will contact you by telephone within the next 7 days to discuss your responses. If possible, please try to complete the survey prior to our phone call. We thank you in advance for your cooperation.

Questions

Section 1 Profile of Ontario Producers

Agronomic Background
1. Please indicate your total acreage in production____________________ .

2. How many acres of conventional and Roundup ready soybeans did you plant in the crop years 2001 and 2000?

	2001	2000
Conventional Soybeans		
Roundup Ready Soybeans		

3. Do you currently produce livestock on your farm?

❑ Yes ❑ No

If you responded yes, please fill out the table below. Otherwise continue to question 4.a).

Livestock	Total Head
Beef Steers/Heifers	
Beef Cow-Calf	
Dairy	
Hogs	
Chicken	
Turkey	
Sheep	
Other	

Section 2A Tillage Practices

4.a) How many of your soybean acres were no-till[8], reduced tillage[9] or conventional tillage[10] in 2001 and 2000?

	2001	2000	2001	2000
	Conventional Soybeans		Roundup Ready Soybeans	
No-Till				
Reduced Tillage				
Conventional Tillage				

Note to Leads – make sure that totals add up to value(s) given in question 1.

[8] **No-till/strip-till** - The soil is left undisturbed from harvest to planting except for strips up to 1/3 of the row width (strips may involve only residue disturbance or may include soil disturbance). Planting or drilling is accomplished using disc openers, coulters, row cleaners, in-row chisels or roto-tillers. Weed control is accomplished primarily with crop protection products. Cultivation may be used for emergency weed control. Other common terms used to describe No-till include direct seeding, slot planting, zero-till, row-till, and slot-till.

[9] **Reduced tillage** (15-30% residue) - Full-width tillage which involving one or more tillage trips which disturbs all of the soil surface and is performed prior to and/or during planting. There is 15-30% residue cover after planting or 500 to 1,000 pounds per acre of small grain residue equivalent throughout the critical wind erosion period. Weed control is accomplished with crop protection products and/or row cultivation.

[10] **Conventional tillage or intensive-tillage** - Full width tillage which disturbs all of the soil surface and is performed prior to and/or during planting. There is less than 15 percent residue cover after planting, or less than 500 pounds per acre of small grain residue equivalent throughout the critical wind erosion period. Generally involves plowing or intensive (numerous) tillage trips. Weed control is accomplished with crop protection products and/or row cultivation.

Source of definitions: CTIC, http://www.ctic.purdue.edu/ctic/#

4.b) How many of your soybean acres were solid seeded (<14 inch row), vs planted in rows (> 14 inches)?

	2001	2000	2001	2000
	Conventional Soybeans		Roundup Ready Soybeans	
Solid Seeded				
Planted in Rows				

4.c) How many passes did you make on your soybean field(s) with the following equipment?

	2001	2000	2001	2000
	Conventional Soybeans		Roundup Ready Soybeans	
Moldboard plough				
Chisel plough				
Disk				
Field cultivator				
Row cultivator				
Sprayer				

IN THE LAST THREE YEARS, would you say that:

5.a) You are now making fewer tillage passes on your conventional soybeans?

i) ❑ Yes ❑ No

You are now making fewer tillage passes on your RR soybeans?

ii) ❑ Yes ❑ No

If yes, how many fewer passes? ________________

5.b) You are now leaving more crop residue on your conventional soybean acres?

i) ❑ Yes ❑ No

You are now leaving more crop residue on your RR soybean acres?

ii) ❑ Yes ❑ No

5.c) You have more no-till acres in your conventional soybeans?

i) ❑ Yes ❑ No

You have more no-till acres in your RR soybeans?
ii) ❑ Yes ❑ No

If yes, how many acres have you converted to no-till? ________________

6. a) Please indicate whether the following has had an impact on your adoption of reduced tillage or no-till in soybeans during the past 3 years?

Improvements in reduced tillage equipment or no-till planters and drills

i) ❑ Yes ❑ No

The improvement of post emergent crop herbicides

ii) ❑ Yes ❑ No

The introduction of Roundup Ready soybeans

iii) ❑ Yes ❑ No

Less time required and/or spent in the field

iv) ❑ Yes ❑ No

Cost of burndown herbicides

v) ❑ Yes ❑ No

The availability of burndown herbicides

vi) ❑ Yes ❑ No

vii) Other

____

6.b) Of the questions marked 'yes' in 6.a), please identify in order the three that have had the greatest impact (1 = greatest impact).

1 ____________
2 ____________
3 ____________

Section 2B – To be answered **ONLY** by producers **WHO DO NOT GROW** Roundup Ready soybeans.

7.a) Have you considered trying Roundup Ready soybeans in your operation?

❑ Yes ❑ No

7.b) What factors or obstacles, if any, have prevented you from trying Roundup Ready soybeans?

Technology fee
i) ❑ Yes ❑ No

Crop Yields
ii) ❑ Yes ❑ No

Cost of weed control
iii) ❑ Yes ❑ No

Seed availability
iv) ❑ Yes ❑ No

Don't know
v) ❑ Yes ❑ No

vi) Other

____

7.c) Of the questions marked 'yes' in 7.b), please identify in order the three that have been the greatest obstacles (1 = greatest obstacle).

1 _____________
2 _____________
3 _____________

Section 3 Herbicide Use

8. If you currently grow Roundup Ready soybeans, what herbicides did you use with conventional soybeans that are no longer required for your RR soybean production?

____

____

____

Section 4 Profile of Farm Profitability

Operating Expenses

9. Please use the table below to indicate your operating expenses for the production of conventional and RR soybean crops on your farm in 2001 and 2000. We remind you that the information that you provide is confidential and under no circumstance will your anonymity be comprised.

2001	Conventional Soybeans	Roundup Ready Soybeans
Seed ($/acre)		
Technology Fee		
Herbicide ($/acre)		
Annual Grass		
Broadleaf Weeds		
Other Weed Control		
Tractor and Machine Expenses		
Fuel		
$/Acre		
2000		
Seed ($/acre)		
Technology Fee		
Herbicide ($/acre)		
Annual Grass		
Broadleaf Weeds		
Other Weed Control		
Tractor and Machine Expenses		
Fuel		
$/Acre		

Revenue

10. Please use the table below to indicate the acreage, yield and price that you received for your soybean crop in 2001 and 2000.

2001	Harvested Acreage	Yield (bu/acre)	Price ($/bu)
Conventional Soybeans			
RR Soybeans			
2000			
Conventional Soybeans			
RR Soybeans			

11. Please select the applicable **total gross farm income** class for the year 2001 and 2000. Again, we remind you that the information that you provide is confidential.

2001

❑ Less than $50,000

❑ $50,000 - $100,000

❑ $100,000 - $199,999

❑ $200,000 - $500,000

❑ Greater than $500,000

2000

❑ Less than $50,000

❑ $50,000 - $100,000

❑ $100,000 - $199,999

❑ $200,000 - $500,000

❑ Greater than $500,000

Section 5: Farmers Perceptions about Roundup Ready (RR) Soybeans

12. Given the following statements about Roundup Ready (RR) soybean technology, please indicate whether you agree or disagree with the statements. Using a five point scale where "1" = Strongly Disagree and "5"="Strongly Agree", please rate the following statements:

i)	RR soybeans save labour.	1	2	3	4	5
ii)	RR soybeans save fuel.	1	2	3	4	5
iii)	RR soybeans reduce biodiversity[11]	1	2	3	4	5
iv)	RR soybeans increase biodiversity	1	2	3	4	5
v)	RR soybeans have made it possible for more growers in my area to adopt reduced tillage practices.	1	2	3	4	5
vi)	RR soybeans have made it possible for more growers in my area to adopt no tillage practices.	1	2	3	4	5
vii)	Seed technology has made no-till soybeans feasible in my operation.	1	2	3	4	5
viii)	Seed technology has made reduced tillage soybeans feasible in my operation.	1	2	3	4	5
ix)	Lower herbicide costs are a reason farmers adopt RR soybeans.	1	2	3	4	5
x)	Environmental benefits associated with reduced pesticide use are a reason farmers adopt RR soybeans.	1	2	3	4	5
xi)	The environment has been improved as a result of the use of RR soybeans on my farm.	1	2	3	4	5
xii)	I believe that the overall profit per acre of RR soybeans is greater than the overall profit on conventional soybeans	1	2	3	4	5

Source: American Soybean Association, 2001. Conservation Tillage Study.

The George Morris Centre thanks you for your time and interest.

[11] Refers to the variety and variability of living organisms (flora and fauna) within the ecological complexes in which they occur.