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Growers of Genetically Modified Grain Corn and Soybeans in Quebec and Ontario: A Profile

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Note of appreciation: Canada owes the success of its statistical system to a longstanding partnership between Statistics Canada and the citizens, businesses and governments of Canada. Accurate and timely statistical information could not be produced without their continued co-operation and good will.

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Growers of Genetically Modified Grain Corn and Soybeans In Quebec and Ontario: A Profile

Summary

A hot topic in agricultural today is the potential and risks represented by biotechnology, in particular those products obtained using genetically modified seed (GMS). While some sing the praises of GMS, others consider it a potential threat to human health and the environment. In to facilitate a national public debate on the issue, Statistics Canada has been collecting and analyzing data since June 2000 on GMS used in grain corn and soybeans cropping in Quebec and Ontario.

According to the June 2000 Crops Survey, 16% of all soybean acreage in Quebec, and 18% of that in Ontario, was planted with genetically modified seed (GMS). The figure for grain corn in both provinces was 27%. Most farms using corn and soybean GMS are located in areas of Ontario and Quebec where production of both crops is concentrated.

Although farms using GMS can be found in all size categories, there were many small ventures (< 490 acres) with this technology. Farms using GMS had a smaller ratio of grain-corn or soybean acreage to field crops as a whole; furthermore, more than 58% of grain-corn producers and more than 40% of soybean growers also are involved in livestock.

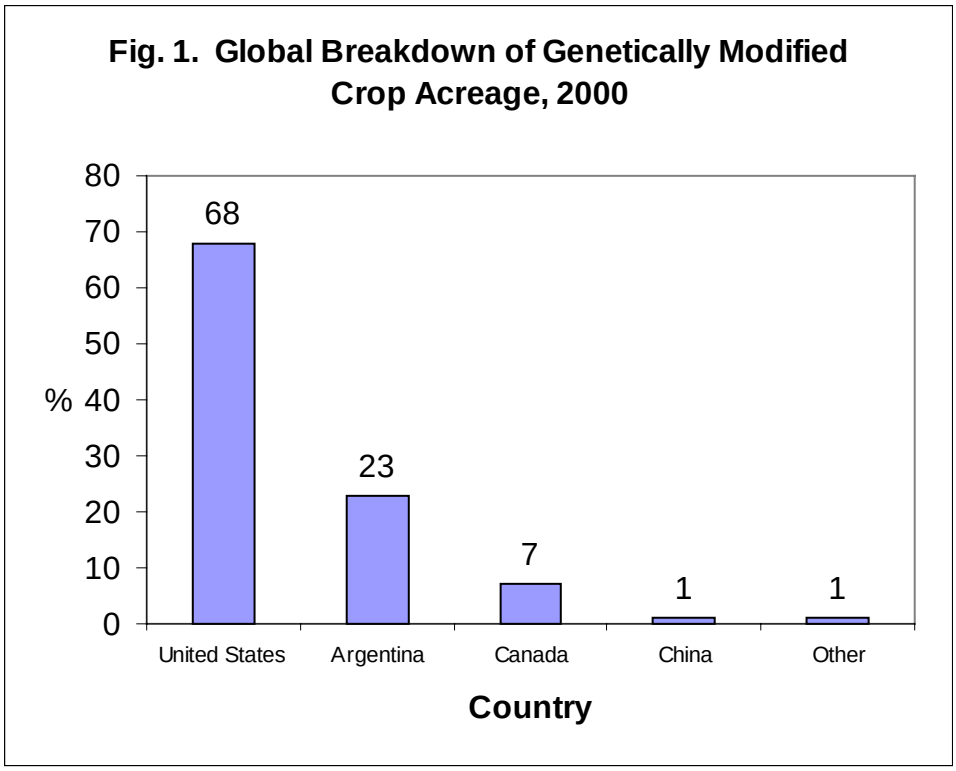
According to data from the November 2000 Crops Survey, average yields of genetically modified (GM) grain corn are higher than those for non-genetically modified (NGM) grain corn, while soybean differences are negligible. Given the number of variations in yield data from the agricultural areas examined, at present, it is very difficult to assess the actual impact of GMS on the production and yield of these two crops based on information from a single year. Furthermore, the wet, cool 2000 growing season was unfavorable for both crops, resulting in lower yields in the two provinces. Further observation is thus necessary for a more comprehensive analysis. In 2001 and subsequent years, Statistics Canada will therefore continue to examine the use of GMS in corn and soybean production among Canadian growers, in an effort to put valid statistical data to use in establishing the first reliable profile of the adoption of this new technology, analyze why growers embrace or abandon GMS, and establish the actual impact of GMS on corn production, thus determining its profitability.

I. Introduction

A hot topic in agricultural today is the problem of products obtained through biotechnology—in particular, genetically modified seed (GMS). Internationally, GMS acreage rose 11% in 2000, from 98.5 million to 109 million acres. As shown in Figure 1, almost all genetically modified crops are found in the Western Hemisphere. But what exactly do we mean by GMS in the case of grain corn and soybeans?

In the case that concerns us here, GMS are seeds from a given variety of grain corn of soybean whose gene pool has been modified through genetic engineering by the incorporation of a foreign gene from

another species or variety, in order to transfer certain qualities or characteristics to the receiving specie or variety.[1]



Source: *Agriweek*, January 15, 2001

Views on the advantages and risks represented by products obtained from genetically modified plants vary considerably. Scientists and companies who sell GMS and related chemicals feel that the use of genetically modified plants, especially those that are resistant to herbicides and insects, is the best means of controlling pests, reducing the use of chemical pesticides and associated costs, and increasing crop yields. Growers second this opinion, especially as genetically modified plants allow them greater flexibility in agricultural practices.

At the opposite end of the spectrum are environmental and other positions. There are fears that useful insects may be affected and eliminated together with the pests in question, and that resistant insects and weeds that are more difficult to control will then appear. Some people even think that food from genetically modified plants may cause allergies.[2]

These concerns are so great that countries such as Japan, Korea, Australia and New Zealand are drafting labelling regulations[3]. Consumers and legislation in most countries require that, in addition to

[1] In the case of Bt-corn, on of the genes cry1Ab, CryAc or Cry9C from *Bacillus thuringiensis*, which are responsible for producing the precursor of a toxin that kills the European corn borer, has been introduced. When the larvae of this small butterfly eat grain corn that has acquired the gene, the precursor is transformed into a toxin, and they die†.
The gene in corn and soybean Roundup Ready protects these crops from Roundup (glyphosate), a nonselective herbicide generally used for weed control.

[2] Economic Research Service (USDA), J. Fernandez-Cornejo and W. McBride, *Genetically Engineered Crops for Pest Management in U.S. Agriculture*, Research Report AER-786 (May 2000).

[3] In Canada, existing legislation requires labelling only in the case of modifications to nutritional value, toxicity or allergenic components.

labelling, traditional varieties be segregated from their genetically modified counterparts[4]. A solution to the problem is hard to find. Variety segregation is technically difficult and costly, on the farm as well as in storage and transit. According to a recent U.S. survey, most growers are not planning on implementing segregation, given the high cost of this operation.[5]

Because of possible implications of the current debate about GM crops on Canadian and worldwide agricultural industry, the present study has been undertaken in order to provide to Canadians reliable information on the use and the benefits of GM crops. The study consists in collecting and analyzing data and to publish results on GM grain corn and soybean in Canada.

II. Methodology

The main goal of this study is to conduct a detailed data analysis, over at least three campaigns, in order to establish a profile of growers who sow all or part of their soybean or grain-corn fields with genetically modified seed (GMS). At the same time, we hope to evalute the actual impact of GMS use on crop yield, and examine developments in seeded acreage as well as the process involved in the adoption of GMS as a farm input.

Our working hypothesis is that growers experiment with and adopt new technologies to meet specific needs and improve performance. To verify this hypothesis, we examined the characteristics of farm operations which can justify the use of GMS, as well as other traits these establishments might have in common (see Table 1 below). We applied logistical models to the data using the Wesvar Complex Samples 3.0 software program (see Table 3 for findings). We also established certain noteworthy indices, such as the percentage of grain-corn and soybean farms using GMS, and the percentage of such farms that also raised livestock (see following). Yield data have been taken from the November 2000 Crops Survey. Data were analyzed using the SUUDAN 7.5 "DESCRIPT" procedure. Please note that, for the purposes of this study, yield estimates with a coefficient of variation (CV) higher than 25 were considered inaccurate, and not reported.

Table 1. Overview of Variables

Variable	Description	Quebec and Ontario		Quebec		Ontario	
		Average	CV (%)	Average	CV (%)	Average	CV (%)
Dependent Variables							
d261 (dichotomic)	Use of GM soybeans	0.16	4	0,10	11	0.18	5
d260 (dichotomic)	Use of GM grain corn	0.27	3	0.35	5	0.24	4
Independent Variables							
C201	Total acreage	324	1	341	2	319	1
Pgrain corn	Ratio of grain-corn acreage to field-crop acreage	0.46	1	0.62	2	0.40	2
Psoybeans	Ratio of soybean acreage to field-crop acreage	0.37	2	0.18	6	0.43	2
Age	Age of farm manager	53	1	50	1	53	1

[4] Economic Research Service (USDA), "Biotechnology: U.S. Grain Handlers Look Ahead," *Agricultural Outlook* (April 2000), Special Article.
[5] *Agriweek* 15 January 2001 [Winnipeg].

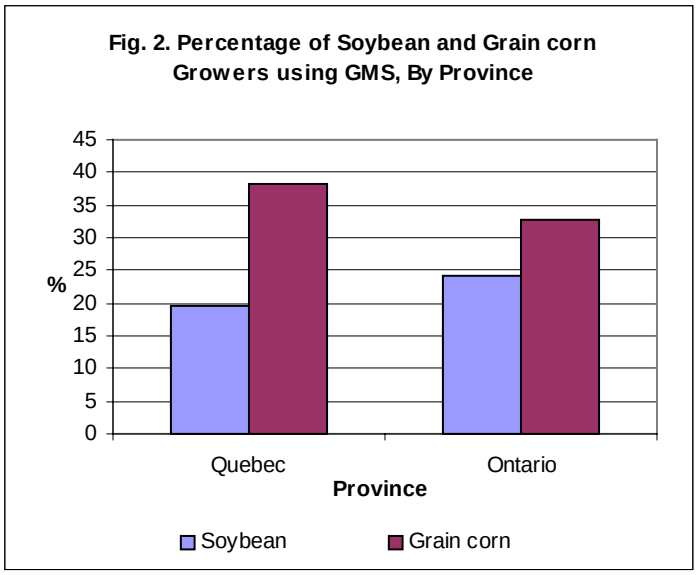
III. Findings

Soybean and grain-corn growers have already used genetically modified seed (GMS).

The June 2000 Crops Survey, involving a total of 33,571 growers—9,417 from Quebec and Ontario alone—showed that 16% of all soybean acreage in Quebec, and 18% in Ontario, was planted with genetically modified seed (GMS). The percentage for grain-corn acreage planted with GMS in both provinces was 27%.

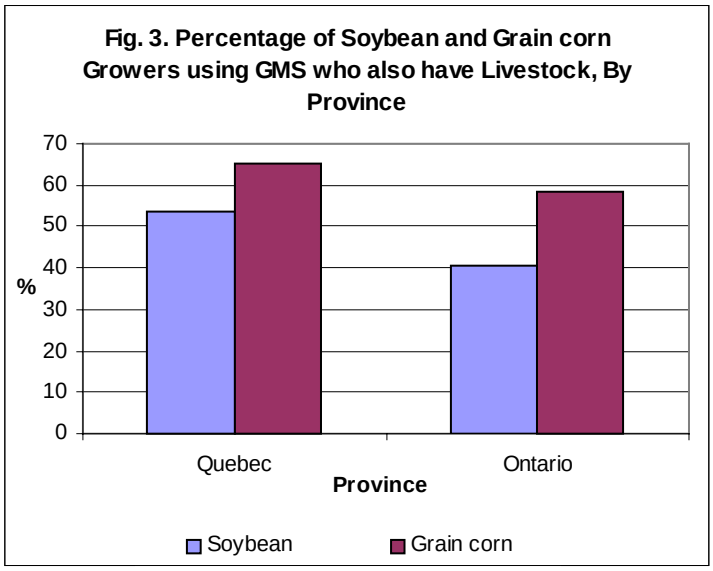
More Quebec and Ontario growers used grain-corn than soybean GMS.

The percentage of grain-corn growers using GMS was 38% for Quebec and 33% for Ontario; as regards soybeans, the figures were 20% for Quebec and 24% for Ontario (Figure 3).



More than 40% of farms using GMS were also involved in livestock.

In Quebec, 65% of grain-corn growers using GMS also have livestock; the figure for soybeans is 54%. The figures for Ontario are 58% and 41%, respectively (Figure 3).



Farms with the most common cropping plans[6] implemented by grain-corn and soybean growers in Quebec and Ontario also accounted for almost all GMS users.

The cropping plans implemented in 2000 by Ontario and Quebec grain-corn and soybean producers are presented in Table 2 below. The most widespread plan in Quebec was "grain corn and soybeans"; in Ontario, it was "grain corn, soybeans and winter wheat".

Table 2. Main 2000 Cropping Plans, as Implemented by Ontario and Quebec Grain-Corn and Soybean Growers

	Percentage of Grain-Corn and Soybean Growers Implementing Plan	
Cropping Plan	Ontario	Quebec
Grain Corn - Soybeans - Winter Wheat	24	0
Grain Corn – Soybeans	20	26
Grain Corn Only	13	24
Soybeans Only	13	5
Soybeans - Winter Wheat	8	0
Grain Corn – Barley	5	15
Grain Corn - Soybeans – Barley	3	12
Grain Corn – Oats	1	6
Other	13	12

In Ontario, a high percentage of farms using grain-corn or soybean GMS (74% for grain corn and 78% for soybeans) implemented one of the following cropping plans:

1. Grain corn - soybeans - winter wheat (33% GM soybeans and 33% GM grain corn);
2. Grain corn - soybeans (23% GM grain corn);
3. Grain corn only (11% GM grain corn);

[6] A cropping plan consists of a breakdown of the various crops to be produced over a given growing season. If a farmer intends to plant only grain corn in a given year, the plan will be for "grain corn only"; if grain corn and soybeans are chosen, the plan will be for "grain corn and soybeans", and so on.

4. Soybeans only (17% GM soybeans).

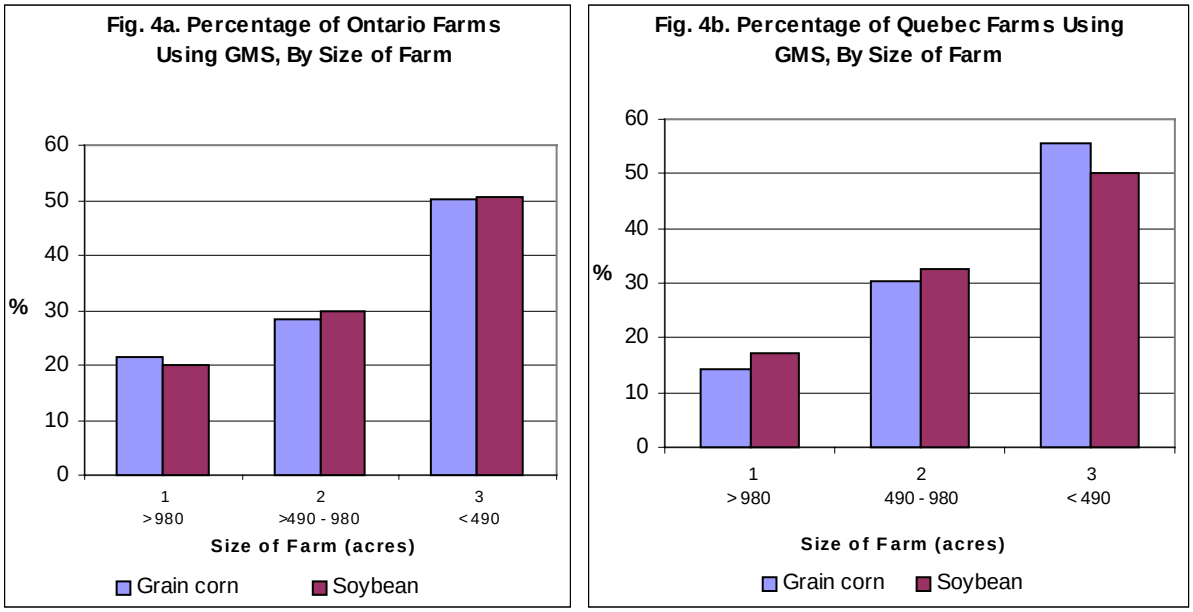
In Quebec, of all farms using GMS, 87% with GM soybeans and 79% with GM grain corn implemented one of the following cropping plans:

1. Grain corn - soybeans (45% GM soybeans and 40% GM grain corn);
2. Grain corn only (23% GM grain corn);
3. Grain corn - soybeans - barley (26% GM soybeans and 16% GM grain corn);
4. Soybeans only (16% GM soybeans).

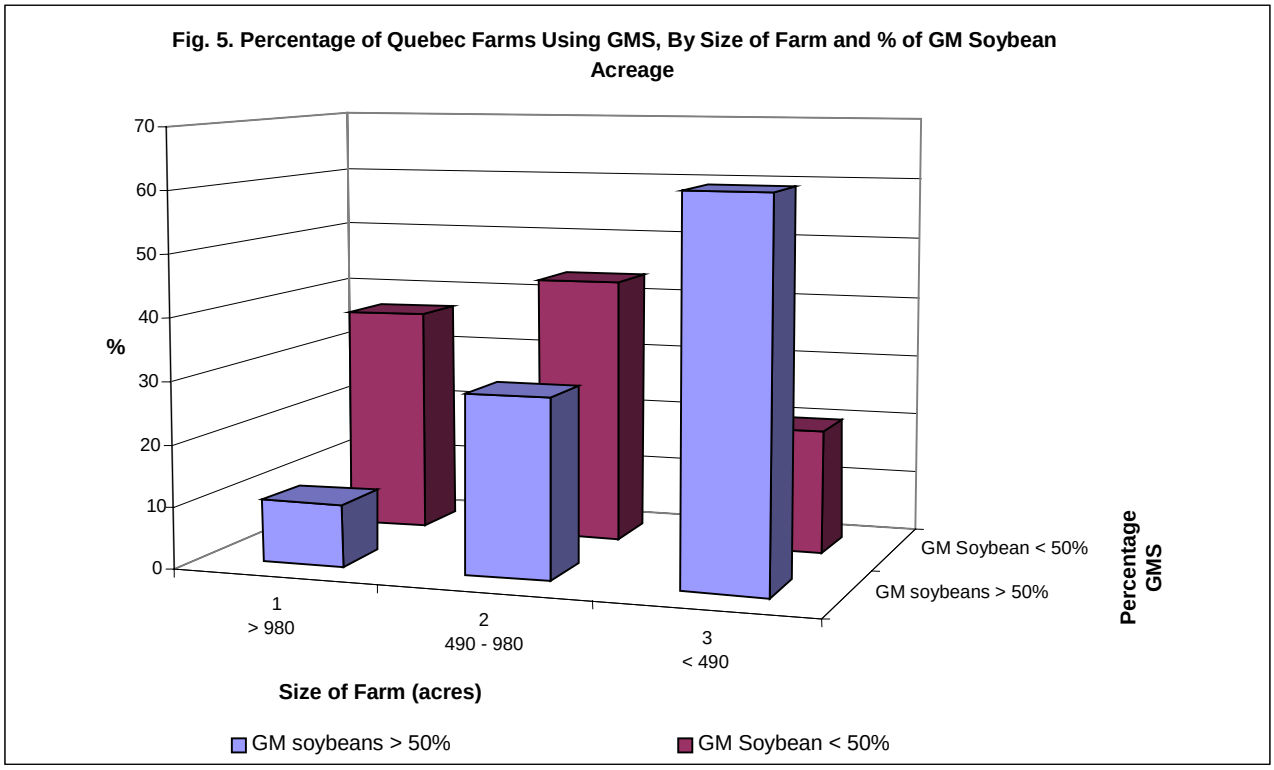
The likelihood of finding GMS is lower if the farm is large (in terms of total cultivated acreage) and the ratio of soybeans or grain corn to field crops is high.

Although GMS can be found in all farm size categories, the smallest operations (< 490 acres) accounted for the highest level of use (Figure 4, Table 3). This category also featured the most farms that had planted their soybean or grain-corn fields with GMS.

Fig. 4. Percentage of Farms Using GMS, By Farm Category and Province



As shown in Figure 5, with respect to soybeans in Quebec, most farms having planted 50% or more of their soybean acreage with GMS are under 490 acres in size (small farms), while those with less than 50% fall into the larger categories.



Furthermore, farms with a low percentage of grain corn (Pgrain corn) or soybeans (Psoybeans) in relation to total field-crop acreage (wheat, grain corn, soybeans, oats and barley) were also most likely to use GMS (see Table 3).

Table 3. Logistical Models: Characteristics of Farms Having Planted Some GM Soybeans or Grain Corn

	Quebec		**Ontario**	
	Estimate		**Estimate**	
Parameter	*GM Soybeans*	*GM Grain Corn*	*GM Soybeans*	*GM Grain Corn*
F-Fit test	2.3942*	11.6804***	5.6734***	12.9168***
Intercept	2.2096***	1.9466***	1.1351***	0.7037**
C201	-0.0006**	-0.0011***	-0.0004***	-0.0008***
Psoybeans	-1.6586**		-0.2182	
Pgrain corn		-1.5215***		-0.063
Age	0.0009	-0.0006	0.0052	0.0067
*** significant at 1%, ** significant at 5%, * significant at 10%				

Profile of Farms Using Soybean and Grain-Corn GMS

1. GM grain corn and soybeans are used by all farm size categories, indicating that GMS is of interest to all soybean and grain-corn growers as an alternative means of weed and pest management.

2. Although more farms now use GM grain corn, acreage actually planted with genetically modified seed remains low. Given that a market for GM products is still far from guaranteed, interested growers seem to be cultivating small areas only- i.e., just enough for their own consumption or the local market, which is less restrictive in terms of quality control.

3. Smaller farms (in terms of total cultivated acreage) have more GM soybeans or grain corn than larger farms. The smaller the farm, the more flexible it seems about adopting new technologies like GMS, and:

    - the less equipment it likely has for pesticide application, meaning that such technologies can be adopted with less financial risk; and
    - the fewer the marketing restrictions it experiences, as the local market is not as strict as the international scene.

4. More than 70% of GMS is found on farms featuring grain corn or soybeans only in their cropping plan, as well as the two main cropping plans implemented in Quebec and Ontario: grain corn/soybeans and grain corn/soybeans/winter wheat, respectively. This, too, demonstrates the attraction of GMS for various cropping plans, and, as a result, for various categories of grain corn and soybean growers in the two provinces.

5. Small farms with a low grain corn or soybean/field-crop ratio used more GMS than others. Specialized operations (soybeans and grain corn) would thus be slow to adopt this new technology, given the market on which they depend. The main focus of farms making the most use of GMS was therefore not grain corn or soybeans, which is also confirmed by the following two paragraphs.

6. Growers who use GMS also have livestock. Small farms with livestock most often proved to be involved part-time in beef-cattle and hay production. Given these facts, farms using GMS, especially as regards grain corn, probably use their crops to meet their own needs, in particular for feeding animals.

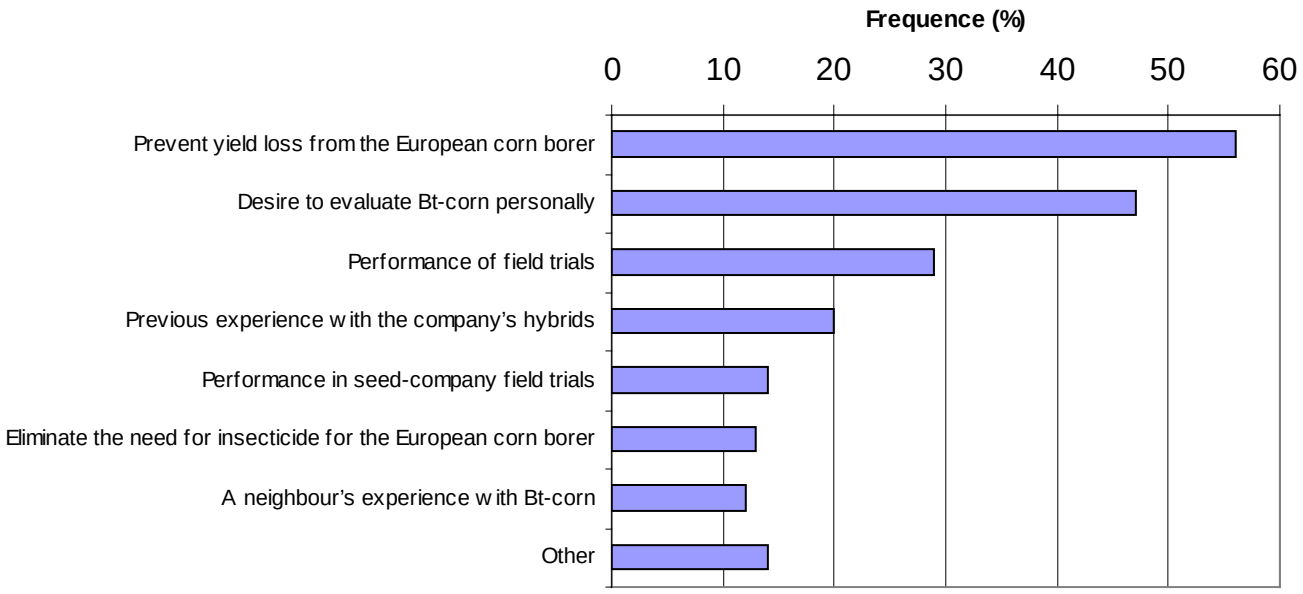
Confirming the logistical model findings, growers told us that Roundup Ready grain-corn and soybean GMS has given them greater flexibility in controlling weeds, since they can get by with fewer chemicals and treatments. On the environmental side, they feel, in particular, that Roundup leaves fewer residues in the soil than other products.

Further to the survey of Ontario grain-corn growers on the implementation of recommendations involving the use of refugia for controlling the development of European corn borer resistance in Bt-corn, Powell et al. (1999) reported that the main reason given for using genetically modified grain-corn seed was to prevent yield loss from the European corn borer (56% of responses), followed by the desire to evaluate Bt-corn personally (see Figure 7).[7] These reasons, which are similar to those mentioned above, indicate that growers use GMS to control the European corn borer and that some growers are still at the experimental stage, hoping to determine whether the use of GMS will help make their job easier.

[7] Powell, D.A., S.E. Grant, and S. Lastovic, *A Survey of Ontario Corn Producers to Assess Compliance with Refugia Recommendations to Manage Development of Resistance to Genetically Engineered Bt-corn in The European corn borer, 1999*, Technical Report No. 009, July 21, 1999 (http://www.plant.uoguelph.ca/safefood/).

While growers are extremely satisfied with the success of GMS in controlling the European corn borer, they also say they use their GM crop yields solely for their own needs, notably because of the marketing problems inherent in this type of production.

Fig. 6. Reasons Given by Ontario Producers for Growing Bt-Corn



Data source: Powell, D.A., S.E. Grant, and S. Lastovic, *A Survey of Ontario Corn Producers to Assess Compliance with Refugia Recommendations to Manage Development of Resistance to Genetically Engineered Bt-corn in The European corn borer, 1999*, Technical Report No. 009, July 21, 1999 (http://www.plant.uoguelph.ca/safefood/).

Data from the November 2000 Crops Survey could not be used to measure the actual impact of GMS on grain corn and soybean yields.

Based on the November 2000 Crops Survey, it is difficult to measure the actual impact of genetically modified grain corn and soybean seed on crop yields. The wet, cool 2000 growing season was unfavorable for both crops, resulting in lower yields in the two provinces.

Grain-corn yields dropped 23.2 bushels/acre in Quebec. Average soybean yield was 37.9 bushels/acre, as compared with 41.2 for the previous growing season.[8]

Despite regional variability and lower corn yields, our statistical analysis shows the average GM grain-corn yield was significantly higher than that for NGM grain corn at the provincial level. In Quebec, GM grain-corn yield was 101.2 bushels/acre, or about 11 more per acre than NGM grain corn (89.7/acre). In Ontario, GM grain-corn yield was 109.0 bushels/acre, or approximately five bushels/acre more than NGM grain-corn yield (104.2/acre) (see Tables 4 and 5).

[8] Statistics Canada, *Estimates of Production of Principal Field Crops, November 2000*, Field Crop Reporting Series No. 8, Vol. 79, Catalogue No. 22-002-XPB, ISSN 0575-8548.

In Quebec, GM soybean yield was 38.6 bushels/acre, or about 1.5 bushels more than NGM soybeans. In Ontario, the difference in yield was approximately 1.0 bushel/acre more for GM soybeans, at 38.9.

The findings show that both Quebec and Ontario experienced lower soybean yields—a fact attributable to late seeding caused by the same wet weather that affected grain corn, and that prevailed in both regions at the beginning of the growing season. Yields were even lower in Quebec, probably as a consequence of the disastrous effects of two late-season frosts.

In order to measure the impact of GMS use on yield, we compared the average yields of growers who had planted their entire corn acreage with genetically modified seed (FGM) to those of growers who had used both GMS and regular corn (FGNGM), as well as to those of growers who had planted regular grain corn only (FNGM). The findings show that, at the provincial level, in Quebec and Ontario alike, average corn yields for FGM and FGNGM growers were not statistically different (Tables 6 and 7). In Ontario, average grain-corn yields for FGM and FGNGM growers were significantly higher than those for FNGM growers at the provincial level and in Agricultural Areas 3 and 4. The same holds true at the provincial level and in Agricultural Area 13 in Quebec (Table 7).

Table 4. Comparison of Average GM and NGM Grain-Corn Yields, Based on Acreage (Ontario)

Level of Analysis	Group	Average Yield	CV (%)	A-B Comparison†	Difference in Yield	T-Test
Province:	GM	109.0	1	GM – NGM	4.8	2.86***
	NGM	104.2	1			
Area 1[9]	GM	118.4	2	GM – NGM	4.6	2.06**
	NGM	113.8	1			
Area 2	GM	108.1	2	GM – NGM	7.1	2.92***
	NGM	101.0	1			
Area 3	GM	98.6	4	GM – NGM	2.0	0.29
	NGM	96.6	4			
Area 4	GM	90.9	5	GM – NGM	9.2	1.96*
	NGM	81.7	3			

GM = genetically modified; NGM = non-genetically modified; † = comparison between A and B
***: A-B statistically significant at 0.01
**: A-B statistically significant at 0.05
*: A-B statistically significant at 0.1

[9] Main corn-producing areas in Ontario and Quebec:

Ontario		Quebec	
Area No.	Area Name	Area No.	Area Name
1	Southern Ontario	4	Mauricie-Bois-Francs
2	Western Ontario	7	Lanaudière
3	Central Ontario	9	Laurentides
4	Eastern Ontario	13	Montérégie

Table 5. Comparison of Average GM and NGM Grain-Corn Yields, Based on Acreage (Quebec)

Level of Analysis	Group	Average Yield	CV (%) (%)	A-B Comparisons†	Difference in Yield	T-Test
Province:	GM	101.2	3	GM - NGM	11.5	3.14***
	NGM	89.7	2			
Area 4	GM	81.9	7	GM - NGM	6.0	0.93
	NGM	75.9	4			
Area 7	GM	80.9	8	GM - NGM	3.2	0.53
	NGM	77.7	4			
Area 9	GM	91.7	9	GM - NGM	22.8	1.73*
	NGM	68.9	15			
Area 13	GM	105.6	3	GM - NGM	7.9	1.81*
	NGM	97.7	2			

GM = genetically modified; NGM = non-genetically modified; † = comparison between A and B
***: A-B statistically significant at 0.01
**: A-B statistically significant at 0.05
*: A-B statistically significant at 0.1

As concerns soybeans, there were no significant differences between average GM and NGM yields in either Ontario or Quebec. These findings corroborate statements from growers, who feel that, for soybeans, no existing GM varieties make it possible to increase yield. In the following sections, therefore, our analyses will bear solely on grain corn-yield data at the provincial level and in the four main agricultural areas of each province studied (determined on the basis of the number of growers who had planted grain corn).

Table 6. Comparison of Average Grain-Corn Yields, Based on Overall Farm Yield‡ (Ontario)

Level of Analysis	Type of Farm	Average Yield	CV (%)	Yield Comparison	Difference in Yield	T-Test
Province:	FGNGM	107.2	1	FGNGM – FGM	2.4	0.67
	FGM	104.8	3	FGNGM – FNGM	5.0	2.98***
	FNGM	102.2	1	FGM – FNGM	2.6	0.76
Area 1	FGNGM	116.6	2	FGNGM – FGM	8.2	1.19
	FGM	108.4	6	FGNGM – FNGM	3.4	1.40
	FNGM	113.2	1	FGM – FNGM	-4.8	0.71
Area 2	FGNGM	107.0	2	FGNGM – FGM	-0.2	0.04
	FGM	107.3	4	FGNGM – FNGM	9.2	3.64***
	FNGM	97.8	2	FGM – FNGM	9.4	1.89*
Area 3	FGNGM	99.9	3	FGNGM – FGM	-1.0	0.20
	FGM	100.9	4	FGNGM – FNGM	11.9	2.65***
	FNGM	87.9	4	FGM – FNGM	13	2.22**
Area 4	FGNGM	85.8	4	FGNGM – FGM	0.7	0.10
	FGM	85.1	8	FGNGM – FNGM	5.4	1.22
	FNGM	80.4	3	FGM – FNGM	4.7	0.68

FGM = Farmers with only genetically modified corn; FNGM = Farmers with only non-genetically modified corn; FGNGM: Farmers with both genetically modified and regular corn
***: statistically significant at 0.01
**: statistically significant at 0.05
*: statistically significant at 0.1
‡: average grain-corn yield for farm, regardless of variety

Table 7. Comparison of Average Grain-Corn Yields Based on Overall Farm Yield (Quebec)

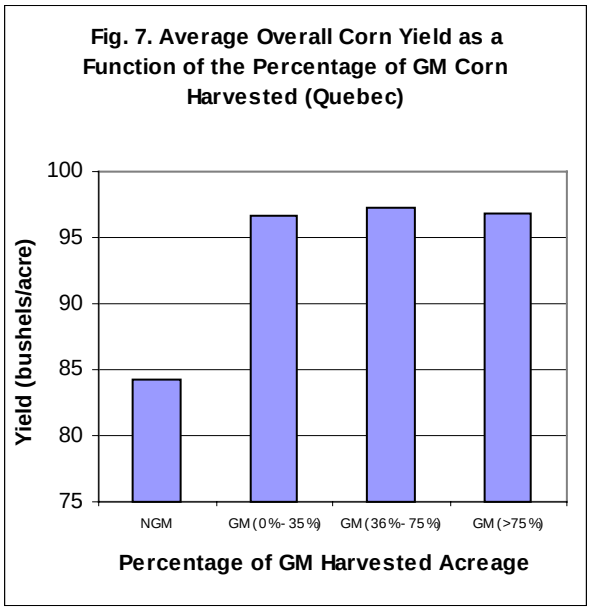
Level of Analysis	Type of Farm	Average Yield	CV (%)	Yield Comparison	Difference in Yield	T-Test
Province:	FGNGM	96.8	2	FGNGM – FGM	-0.5	0.94
	FGM	97.3	7	FGNGM – FNGM	12.6	4.12***
	FNGM	84.2	2	FGM – FNGM	13.1	1.97**
Area 4	FGNGM	78.8	6	FGNGM – FGM	N/A	-
	FGM	I.D.	-	FGNGM – FNGM	6.2	1.02
	FNGM	72.6	5	FGM – FNGM	N/A	-
Area 7	FGNGM	83.8	7	FGNGM – FGM	-1.9	0.13
	FGM	85.7	16	FGNGM – FNGM	3.8	0.47
	FNGM	80.0	7	FGM – FNGM	5.7	0.39
Area 9	FGNGM	95.3	9	FGNGM – FGM	N/A	-
	FGM	I.D.	-	FGNGM – FNGM	16.9	1.69*
	FNGM	74.4	7	FGM – FNGM	N/A	-
Area 3	FGNGM	102.8	3	FGNGM – FGM	-2.8	0.42
	FGM	105.6	6	FGNGM – FNGM	10.3	2.80***
	FNGM	92.5	3	FGM – FNGM	13.1	1.97**

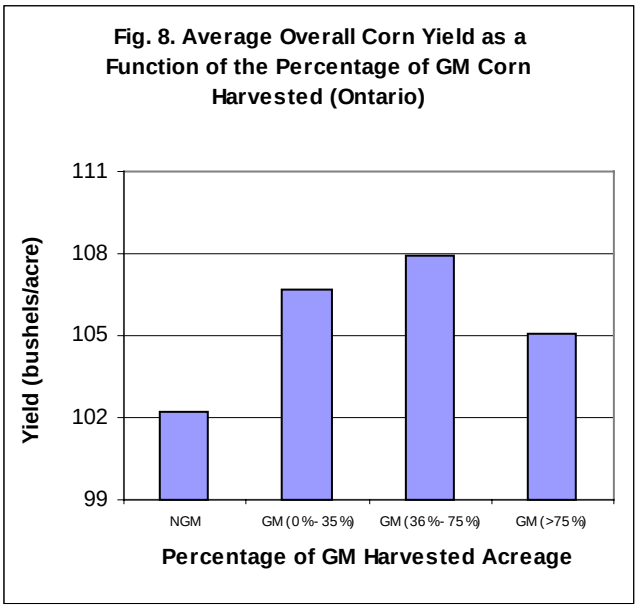
FGM = Farmers with only genetically modified corn; FNGM = Farmers with only non-genetically modified corn;
FGNGM: Farmers with both genetically modified and regular corn
***: statistically significant at 0.01
**: statistically significant at 0.05
*: statistically significant at 0.1
‡: average grain-corn yield for farm, regardless of variety
I.D: innacurate datum
N/A: not applicable

The average overall provincial yield[10] for farms that grew NGM corn only was significantly lower than that for farms that had planted some GM corn.

In Quebec and Ontario, at the provincial level, the average overall yield for FNGM farms was significantly lower than that for farms with GM corn accounting for 35% to 75%, or 0% to 35%, of total harvested corn acreage (Tables 8 and 9, Appendix 1; Figures 7 and 8 below). In Quebec, the average overall yield for FNGM farms was lower than that for farms on which GM corn accounted for 75% of total harvested corn acreage (Table 8, Appendix 1).

[10] Yield based on total harvested acreage, regardless of variety (GM or NGM grain corn).





The difference between average overall NGM and GM corn yields varies from one agricultural area to another.

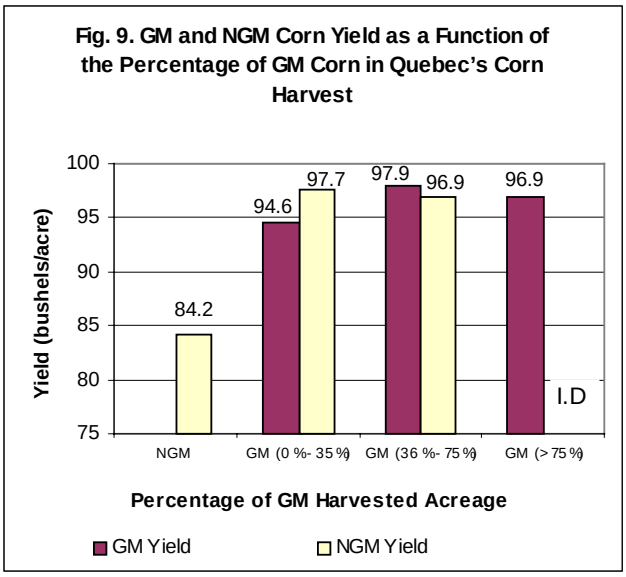
In Area 13, Quebec's main corn-producing area, average overall yield for FNGM farms was significantly lower than that for farms with GM corn accounting for more than 35% of total harvested corn acreage. No significant differences were observed in any other areas except Area 4, where overall yield for FNGM farms was lower than that for farms with GM corn accounting for 35% to 75% of total harvested corn acreage (Table 8, Appendix 1; Figure 13, Appendix 2).

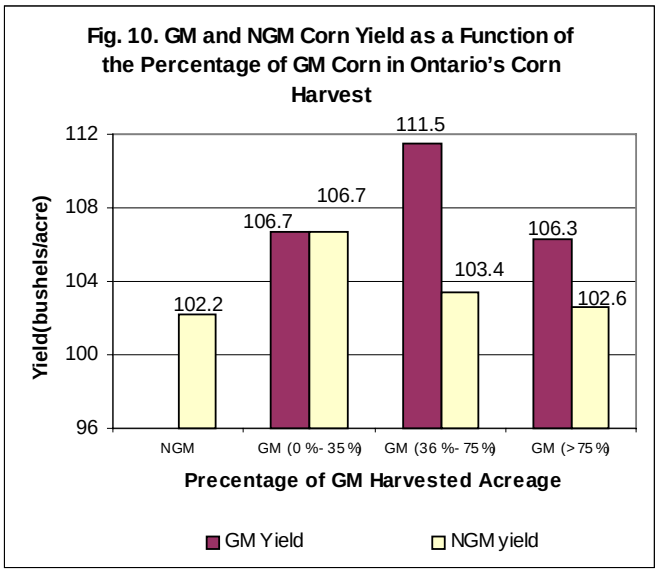
In Agricultural Areas 2 and 3 of Ontario, average overall yield for FNGM farms was was significantly lower than that for farms with GM corn accounting for more than 35% of total harvested corn acreage. In Area 1, however, average overall yield for FNGM farms was statistically lower than that for farms with GM corn accounting for 35% to 75% of total harvested corn acreage. For Area 4, this situation was observed between FNGM farms and those with GM corn accounting for 0% to 35% of total harvested corn acreage (Table 9, Appendix 1; Figure 14, Appendix 2).

These findings show that GM corn has a significant impact on overall yield. In Quebec, farms that used part or all of their land for GM corn had an average yield 12.5 to 13.0 bushels/acre higher, depending on the percentage of GM corn sown. In Ontario, the figures were 2.9 to 5.7 bushels/acre. At the agricultural-area level, the effect of GM corn on overall yield varied from one area to another. Given the poor conditions that characterized the corn-growing season, it is very difficult at present to determine the actual impact of GM corn on average overall corn yield under normal growing conditions.

It is difficult to establish an exact relationship between the percentage of GM corn harvested and GM corn or NGM corn yield.

The findings show that increasing the percentage of GM corn sown does not guarantee a better yield. While a tendency for GM yields to increase with the ratio of GM corn to total corn acreage may be seen in Areas 4 and 13 in Quebec and Areas 2 and 3 in Ontario, the opposite trend can be observed in Areas 1 and 4 in Ontario. Furthermore, GM corn yield is not always higher than NGM grain-corn yield (Figures 17 and 18, Appendix 2). These results make it difficult to determine the actual impact of genetically modified corn seed on overall corn yield. Figures 9 and 10 illustrate the situation at the provincial level for Quebec and Ontario.





D.I.: inaccurate data

There is a relationship between total seeded corn acreage and percentage of GM corn.

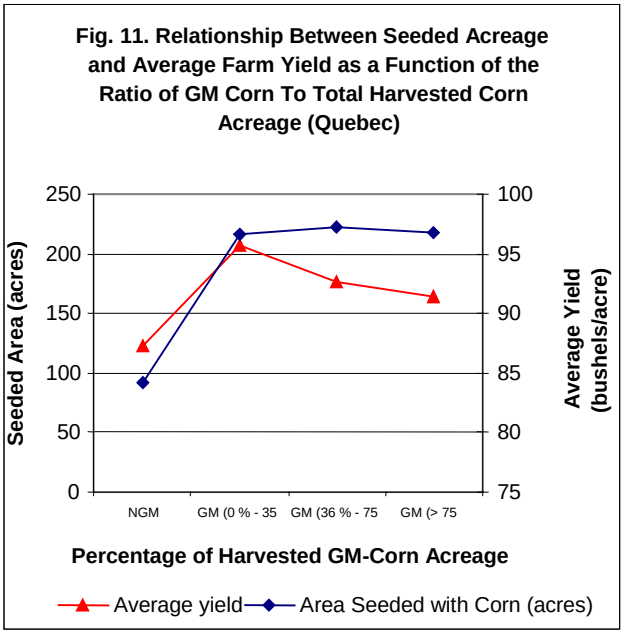
In general, for Quebec as well as Ontario, total seeded corn acreage for FNGM farms is lower than that for GM corn farms. Among the latter, those with GM corn occupying more than 75% of total harvested acreage had planted less land with corn. More specifically, farms with harvested GM-corn acreage of 0% to 35% were those that had planted more corn in terms of total acreage (Figures 11 and 12). This trend occurred in Quebec Agricultural Areas 4, 7 and 13, and Ontario Agricultural Areas 2 and 4 (Figures 15 and 16, Appendix).

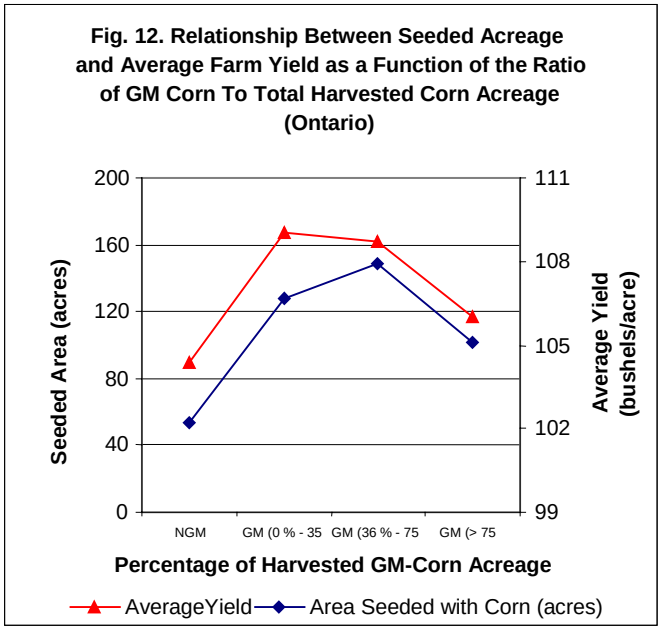
According to these findings, it would appear that growers who seed small amounts of land with corn tend not to use GM seed. A possible explanation for this situation is the high cost of the seed. These growers probably still have doubts about the profitability of the technology for small areas of land, given existing market constraints. Furthermore, farms with higher average seeded corn acreage tend to use only a small percentage of their land for GM corn (between 0% and 35%). Given that, for these establishments, corn appears to be the main crop, several reasons could explain this state of affairs, including:

- a wish to minimize the risk of lost revenue, given the current market context for GM corn;

- cropping practices. According to related recommendaitons, growers who harvest GM corn should use at least 20% of total corn acreage NGM corn as a means of monitoring Bt-corn resistance to the European corn borer.

Farms on which GM corn accounts for more than 75% of harvested acreage are lower in total corn acreage than those using smaller percentages of GM corn. At present, it is difficult to understand the reason for this situation. However, it may be that these farms use most of their crop for, or sell it on the local market as, animal feed.





IV. Conclusion and Outlook

The findings of our study indicate that GMS is of interest to all farm categories, even though smaller farms use it more than large ones. Small farms have more flexibility than large ones, especially as regards marketing potential and investment risks.

Although these findings provide a good foundation, an exact profile of growers who use GMS is difficult to establish from just one survey. Other data will be needed to provide more information and an adequate understanding of the role and development of GM-corn and soybean technology.

The November 2001 Crops Survey will allow us to compare grain-corn and soybean yields obtained with and without GMS. We feel that, by monitoring developments in GMS acreage, the impact of GMS on corn yields, and the number of farms using this technology, it will be easier to explain why growers turn to GMS.

These two parameters (changes in acreage and number of growers using GMS) will also make it possible to understand market behaviour and consumer acceptance of genetically modified products.

Given the fact that, according to the information at our disposal, one of the main reasons for using GMs is to facilitate farm work, the requirements imposed by certain importing countries stipulating that grain must be segregated in the field and during storage and handling may very well prove difficult for Canadian growers.

In 2001 and subsequent years, Statistics Canada will therefore continue to examine the use of GMS in corn and soybean production among Canadian growers, in an effort to put valid statistical data to use in establishing the first reliable profile of the adoption of this new technology, analyze why growers embrace or abandon GMS, and establish the actual impact of GMS on corn production, thus determining its profitability.

V. Acknowledgements

This study was made possible by the cooperation and experience of my colleagues in the Agriculture Division. I would particularly like to thank Oliver Code, chief of the Crops Section and manager of the project on genetically modified seeds, for his advice. Also, I would like to thank Martin Beaulieu, Marco Marin, Sylvain Cloutier and Daniel Bergeron and Lina Di Pietro for their comments on the paper, as well as Phillips Owen of the Social Survey Methods Division for his assistance in implementing the Wesvar and SUDAAN programs to process the data.

APPENDIX 1

Table 8. Comparison Between Average Overall Yield as a Function of the Ratio of GM Corn Acreage to Total Corn Acreage (Quebec)

Level of Analysis	% GM	Average Yield	CV (%)	Yield Comparison	Yield Difference	T-Test
Province:	NGM	84.2	2	NGM – GM0035	-12.5	***
	GM0035	96.7	4	NGM – GM3575	-13.0	***
	GM3575	97.2	4	NGM – GM7510	-12.6	**
	GM 7510	96.8	5	GM0035 – GM3575	-0.5	ns
				GM0035 – GM7510	-0.1	ns
				GM3575 – GM7510	0.4	ns
Area 4	NGM	72.6	5	NGM – GM0035	-8.9	ns
	GM0035	81.5	15	NGM – GM3575	-4.4	**
	GM3575	77.0	8	NGM – GM7510	-11.7	ns
	GM 7510	84.3	24	GM0035 – GM3575	4.5	ns
				GM0035 – GM7510	-2.8	ns
				GM3575 – GM7510	-7.3	ns
Area 7	NGM	80.0	7	NGM – GM0035	1.4	ns
	GM0035	78.6	7	NGM – GM3575	-19.5	ns
	GM3575	99.6	19	NGM – GM7510	-4.5	ns
	GM 7510	84.5	15	GM0035 – GM3575	-20.9	ns
				GM0035 – GM7510	-5.9	ns
				GM3575 – GM7510	15	ns
Area 9	NGM	78.4	7	NGM – GM0035	-18.8	ns
	GM0035	97.2	17	NGM – GM3575	-14.3	ns
	GM3575	92.7	6	NGM – GM7510	N/A	-
	GM 7510	I.D.		GM0035 – GM3575	4.5	ns
				GM0035 – GM7510	N/A	-
				GM3575 – GM7510	N/A	-
Area 13	NGM	92.5	3	NGM – GM0035	-7.6	ns
	GM0035	100.1	4	NGM – GM3575	-11.1	**
	GM3575	103.6	4	NGM – GM7510	-14.9	***
	GM 7510	106.4	7	GM0035 – GM3575	-3.5	ns
				GM0035 – GM7510	-6.3	ns
				GM3575 – GM7510	-2.8	ns

NGM: non-genetically modified grain corn only
GM0035: 0% to 35% of total harvested corn acreage occupied by GM corn
GM3575: 35% to 75% of total harvested corn acreage occupied by GM corn
GM7510: more than 75% of total harvested corn acreage occupied by GM corn

***: statistically significant at 0.01
**: statistically significant at 0.05
*: statistically significant at 0.1
ns: not statistically significant
I.D.: inaccurate datum
N/A: not applicable

Table 9. Comparison Between Average Overall Yield as a Function of the Ratio of GM Corn Acreage to Total Corn Acreage (Ontario)

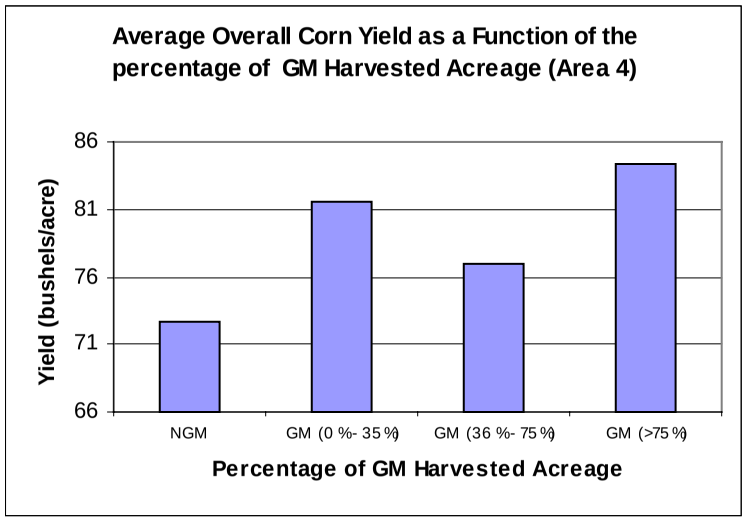
Level of Analysis	% GM	Average Yield	CV (%)	Yield Comparison	Yield Difference	T-Test
Province:	NGM	102.2	1	NGM – GM0035	-4.5	*
	GM0035	106.7	2	NGM – GM3575	-5.7	**
	GM3575	107.9	2	NGM – GM7510	-2.9	ns
	GM 7510	105.1	2	GM0035 – GM3575	-1.2	ns
				GM0035 – GM7510	1.6	ns
				GM3575 – GM7510	2.8	ns
Area 1	NGM	113.2	1	NGM – GM0035	-5.6	ns
	GM0035	118.8	3	NGM – GM3575	-3.9	***
	GM3575	117.1	2	NGM – GM7510	3.8	ns
	GM 7510	109.4	4	GM0035 – GM3575	1.7	ns
				GM0035 – GM7510	9.4	ns
				GM3575 – GM7510	7.7	ns
Area 2	NGM	97.8	2	NGM – GM0035	-5.5	ns
	GM0035	103.3	3	NGM – GM3575	-11.2	***
	GM3575	109	3	NGM – GM7510	-9.8	***
	GM 7510	107.6	3	GM0035 – GM3575	-5.7	ns
				GM0035 – GM7510	-4.3	ns
				GM3575 – GM7510	1.4	ns
Area 3	NGM	87.9	4	NGM – GM0035	-5.6	ns
	GM0035	93.5	3	NGM – GM3575	-14.5	**
	GM3575	102.4	4	NGM – GM7510	-13.2	***
	GM 7510	101.1	3	GM0035 – GM3575	-8.9	ns
				GM0035 – GM7510	-7.6	*
				GM3575 – GM7510	1.3	ns
Area 4	NGM	80.4	3	NGM – GM0035	-12.2	**
	GM0035	92.6	5	NGM – GM3575	-1.7	ns
	GM3575	82.1	7	NGM – GM7510	-4.6	ns
	GM 7510	85	6	GM0035 – GM3575	10.5	ns
				GM0035 – GM7510	7.6	ns
				GM3575 – GM7510	-2.9	ns

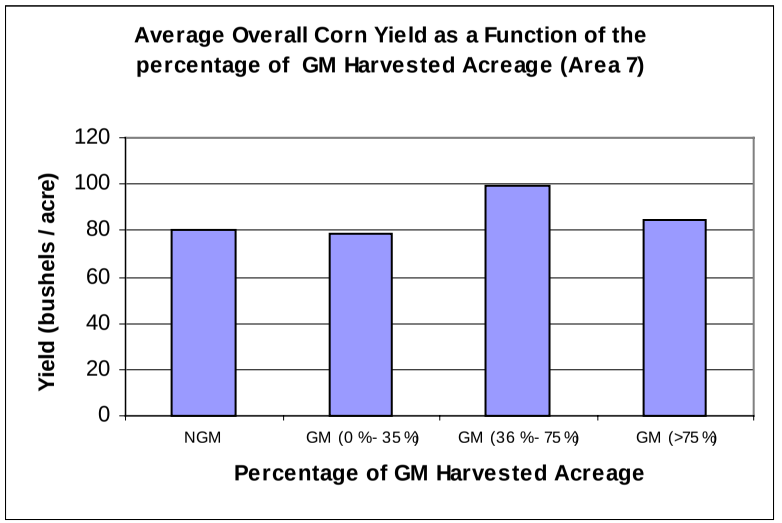
NGM: non-genetically modified grain corn only
GM0035: 0% to 35% of total harvested corn acreage occupied by GM corn
GM3575: 35% to 75% of total harvested corn acreage occupied by GM corn
GM7510: more than 75% of total harvested corn acreage occupied by GM corn

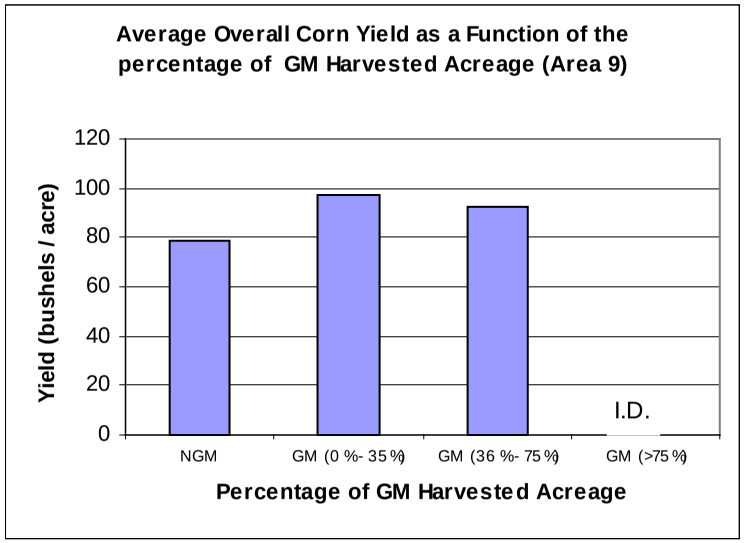
***: statistically significant at 0.01
**: statistically significant at 0.05
*: statistically significant at 0.1
ns: not statistically significant

APPENDIX 2

Fig. 13. Average Overall Corn Yield as Function of The Precentage of GM Harvested Acreage in Quebec's Main Corn-Producing Areas







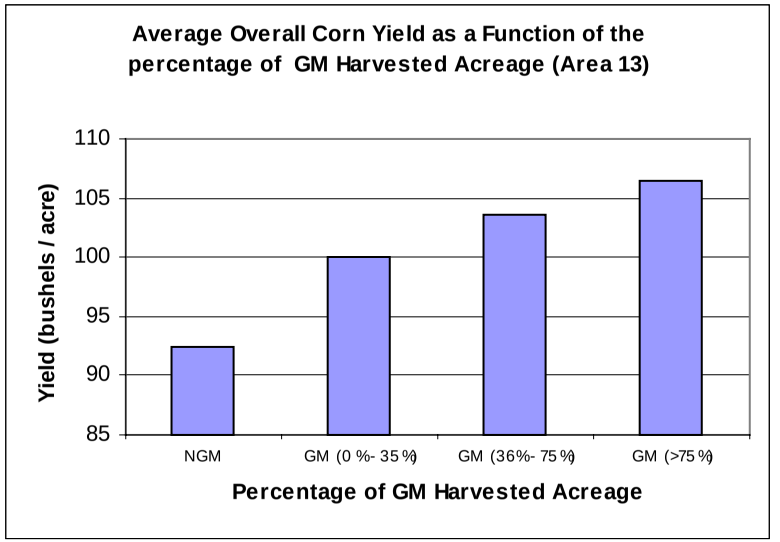
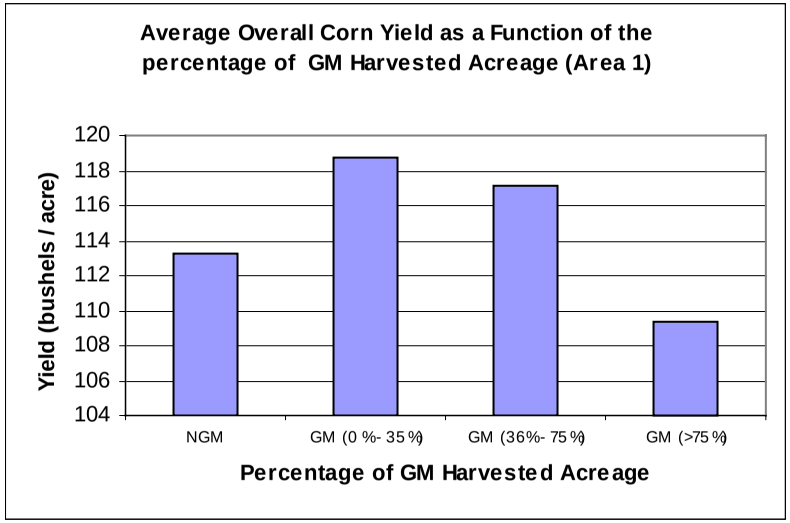
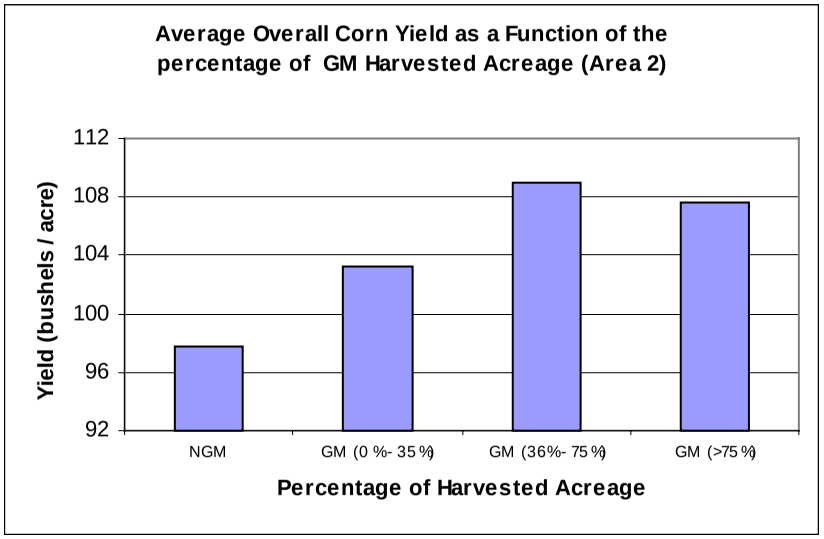
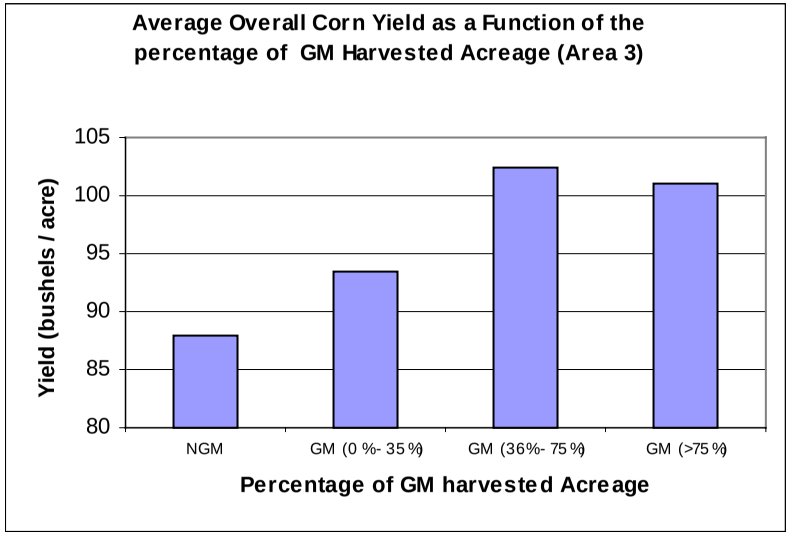


Fig. 14. Average Overall Corn Yield as Function of The Precentage of GM Harvested Acreage in Ontario's Main Corn-Producing Areas







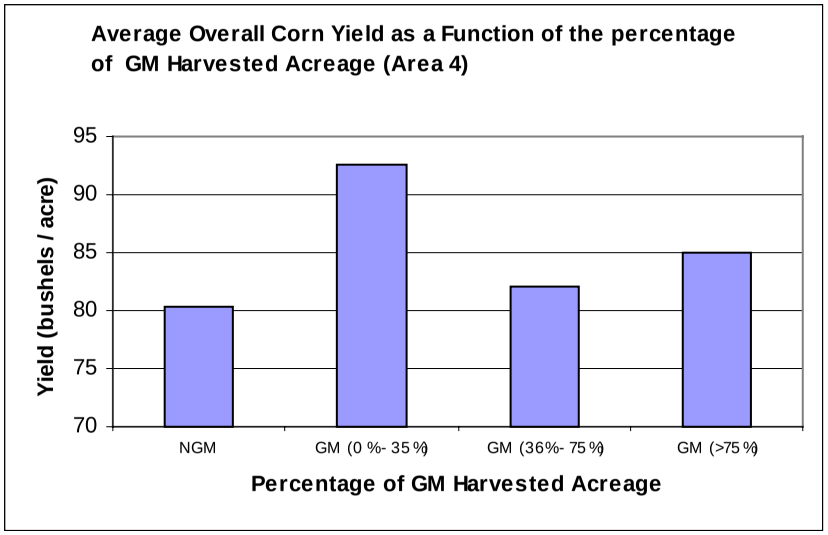
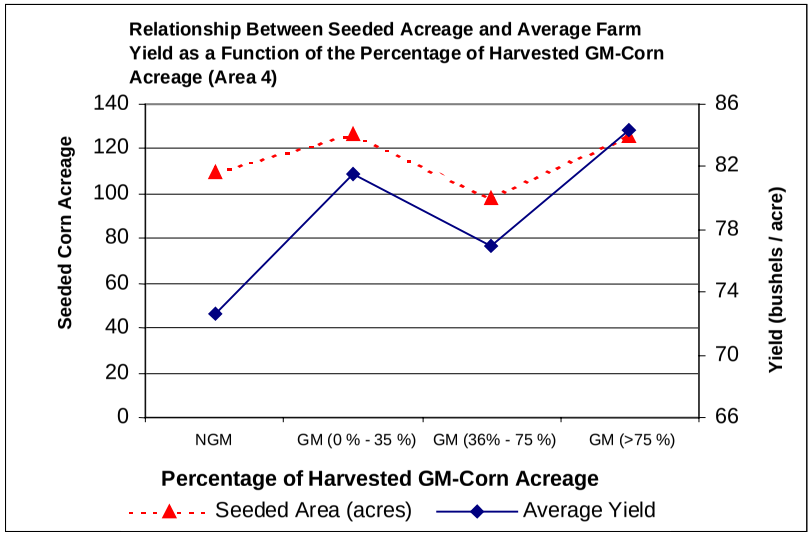
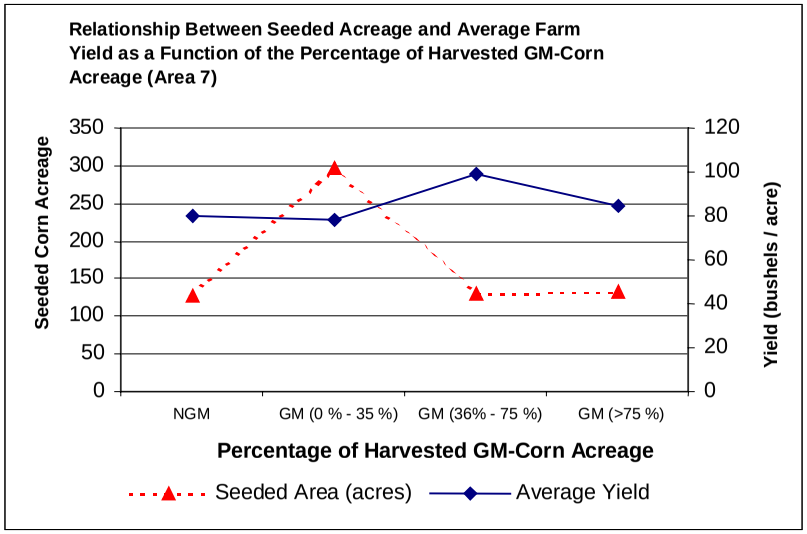
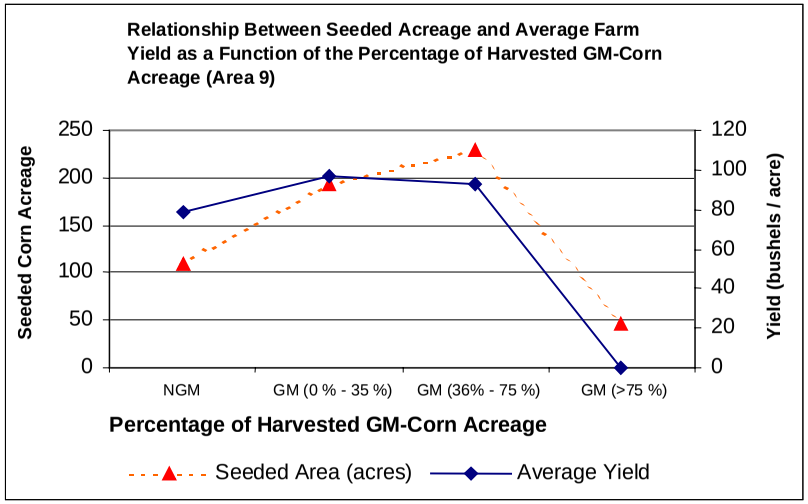


Fig. 15. Relationship Between Total Seeded Corn Acreage and Overall Yield as a Function of the Percentage of Harvested GM-Corn Acreage in Quebec's Main Corn-Producing Areas







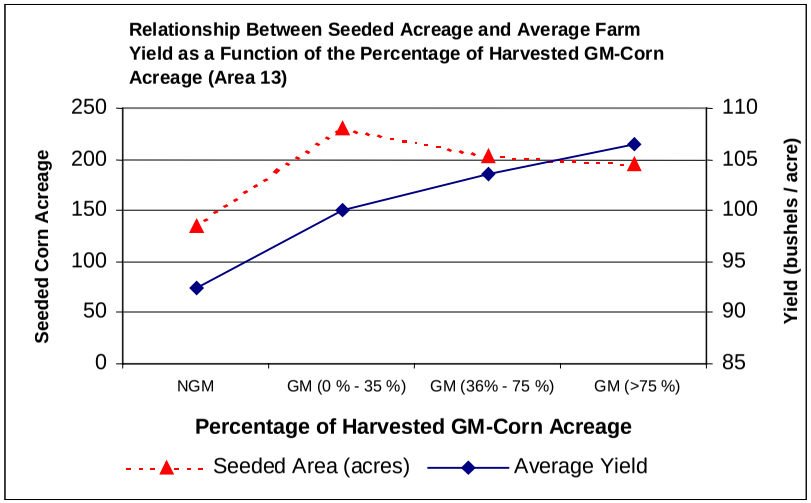
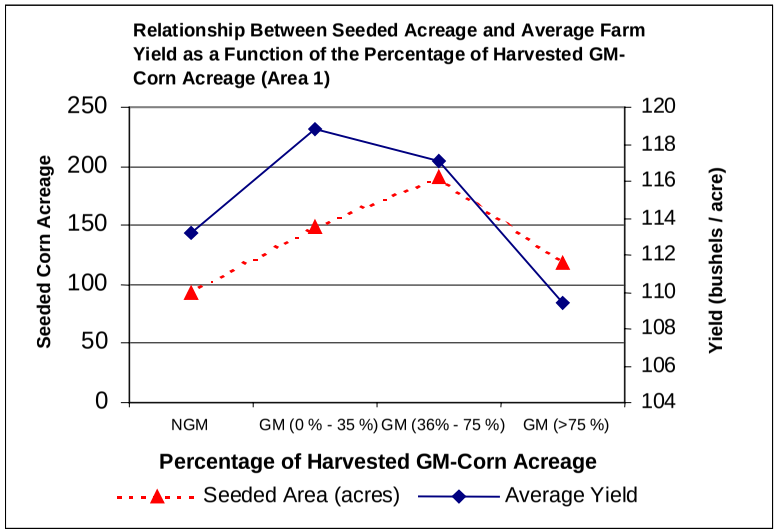
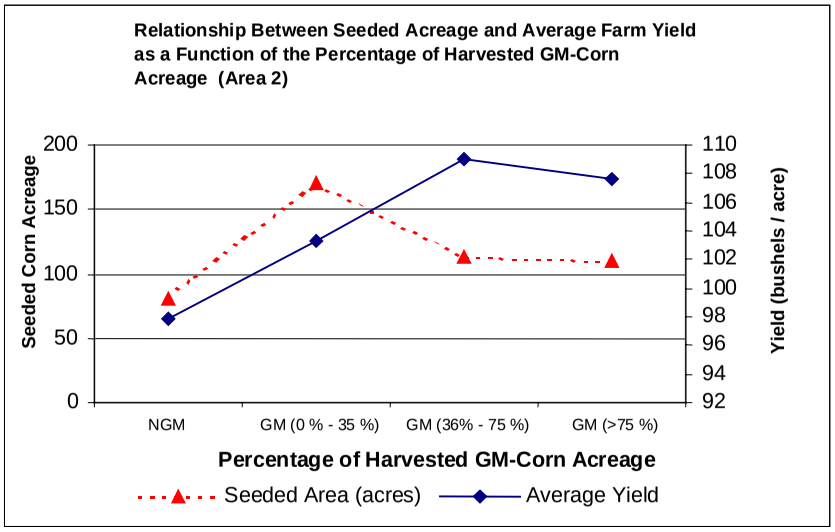
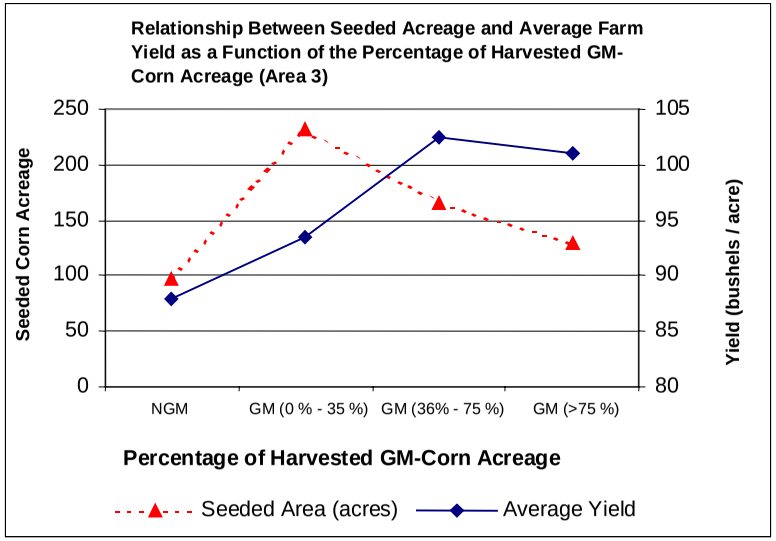


Fig. 16. Relationship Between Total Seeded Corn Acreage and Overall Yield as a Function of the Percentage of Harvested GM-Corn Acreage in Ontario's Main Corn-Producing Areas







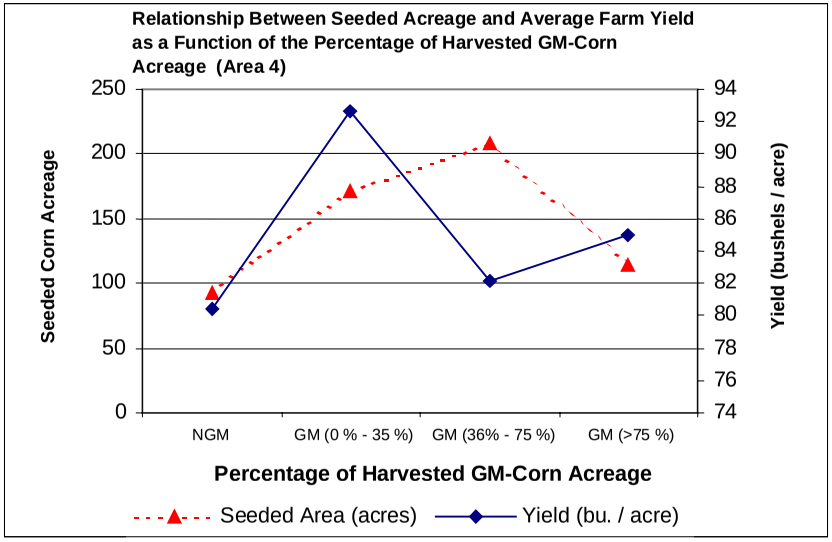


Fig. 17. GM and NGM Corn Yield as a Function of Ratio of Harvested GM-Corn Acreage to Total Harvested Corn Acreage in Quebec's Main Producing Areas

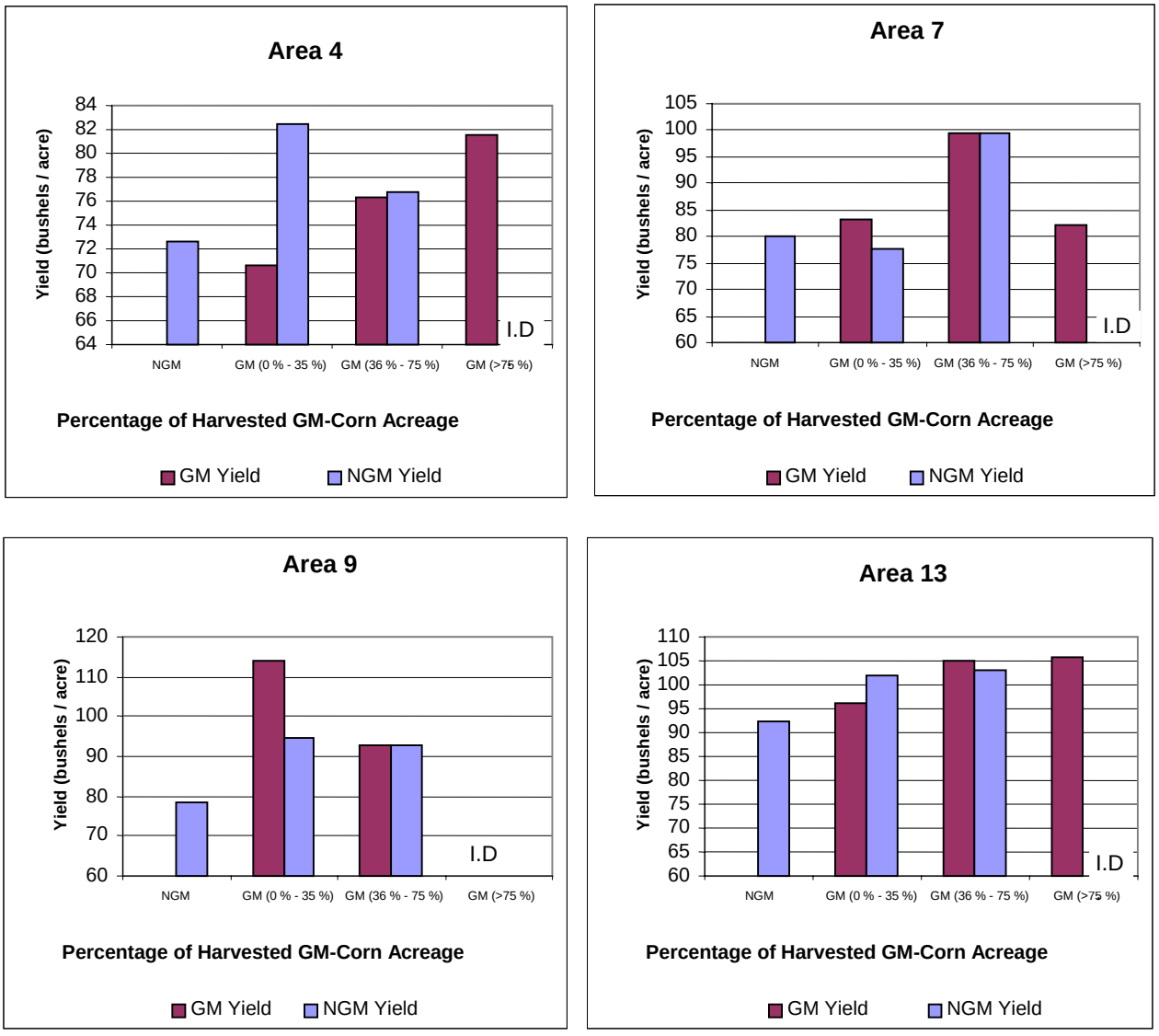


Fig. 18. GM and NGM Corn Yield as a Function of Ratio of Harvested GM-Corn Acreage to Total Harvested Corn Acreage in Ontario's Main Producing Areas