Cost-Benefit Analysis of Two Successful Innovation Cases

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Submitted By:

Don Ference, President
Ference & Company Consulting Ltd.
550-475 West Georgia Street
Vancouver, BC V6B 4M9
Tel: 604-688-2424 (extension #304)
Email: ference@shaw.ca
Website: www.ferenceandco.com

I. Introduction

A. Background

For different accountability purposes and to inform the development of future innovation programming, the Program Design and Performance Division of Agriculture and Agri-Food Canada's (AAFC) Innovation Programs Directorate (IPD) is developing a bank of success stories illustrating the results of innovation programming by examining specific cases. To support this work, cost-benefit analyses (CBA) on two such cases were conducted to estimate their return on investment. The success story bank is intended to serve three main objectives:

- Inform the next policy framework development;
- Increase accountability by providing information for program evaluations, the GF2 mid-term report, Departmental Performance Reports, etc.; and,
- Highlight success stories to communicate to producers, stakeholders, and external audiences.

A "success story" case, herein referred to as a "case", is an innovation resulting from work supported by AAFC that has been commercialized or broadly adopted by the sector, that has a major impact, and for which we can measure benefits in terms of return on investment. This will inform the development of the next innovation program as well as provide evidence of the impacts of such programs.

At the outset of this study, AAFC identified two cases which met the above requirements: swath-grazing and the development of midge-resistant wheat. To gather information on these cases, AAFC conducted interviews with the primary scientists responsible on both cases, as well as an industry representative for the swath grazing case. The interviews covered major milestones for the development along the innovation continuum as well as benefits, requirements for adoption, and results in terms of commercialization and industry adoption. The interviews confirmed considerable benefits of both cases, and the availability of sufficient data to conduct CBA.

This report presents the results of ex-post CBA analyses of the two innovation cases funded through AAFC programming and identified by IPD. For each innovation case, it was necessary to calculate the Net Present Value of benefits and the Benefit:Cost Ratio. In addition, it was necessary to explain other intangible impacts which could not be quantified in dollar value, such as environmental and health benefits.

B. CBA Methodology

The following section provides a step-by-step overview of the CBA conducted to assess the return on investment for the two cases, as follows:

1. Develop a stream of annual costs incurred to develop the innovation: This includes not only costs incurred by AAFC, but also the costs incurred by provincial governments, industry, and producers.

2. Develop a stream of annual gross quantifiable benefits derived from the innovation: The benefits (e.g. cost savings, reduced losses) include the benefits achieved by producers each year in the relevant areas in Canada each year since the innovation was developed. The benefits stream contains not only benefits already achieved but also projected benefits in future years.

3. Convert the streams of gross benefits and costs into a net present value using a discount rate.

4. Determine the net benefits by subtracting the net present value of the stream of costs from the net present value of the stream of gross benefits.

5. Determine the benefit:cost ratio by dividing the net present value of the stream of gross benefits by the net present value of the stream of costs.

6. Determine other intangible impacts such as environmental and health benefits.

C. Outline of Report

The next chapter of the report summarizes the findings of the benefit cost analysis related to the swath grazing innovation. Chapter 3 contains the findings related to the midge resistant wheat innovation.

II. Swath Grazing Innovation

A. Description of Innovation

Swath grazing is a winter stockpiled grazing system used primarily for beef cows in the Canadian prairies. Swath grazing typically involves seeding a cereal crop late (mid-late June) and swathing the crop in concert with maximum yield in mid-September (i.e. in the soft dough stage prior to a killing frost). Beef cows then graze the swaths during the fall and winter months in an effort to minimize the number of days feed needs to be delivered to the cow. Beef cows have successfully grazed swaths through snow as deep as 45 centimeters. As cow/calf managers continue to look for ways to effectively reduce feed costs, more and more crops are being considered for swath grazing. Swath grazing costs include the seed, seeding, crop inputs and swathing. Typically, access to swaths is managed utilizing electric fence to minimize waste. Swath grazing provides an alternative method for extending the grazing season into the winter with lower feed costs, reduced labour costs, lower stored feed costs and manure hauling costs than cows wintered in a traditional winter feeding system on roughage.

B. Study Methodology

To determine the costs incurred by AAFC related to the swath grazing innovation, the available cost information provided by AAFC was reviewed. To review the costs incurred by other organizations as well as to obtain information on the benefits of the swath grazing innovation, interviews with the following individuals were conducted:

- Dr. Vern Baron, Research Scientist, AAFC
- Dr. Shannon Tracey, Senior Research Officer, Alberta Livestock and Meat Agency Ltd.
- Dr. Jeff Braidek, Research Specialist, Saskatchewan Ministry of Agriculture
- Kathy Larson, Beef Economist, Western Beef Development Centre
- Dr. Reynold Bergen, Science Director, Beef Cattle Research Council, Canadian Cattlemen's Association
- Joan Unger, Alberta Agriculture and Forestry
- Alan Hall, Alberta Agriculture and Forestry
- Duane McCarthy, retired from AAFC
- Grant Lastiwka, Livestock/Forage Business Specialist, Alberta Agriculture and Forestry
- Karin Schmid, Beef Production Specialist, Alberta Beef Producers
- Diane Westerland, Chinook Applied Research Associates

A review of research reports and other relevant publications related to swath grazing was also conducted. A list of sources reviewed is available in Appendix 1 of this document.

C. Costs

Funding for the swath grazing innovation commenced in 1995 and has continued to the present. Some swath grazing projects are currently underway and will terminate in 2018. The total amount of funding provided by different organizations for the swath grazing innovation is estimated to be approximately $10 million from 1995 to 2018. As indicated below, about one half of the funding has been provided by AAFC, with the remainder being provided by the Government of Alberta, the Government of Saskatchewan, and industry.

Source of Funding for Swath Grazing Innovation

Organization	Amount of Funding (millions)
AAFC	$5.4
Government of Alberta	$1.1
Government of Saskatchewan	$1.1
Industry	$2.3
Total	**$9.9**

D. Benefits

Adoption Rate of Swath Grazing

Based on the consensus of researchers and other stakeholders interviewed, the adoption of the swath grazing innovation gradually increased from about 5% in 1997, when the results of the first swath grazing research were made known, to about 15% of cattle producers in the prairies by 2002. The onset of mad cow disease (BSE) in 2003 resulted in a dramatic increase in the adoption of swath grazing in the prairies, because ranchers were facing financial difficulties and needed to keep feed costs low. The consensus of respondents is that the adoption rate of swath grazing peaked at about 30% in 2003 as a result of BSE and has declined slightly since then. During the period from 2005 to 2015, three surveys were undertaken that have indicated the adoption rate of swath grazing:

- In 2007, about **23% of farms in western Canada used swath grazing** to extend the grazing season as reported in the 2011 report entitled *An Economic Assessment of Feed Costs within the Cow/Calf Sector* prepared by the Saskatchewan Forage Council for the Western Canadian Feed Innovation Network.

- A survey of 1,009 beef operations in Canada in 2012 (Shepard) indicated that **25% grazed swathed cereal crops,** 52% grazed bales, 44% grazed rolled or processed forages, 29% grazed stockpiled forages, 7.1% grazed standing corn and 1.9% grazed other feedstuffs.

- The 2014 Western Canadian Cow-Calf Survey reported that **17% of survey respondents** indicated that they swath graze. Some other winter feeding methods used are bale graze (33%), stockpile graze (18%), standing corn (6%), crop residue (17%), bale processor (46%), rolled forage (28%) and bale feeders (67%). Because 2014 was a year of unusually high snowfall, reducing the attractiveness of swath grazing due to animals having a harder time getting to the swath, several researchers suspected the 17% adoption rate underestimates average for swath grazing in recent years.

Some of the researchers and industry representatives interviewed indicated that the above surveys underestimate the adoption rate of swath grazing because they are based on the percentage of producers that use swath grazing rather than the percentage of cows fed by swath grazing. These respondents explained that swath grazing allows producers to feed larger cow herds without a corresponding increase in time or labour, contributing to economies of scale. Because larger producers are more likely to use swath grazing than smaller producers, the percentage of cows fed by swath grazing is likely higher than the percentage of producers that employ swath grazing. These surveys could also underestimate the adoption rate of swath grazing in the prairie provinces (i.e. Alberta, Saskatchewan and Manitoba), due to more favourable weather conditions for the grazing system there compared to other provinces.

For the purposes of the cost benefit analysis, the adoption rate of swath grazing for the period from 2005 to 2015 was conservatively assumed to be 22%, which is the average of the adoption rates indicated in the above three surveys. Based on the respondents interviewed, the adoption rate of swath grazing is projected to increase slightly in the future due to its relative cost advantages compared to most other winter feeding methods. However, the respondents also noted some constraints to significant increases in swath grazing, including: increasing use of other cost effective winter feeding methods such as standing corn, stockpiling and bale grazing; wildlife issues because the deer and elk feed on the swath; difficulties in convincing producers to change long standing practices; and weather conditions such as a heavy snowfall. Based on consensus of respondents, the adoption rate of swath grazing is expected to increase slightly from 2016 to 2025, to an average of 25%.

The swath grazing technology has been aimed primarily at the cow/calf sector in the prairies where 95% of Canada's tame and native forage acres and 87% of the beef cow herd are located. While swath is used to a lesser extent in some other parts of Canada, the weather conditions are such (i.e. more rain in the fall or snowfall in the winter) that swath grazing is not as suitable as in the prairies. The other constraint to swath grazing in the rest of Canada is land availability. To determine the number of cows fed by swath grazing, the adoption rate has been multiplied by the total number of beef cows in the prairies (Alberta, Saskatchewan and Manitoba). The source of data for the population of beef cows in the prairies is Statistics Canada's annual reporting on the number of cows at least four years old. To determine the projected number of cows from 2016 to 2025, we have used the used a linear exponential smoothing method that is based on the historical data provided by Statistics Canada up to 2015.

Benefits of Swath Grazing

The benefits of swath grazing are the reductions in labour, machinery and fuel expenses associated with baling forage, hauling it to the farmyard, delivering it to the cattle through the winter, then hauling the manure from the winter feeding area to the field the following spring. With swath grazing, the cattle do all that work.

A study by Baron et al (2014) indicated that total daily feeding costs per cow using swath grazing amounted to $0.78 using triticale as the source of feed, $1.05 using corn, and $1.24 using barley. The daily costs for all three feed sources are lower than the traditional winter feeding method (i.e. pen-fed method), which was estimated to cost $1.98 per cow per day. The types of costs employed for the cost comparison included feed production, feed processing and delivery, yardage, bedding activities and manure removal costs. For feed production, seed, fertilizer and herbicide inputs were taken into account for all swathed crops and crops used for the control diet (traditional pen fed method). Equipment used for each crop or animal management activity was referenced to Farm Machinery Custom and Rental Rate Guide 2008-09 to determine a work rate for the actual equipment combination used. This established a fixed (including depreciation) and operating (including fuel, lubricants and repairs) cost for equipment used in cropping operations and hours of labour ($14.66 per hour) that could be extrapolated to cost per hectare for each activity. Cost of land and operating interest were not included in the analyses. Yardage costs included the cost of all activities associated with feed processing and delivery, bedding activities and manure removal. Time spent for activities was recorded on a pen or paddock basis such that at the end of the feeding period, the sum of all the events provided a total time requirement for labour and equipment. Operating and fixed costs for equipment used in the activities were determined by multiplying the cost per hour found in the Farm Machinery Custom and Rental Rate Guide 2008-09 for each piece of equipment by the time taken for the activity on a pen or paddock basis. The costs of adopting the swath grazing technology were included in the study by Baron et al. (2014) because all equipment requirements were included in the cost analysis. The primary equipment required for swath grazing is a movable electric fence and cattle watering facilities, in some instances. The individual and composite costs were converted to a per-cow feeding day basis that paralleled feed costs by dividing pen and paddock costs by cow number per-pen or paddock. A total cost per cow-day was determined by adding costs of feed, yardage, bedding and salt and minerals.

By comparing the difference in daily feeding costs, the savings achieved by swath grazing compared to the traditional winter feeding method are $1.20 for triticale, $0.93 for corn, and $0.74 for barley. The number of days that cows can be fed with swath grazing depends on the weather and can vary considerably from 100 to 200 feeding days per year. However, as cows get closer to calving, most producers prefer to switch from swath grazing to a higher energy feed. According to the researchers interviewed, a conservative estimate of the number of days that cows can be fed from swath grazing is 100 days per year. Therefore, the annual savings achieved from using swath grazing with barley compared to the traditional winter feeding method are $74 per cow, $93 per cow with corn and $120 per cow using triticale.

Barley has been the predominant form of feed used for swath grazing to date. However, the researchers interviewed indicated that due to recent studies (Baron et al., 2014), the increased cost savings resulting from triticale compared to barley will likely result in triticale becoming the predominant source of feed used in swath grazing. Some researchers also indicated that corn may be used as well, but the savings are considerably less for corn compared to triticale due to higher input costs.

For the purposes of the cost-benefit analysis, it has been assumed that barley has been used for swath grazing during the period from 1995 to 2015. For the next ten years (2016 to 2025), it has been assumed that the proportion of cows fed with swath grazing from barley will gradually decrease to 25%, while the proportion of cows that will be fed swath grazing from triticale will increase to 75%.

As an illustration of the benefits, there were approximately 3.1 million beef cows in the prairies on July 1, 2015. Based on an adoption rate of 22%, the number of beef cows in the prairies that swath grazed with barley is estimated to be approximately 690,000. Because swath grazing with barley results in a winter feeding cost savings of $74 per cow compared to the traditional winter feeding method, total costs savings resulting from the swath grazing innovation in 2015 are estimated to be approximately $34 million.

E. Cost Benefit Analysis

To undertake the cost benefit analysis, we have converted the streams of gross benefits and costs to present values using a discount rate. A discount rate of 2% has been employed as it is the average Bank of Canada rate for long-term real return bonds (i.e. exclusive of inflation) during the last 20 years, and the projected rate for the next 10 years.

Based on the discounted cash flow analysis, the total gross benefits (1995 net present value) of the swath grazing innovation during the period from 1995 to 2025 are estimated to total about $1.31 billion. By subtracting the discounted costs to fund the swath grazing innovation, the net benefits (1995 net present value) of the swath grazing innovation is approximately $1.30 billion. By dividing the net present value of the total gross benefits by the net present value of the total costs, the benefit cost ratio of the swath grazing innovation is approximately 170:1.

F. Other Benefits

Some of the other benefits achieved by swath grazing mentioned by interviewees are as follows:

- Swath grazing saved a lot of cattle producers from going bankrupt during the BSE crisis in 2003 because it dramatically reduced winter feeding costs.
- Swath grazing taught people about the value of extended grazing and resulted in other types of extended grazing options such as bale grazing, stockpiling and standing corn.
- Improved manure management because manure is applied directly to the land. This enhanced productivity of the manure has environmental benefits because it results in reduced chemical fertilizer requirements.
- Reduced fossil fuel requirements results in a reduction in greenhouse gas emissions.

- Reduced farm labour requirements.

III. Midge Resistant Wheat Innovation

A. Description of Innovation

Orange wheat blossom midge is a pest that can significantly reduce crop yield and grade. Crop damage occurs when the midge larvae feed on the developing wheat kernel. Grain damage ranges from a slight change in shape, to a kernel that is completely shrunken and deformed, to complete abortion of the kernel. The damaged kernels can cause downgrading in wheat samples and many are blown out of the combine during harvest.

Work on developing midge tolerant wheat varieties began in 1996 when genetic resistance to the midge was detected in some soft winter wheat varieties. By 2002, scientists in Winnipeg had determined that a single gene, known as *Sm1,* confers midge resistance. When the midge insect begins to feed on the seed, the *Sm1* gene causes the level of phenolic compounds (naturally occurring organic acids in wheat kernels) to elevate more rapidly than in wheat kernels without the *Sm1* gene. The higher levels of phenolic acids cause the midge larvae to stop feeding and the larvae starve to death. The mechanism that triggers the production of phenolic acids does not operate if midge larvae are not feeding on the seed, and in addition, these acids are reduced to normal levels by the time wheat reaches maturity, thus not affecting the quality or food value of the harvested grain.

By 2010, the first midge tolerant varietal blends of certified CWRS wheat seed were being commercially grown by Western Canadian grain producers. As shown below, several spring wheat varieties have since been developed by Canadian wheat breeders at AAFC in Winnipeg and Swift Current, and the Crop Development Centre at the University of Saskatchewan:

- AC® Unity VB
- AC® Goodeve VB
- AC® Glencross VB
- AC® Fieldstar VB
- AC® Shaw VB
- CDC Utmost VB
- AC® Conquer VB
- AC® Vesper VB
- AC® Enchant VB
- AAC Marchwell VB
- CDC Titanium VB
- AAC Jatharia VB
- AAC Prevail VB
- AAC Cameron VB
- AAC Tenacious VB

B. Study Methodology

To determine the costs incurred by AAFC related to the midge resistant wheat innovation, the available cost information provided by AAFC was reviewed. To review the costs incurred by other organizations as well as to obtain information on the benefits of the midge resistant wheat innovation, the following individuals were contacted:

- Ian Wise, Research Scientist AAFC (retired)
- Mike Espeseth, Communications Manager, Western Grains Research Foundation
- Barb Kammener, Finance Manager, Western Grains Research Foundation
- Curt McCartney, Research Scientist, AAFC
- Kofi Agbor, Crop Development Centre, University of Saskatchewan
- Jeff Reid, General Manager, SeCan
- Brenda Trask, SeCan
- Michael Jackman, Commercialization Officer, AAFC
- E. Ann de St Remy, Office of Intellectual Property and Commercialization, AAFC
- Cezarina Kora, Senior Strategy Coordinator, Pesticide Risk Reduction Program, AAFC

A review of the research reports and other relevant publications related to midge resistant wheat was also conducted, and a list of sources consulted is included in Appendix 1 of this document.

C. Costs

Approximately $16.3 million in funding has been and will be provided to develop midge tolerant wheat from 1997 to 2019. Of this total, about $10 million has been provided by AAFC, while the remainder has been provided by a number of organizations including SeCan, Western Grains Research Foundation, the Alberta Crop Industry Development Fund and the Saskatchewan Agriculture Development Fund.

D. Benefits

Adoption Rate of Midge Tolerant Wheat

Since the launch of the first commercial midge tolerant wheat varieties in 2010, the industry has witnessed strong uptake of the technology. As indicated in the following table, approximately 2 million acres of midge tolerant wheat have been planted each year from 2013 to 2015. During this period, the proportion of total wheat acreage in western Canada planted in midge tolerant wheat was approximately 17%.

Adoption Rate of Midge Tolerant Wheat in Western Canada

Year	Number of Acres of Midge Tolerant Wheat	Total Insured Acres of Wheat Planted	Proportion of Acres Planted in Midge Tolerant Wheat
2013	2,051,968	12,900,819	15.9%
2014	1,992,843	10,860,133	18.4%
2015	1,937,420	11,438,627	16.9%
Average	**1,994,077**	**11,733,193**	**17.0%**

Benefits of Midge Tolerant Wheat

The most tangible benefit of midge tolerant wheat is the reduction of production losses. Midge damage occurs when midge larvae feed on developing wheat kernels. Affected kernels are shrunken and deformed, leading to reduced yields and grade-related losses. A detailed investigation of midge damage to wheat was conducted by the Cereal Research Centre (Wise et al.). As indicated in the following table, the financial loss incurred by all wheat producers as a result of midge damage was an average of $62.1 million per year during the seven year period from 2004 to 2010.

Yield Loss and Financial Loss to Producer Caused by Midge in Western Canada

Year	Yield Loss	CWRS Production (millions of metric tonnes)	Production Loss (thousands of metric tonnes)	CWRS No. 1 Price (per metric tonne)	Loss to Producer (millions)
2004	0.07%	14.58	10.2	$205.10	$2.1
2005	0.24%	15.04	36.1	$195.14	$7.0
2006	3.61%	16.18	584.1	$212.89	$124.4
2007	5.46%	11.59	632.8	$372.06	$235.4
2008	0.74%	15.39	113.9	$311.36	$35.4
2009	0.32%	16.15	51.7	$236.80	$12.2
2010	0.33%	15.22	50.2	$344.96	$18.0
Average	**1.54%**	**14.88**	**211.3**	**$268.33**	**$62.1**

A study undertaken by AAFC (M. Jackman) estimated that the annual economic losses caused by midge were approximately $40 million dollars for western Canada wheat farmers.

The two studies mentioned above (Wise et al. and M. Jackman) examined the overall loss to all wheat acres in western Canada and they included every field, whether it has any midge or not. However, for the fields that have midge the actual yield loss is much higher than the average indicated in the above two studies. Some industry representatives indicated that farmers who grow midge tolerant wheat report benefits amounting to $36 per acre (based on a 15% yield loss on a yield of 40 bushels per acre for wheat priced at $6 per bushel). Other industry representatives indicated that the net savings resulting from midge tolerant wheat range from $20 to $70 per acre, depending on the extent of midge infestation. For the purposes of the cost benefit analysis, we have conservatively assumed the net savings, taking into account the increased seed cost of midge tolerant wheat varieties for the producer, to be approximately $20 per acre.

It was assumed that the acreage planted in midge tolerant wheat will remain at the current level of about 2 million acres over the next 15 years and that all midge resistant wheat has been planted on acres previously affected by midge infestation. Consequently, the annual savings resulting from midge tolerant wheat are estimated to be about $40 million per year. The assumption that the adoption rate of midge will remain at the current level of about 2 million acres or 17% of the total wheat acreage planted is based on the following: midge infestations have declined in recent years according to some individuals interviewed, and use of midge resistant wheat is expected to reduce the size of the wheat midge population over time; seeds for midge resistant wheat varieties are more expensive than some other wheat varieties; some farmers are employing other non-pesticide pest reduction practices such as ensuring there are sufficient predators (e.g. wasps and other biocontrol agents) to control midge populations; and some farmers will continue to use pesticides to deal with midge infestations. Another factor that may constrain the adoption rate of midge tolerant wheat is some farmers have recently become interested in planting wheat varieties that are resistant to fusarium head blight, a fungal disease of cereal crops that affects kernel development.

E. Cost Benefit Analysis

To undertake the cost benefit analysis, we have converted the streams of gross benefits and costs into present value using a discount rate. A discount rate of 2% has been employed as it is the average Bank of Canada rate for long-term real return bonds (i.e. exclusive of inflation) during the last 20 years, and the projected rate for the next 10 years.

Based on the discounted cash flow analysis, the total gross benefits (1997 net present value) of the midge tolerant wheat innovation are estimated to total $468 million. By subtracting the net present value of the costs of about $12.2 million to fund the midge tolerant wheat innovation, the net benefits (1997 net present value) of the midge tolerant wheat innovation are approximately $455.8 million. By dividing the net present value of the total gross benefits by the net present value of the total costs, the benefit cost ratio of the midge tolerant wheat innovation is approximately 37:1.

F. Other Benefits

Some of the other benefits achieved by midge tolerant wheat are as follows:

- Midge-tolerant wheat varieties eliminate the need to use insecticide as a control method. This results in reduced labour requirements because farmers do not have to spray for midge.

- Because it eliminates the need for spraying insecticide on the fields, midge-tolerant wheat also results in considerable environmental benefits to the soil and air. It is also safer for the farmer because the need for spraying chemical insecticide is eliminated, and safer for non-target insects which are not affected by midge resistant wheat as they would be by insecticides.

- Planting of midge-tolerant wheat has a free-rider effect because neighboring wheat fields that do not plant midge tolerant wheat are likely to benefit as well.

- Midge-tolerant wheat varieties offer flexibility in crop rotations and seeding dates.

Appendix 1: References Reviewed

Swath Grazing Innovation

- Vern Baron, Raquel Doce, John Basarab, and Cambell Dick, Swath Grazing Triticale and corn compared to barley and a traditional winter feeding method in central Alberta, Published on the web May 2014
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- Western Canadian Cow-Calf Survey, 2014 Western Canadian Cow-Calf Survey Aggregate Results, Western Beef Development Centre, June 2015
- Saskatchewan Forage Council, An Economic Assessment of Feed Costs within the Cow/Calf Sector, Western Canadian Feed Innovation Network, September 2011
- Farm Environmental Management Survey, Statistics Canada Catalogue no 21-023-X, 2011

Midge Resistant Wheat Innovation

- Midge Tolerant Wheat website www.midgetolerantwheat.ca/wheat/solution.aspx
- Five years of midge tolerance, website www.country-guide.ca/2015/04/23/five-years-of-midge-tolerance/46541/
- Ian L. Wise, Stephen Fox, Marjorie Smith, Cereal Research Centre and Norm Woodbeck, Canadian Grain Commission, An estimate of annual financial losses by producers caused by damage to hard red spring wheat by the wheat midge, *Sitodiplosis mosellana*, in western Canada,
- Michael Jackman, Case study for Midge Resistant Wheat, AAFC