Introduction

The world’s population is increasing by 78 million each year, and by 2030, more than eight billion people will inhabit the Earth. According to the United Nations, global agricultural capacity will be straining to feed this many inhabitants – and the problem will worsen as the world’s population reaches 10 billion by 2035.

Three issues need to be addressed in conjunction with this expected increase in global population levels: protein consumption, the global supply of food and food safety. The consumption of protein is increasing rapidly in the developing world and within 10 years, the world will add one billion consumers of meat and meat products in countries such as China and India as well as other “emerging” nations.

Annual gains in the global food supply have recently declined from three to one percent. Increasing the global supply of food through the expansion of the cultivated land base may not be feasible – and could create environmental havoc in many regions of the world. A new “green revolution” is unlikely to solve the world’s food supply problems because additional production gains through chemistry or mechanization are forecast to be relatively small.

Food safety is an important international concern and most of the world has focussed its attention on livestock. The World Bank predicts that demand for animal products will double within 20 years – and developing countries will supply most of what is required. However, only about 20 percent of the countries of the world have the ability to respond effectively to health crises caused by animal disease. The Food and Agriculture Organization says that in a world without the capacity to deal with diseases in livestock destined for human consumption, a major crisis could occur within 10 years. With these three scenarios unfolding, what are the implications for Canada, a country that provides the world with over $24 billion in agricultural and food products each year?

Wheat, barley and livestock make up a large proportion of Canada’s agricultural and food exports. With its sizable land base and its high level of agricultural productivity, Canada has a competitive advantage over most other nations that produce and export agricultural products. Canadian producers, however, depend on substantial investments in research and development (R&D) in order to stay competitive. When the Canadian public invests in agricultural R&D, it receives a good return on its investment. Proof of that benefit is reflected in the growth in agricultural productivity over the last 40 years – with the agricultural sector outperforming both the manufacturing and business sectors of the Canadian economy.

Recently, however, Canadian livestock producers have found it more and more difficult to sustain a competitive advantage over global competitors. One issue is the rapid increase in the cost of feed grains due to the recent development of the US and Canadian bioethanol sector. Senior research analysts at the George Morris Centre have warned that the Canadian plan for the development of bioethanol runs contrary to other agricultural initiatives and will not be positive for agriculture. Canada has positioned itself as a meat exporting country. Converting Canadian feed grains into bioethanol instead of into meat and livestock makes little economic sense – especially when an increasing prosperous world can afford to pay higher prices for meat protein. In addition, this strategic adjustment is taking place at a time when Canada’s livestock producers are least able to adapt to change.

There is an opportunity for Canadian livestock producers to take advantage of the growth in global population levels, a tightening global food supply and an increasing demand for animal protein from emerging nations. In addition, Canadian livestock producers can meet these needs within a production system with high standards for food safety and the ability to respond quickly and effectively to livestock health emergencies.

Because this project is driven by developments in the manufacture of bioethanol from small grains, Strategic Vision Consulting Ltd. (SVC) has focussed on the development of wheat and barley as feed grains in western Canada. Forage issues, on the other hand, have a national focus.
SVC presents a comprehensive review of feed grains and forage production in Canada by addressing six key issues:

1. Investment in feed grains research in Canada

2. Investment in forage research in Canada

3. The growth of the Canadian bioethanol industry and the shift in plant breeding focus from livestock feed to bioethanol feedstocks

4. Public and private research in feed grains and forages in Canada
   - Limitations on investment in Canadian feed grains research
   - A comparison of the public and private plant breeding research sectors in Canada and the US
   - Canadian requirements for investment and infrastructure to meet end-user needs for feed grains and forages

5. Regulatory impediments limiting investment in Canadian feed grains research
   - Impediments to registration and commercialization of new feed grain varieties
   - Economic losses incurred in Canada
   - Creating a competitive regulatory environment for Canadian feed grain end-users

6. Forward looking competitors
Section 1 - Investment in feed grains research in Canada

Issues covered . . .
A history of feed grains research institutions in western Canada
Organizations that fund feed grains research in Canada

To determine the sources of investment for feed grains research in Canada over more than 20 years, Strategic Vision Consulting (SVC) collected and compiled data through extensive reviews of existing project and program reports and research agency funding databases. SVC also solicited information and opinions in one-on-one consultations with senior managers of Canadian research institutions and funding agencies, feed wheat and feed barley breeders, livestock scientists and crop and livestock producers.

It is a challenge to determine a precise level of investment in feed grains research in Canada over twenty years. Data is difficult to find, programs are fragmented and funding comes from many sources. For the most part, the research summaries and databases required to create a comprehensive picture of feed grains research are simply not available; or if available, may be incomplete or only available on an ad hoc basis.

There are currently 42 cereal crop-breeding programs with 120 unique plant-breeding projects for barley, triticale, oat, rye and wheat in western Canada alone – with most in the public sector. Historically, federal and provincial governments have funded almost all of the feed grains research in Canada. More recently, however, sources of funding have included producer check-off funds, grain companies, seed companies, processors and producer organizations. With public funding levels for feed grains research dropping for more than 20 years, plant-breeders have started working in teams of research scientists from a number of different institutions. Project funding comes from many different sources and the number of sources from which feed grains research specialists draw funds is astounding. To complicate matters further, each of the 42 cereal breeding programs has a unique blend of supporters – and it is very difficult to track research support through this complex web of funding agencies.

SVC has chosen to tackle this issue by first outlining the institutions responsible for feed grains research and then to track funding and project support from Agriculture and Agri-Food Canada (AAFC) and the Western Grains Research Foundation (WGRF). Most provincial governments support agricultural research and development; however, the scope of this project does not allow SVC to track investment in feed grains research over 20 years in all provinces. SVC has chosen Alberta as a representative province for two reasons:

- Alberta is Canada's largest cattle-producing province with 41 percent of the almost 16 million (M) cattle in the country
- The Alberta Agricultural Research Institute (AARI) has a research funding process that is relatively transparent and is open to public scrutiny

SVC will also indirectly measure feed grains research by tracking the number of varieties registered specifically as feed barley or feed wheat.

1. A history of feed grains research institutions in western Canada

Historically, feed grains research in western Canada has been concentrated at four institutions: AAFC in Brandon, Manitoba; the University of Saskatchewan’s Crop Development Centre (CDC) in Saskatoon, Saskatchewan; the Alberta government’s Field Crop Development Centre (FCDC) in Lacombe, Alberta; and the University of Alberta (U of A) in Edmonton, Alberta.

1.1 Agriculture and Agri-Food Canada Brandon

The barley breeding program in Brandon began in 1923. From 1936 onwards, the goal of the program was to breed high-yielding two- and six-row feed and malting varieties. One of the most notable barley varieties from this program is Bonanza – a malting barley variety that was noteworthy for producing higher yields than most feed barley varieties grown in Manitoba at the time.
1.2 The Crop Development Centre
In 1971, the University of Saskatchewan, the National Research Council (NRC) and the Saskatchewan Department of Agriculture joined forces to establish the CDC. For the first three years of operation, the NRC funded scientists and supported staff and then turned over responsibility for staff and operational funding to the Saskatchewan Department of Agriculture. At the time of its founding, the CDC’s directive was to expand research and plant breeding efforts in winter and spring wheat, feed grains and new crops. The current CDC mandate still includes winter and spring wheat and feed barley, but the institution has since added breeding programs for chickpea, dry bean, durum wheat, flax, food and malting barley, lentil, oat and pea, as well as pulse crop pathology.

The CDC receives core and project funding from the government of Saskatchewan, producer groups and private industry. Royalties on the sale of breeder seed, pedigreed seed and commercial grain provide additional sources of revenue. The CDC receives about 40 percent of its funding from crop producers, about 40 percent from industry and about 20 percent from public sources.

1.3 The Field Crop Development Centre
In 1971, the Western Hog Producers (WHP) and the Alberta Pork Producers Marketing Board (APPMB) convinced the Alberta Minister of Agriculture to fund a breeding program for feed barley. The primary objective was to produce high protein, high yielding and high lysine feed barley varieties for the livestock-feeding sector. WHP and APPMB provide the funds for the purchase of research equipment for the FCDC – which, at the time, was located at the U of A.

The FCDC soon expanded the focus of its program to include all feed grains after recognizing the value of a more diversified program, and more specifically, the importance of cereals in producing forage. The FCDC’s goal was to produce high yielding, high feed-value spring barley, as well as triticale and spring and winter wheat to enhance the livestock feeding industry. The mandate for the FCDC included facilitating the use of cereal crops for silage, grazing and researching uses for high-moisture grain. The program started in Edmonton, but moved to Lacombe, Alberta in 1978.

The J. H. Helm Research Centre was opened at the FCDC in 1998. Alberta Barley Commission (ABC) producers contributed $500,000 towards the founding of the research centre and at the same time, AAFC, ABC and Alberta Agriculture and Food (AAF) (formerly Alberta Agriculture and Food and Rural Development (AAFRD)) signed a 10-year agreement to breed barley and support an agronomic research program. ABC estimates that over $400M of farm gate revenues accrue to Alberta producers as a direct result of barley varieties developed at FCDC.

AAF is responsible for the oversight of this program and provides most of the core funding for this program. Over the years, FCDC personnel have been split between different groups within AAF. Even without having to account for this split in personnel, it would be very difficult to estimate the level of core funding for the centre.

The FCDC obtains additional funding for its programs through smaller grants. In the province of Alberta, AARI provides most of the “non-core” funding for research through the Agriculture Funding Consortium (AFC). The FCDC also receives about $700,000 each year, deposited into a barley investment account, from the revenues generated by three identity preserved (IP) FCDC varieties.

Plant pathology and barley agronomy research for the FCDC barley program is the responsibility of AAFC Lacombe – with AAFC contributing one person-year to pathology and one-half person year to agronomy, according to the AAFC/ABC/AAF agreement. AAF added an additional plant pathologist to the FCDC program in 1996. The pathologist has one assistant scientist, one full-time permanent technician and two technical staff on external funding. This team works out of the AAFC Lacombe Cereal Biotechnology Laboratory that opened in 2000.

In 1993, AAF and AAFC created the Alberta/Canada Barley Development Project (ACBDP) to serve Alberta and the Peace River region of British Columbia. In conjunction with the ACBDP, AAFC discontinued its barley breeding programs at Beaverlodge and at Lethbridge and turned over its breeding material to the FCDC.
In 2003, Nagy calculated the economic returns based on the investments made in feed barley research at the FCDC between 1973 and 2001. The study looked at three aspects of the FCDC feed barley breeding program:

- The development of higher-yielding feed barley varieties
- The development of disease resistant varieties that avoid disease threats
- The development of feed barley varieties that produce higher silage yields

Nagy attributed about 52 percent of the benefit of the feed breeding program to increasing yield and 48 percent to disease resistance. The overall Internal Rate of Return (IRR) was 27 percent, with a range of 23 to 31 percent.

FCDC is a typical research institution in that the principle investigators invest a considerable amount of time pulling together the resources required to run a large program. However, the FCDC is unique in the way in which it sources research funds and the institution has its own unique set of supporters. If the FCDC had no access to external funding and had to rely solely on core funding, it could only run a breeding program that was half of its present size. The FCDC needs non-core or “outside” funding to cover the salaries of half of its technical staff. The centre has also acquired about 90 percent of its laboratory equipment using outside funding. Three of the research scientist positions at the FCDC rely on outside funding and the FCDC receives a large proportion of the collaboration costs for barley disease screening from outside of AAF.

1.4 The University of Alberta

In 1976, the FCDC turned the spring wheat breeding program and all of its germplasm over to the U of A.

2. Organizations that fund feed grains research in Canada

Heisey et al. (2001) provide the best overview of the institutional funding for wheat and barley breeding in Canada. In the late 1990s, Canada invested $10.1 M (1996 US dollars) on wheat breeding – about as much as Australia – and most of this investment came from the public sector through AAFC and the Alberta, Saskatchewan and Manitoba governments (Chart 1.1).

![Chart 1.1 – 1999 wheat breeding expenditures at major Canadian prairie institutions](chart1.1.png)

Producer check-off funds provided just over one-quarter of the total investment in wheat breeding.

About $3.1M (1996 US dollars) was invested in barley breeding with just under one-quarter of all funds contributed by producers through the Western Barley Check-off Program (Chart 1.2).
Traditional public funding sources contributed less than half of the total investments in wheat and barley breeding. Federal sources provided most of the funding for wheat breeding and provincial sources were more important for barley breeding. What is interesting is that in this same period, public Canadian institutions were investing about three times as much on improving canola varieties – and this was in addition to the private sector’s already substantial commitment to canola breeding.

2.1 Agriculture and Agri-Food Canada

Since the late 1980s, AAFC has been in a state of almost continuous reorganization, downsizing and rebuilding – suffering from the ravages of fiscal restraint. In 1985-1986, AAFC agricultural research funding was $367M. The first wave of budget cutbacks followed in 1987 and a second wave of budget reductions occurred in 1992.

A name change from Department of Agriculture to Agriculture and Agri-Food Canada in 1993 reflected the transfer of governmental agri-food industry services to AAFC from the departments of Industry, Science and Technology and Consumer and Corporate Affairs.

In 1994, the federal government established a Rural Secretariat to address relevant issues for rural Canadians. The Secretariat’s mandate was executed through the Canadian Rural Partnership (CRP). As part of this initiative, AAFC administered the Canadian Adaptation and Rural Development (CARD) fund – a program designed to help the agricultural sector develop new market opportunities and become more competitive.

In 1995, the federal budget outlined a proposal for a more frugal government that would need fewer employees to deliver government programs. This initiative was expected to cut 45,000 employees, or about 14 per cent of the civil service, from the payroll. These cuts resulted in a substantial reduction in the number and size of many AAFC programs. Within the Research Branch of AAFC, funding was cut from $276.1M for 1995-1996 to $214.7M by 1997-1998. In conjunction with the budget cuts, AAFC closed seven research stations and streamlined the 19 remaining into a network of Centres of Excellence.

The 1995 federal budget also launched the Matching Investment Initiative (MII) and a new market-oriented philosophy for the Research Branch. When the federal government launched the initiative, the MII budget was projected to reach $35M – with private sector partners putting up an additional $70M. In 1997-1998, however, the projected budget had only reached $21 million and by 2001-2002, the federal MII share was only $27 million. This shortfall in funding led some to criticize AAFC for turning its researchers into fund-raisers.

By 2001-2002, AAFC agricultural research funding had risen from its 1995-1996 low of $214.7M to $252M annually. The new Agricultural Policy Framework (APF) also came along in 2002 – with a mandate “to make Canada the world leader in food safety, innovation and environmental sustainability.” Then, in 2003, AAFC made
In the end, fiscal restraint has encouraged AAFC be creative in the area of policy innovation, while limiting the range of options open to the organization. While AAFC was put into a precarious position as a result of severe budget cuts, some have challenged the choices that organization made as it reorganized its research programs.

Historically, AAFC has probably made the greatest contribution to feed grains and forage research of any organization in Canada. Other institutions that have made substantial investments in these areas include WGRF and AARI. The availability of public records makes it possible to track research investments made by these organizations; but in many cases, SVC could only track research investments indirectly.

The most effective way to track Canadian research projects is through the Inventory of Canadian Agri-Food Research (ICAR) database for Canadian agri-food research – which was developed by CARC in 1974. The ICAR database contains comprehensive information on over 4,000 research projects in agriculture, biotechnology, food and human nutrition that have been conducted by federal and provincial institutions, Canadian commercial operations and universities. While the ICAR database is less than perfect in terms of accuracy and completeness, it is the best and most comprehensive source of information available to the general public. The standing committee has been improving the quality of the database over the years by working with the researchers, government agencies, industry organizations and universities that have been responsible for building the database. Currently, this database probably provides the best insight into trends in feed grains and forage research within the AAFC system. SVC has outlined the process of downloading the database and sorting the data in Appendix 1 (page 99).

SVC sorted barley and wheat projects conducted between 1987 and 2005 into three categories:

- Feed breeding and production projects
- Feed breeding projects combined with other objectives
- Food, nutraceutical and grain quality projects

The majority of the work conducted by AAFC in wheat and barley falls into the area of food, nutraceuticals and grain quality (Chart 1.3).
Between 1987 and 1995, the number of new projects each year in food, nutraceuticals and grain quality ranged between seven and 17. The number of projects fell dramatically after the 1995 federal budget – which outlined plans for more prudent government spending and fewer employees. The number of food, nutraceutical and grain quality projects rose between 1999 and 2003 but then fell again in 2004 – presumably because of AAFC’s 2003 transition to horizontal work management teams. Trends in project numbers appear to be an artifact of budgets and management systems.

This analysis of the ICAR database suggests that AAFC mostly focused on food applications, nutraceuticals and grain quality issues – and has not dedicated a great proportion of its resources to feed barley or feed wheat breeding or feed production. The ICAR database also suggests that AAFC conducted at least one or two wheat or barley feed projects each year between 1987 and 2003 – but appears to have discontinued these projects by 2004. Since the AAFC Brandon feed barley research program is still running as of 2007, the most logical conclusion is that the ICAR database is incomplete. This is a particularly significant problem when project numbers in any given area are already low.

The number of scientists working on each project ranged between three and six between 1987 and 2003 (Chart 1.4).
In 2004, the number of scientists per project increases substantially with the move to horizontal work management teams. SVC tallied the number of scientists per team to determine whether declining project numbers were being offset by a larger complement of team members. This does not appear to be the case, though data is limited. What is notable is that by 2004 and 2005 some project teams have as many as 22 members!

AAFC has made funding levels for various project areas more transparent and accessible to the public as of 2007. SVC downloaded Agriculture and Agri-Food Canada 2007 research project data from the AAFC website from plant science and environment and ecology databases and sorted the data into 21 categories. Funding levels are presented for ten categories (Chart 1.5).
Chart 1.5 – Plant science and environment and ecology (2007) – Project funding for forages, fodder and range; feed breeding and feed production; and feed breeding combined with other objectives. These projects are compared to other project areas.

SVC could not classify any of the projects as purely feed breeding or feed production research. AAFC allocated about $2.3M to research on forages, fodder or range and about $800,000 to projects that supported feed wheat or feed barley breeding – but AAFC did not dedicate these projects exclusively to feed research. AAFC allocated $14.6M to crop agronomy, insect and disease management projects and $10.2M to plant breeding technique projects, which, though not directly related to feed breeding, indirectly benefit the livestock sector by supporting the development and production of Canadian feed grains.

2.2 Western Grains Research Foundation

The WGRF is a producer funded and directed research organization set up to administer an endowment Fund and the Wheat and Barley Check-off Funds for the benefit of Prairie farmers. Research goals include the production of new wheat and barley varieties as well as the development of technology to enhance production and support competitiveness.

WGRF was initiated in 1981 by 12 agricultural organizations to manage an endowment fund. The WGRF endowment sourced funds from the old Prairie Farm Emergency Fund – a fund dedicated to supporting a broad range of crop research. WGRF initiated Wheat and Barley Check-off Funds in the 1993-1994 crop year and most WGRF funding comes from these two funds. Scientists can often leverage endowment and check-off funds through matching grants. Producers receive a tax credit for the portion of the check-off investment dedicated to research.

Leading up to the creation of the Barley Check-off fund, public barley breeding programs had been discontinued and/or downsized – and there was little interest in barley breeding in the private sector. At that time, Canada’s competitors had invested in barley breeding and were quickly becoming more competitive than Canadian producers in global markets. The barley check-off fund helped strengthen Canadian breeding programs by collecting $0.50/t from CWB final payments to barley farmers in Saskatchewan and Manitoba – generating over $600,000 annually for barley breeding.
The WGRF producer board allocates funds for breeding programs. The Barley Check-off Fund invests $300,000 per year in feed, forage and malt barley breeding programs at AAFC Brandon – with the funds split about evenly between the feed and forage and the malt barley programs. The fund also contributes $300,000 per year to the University of Saskatchewan’s CDC for barley breeding – with about a 50:50 split between malt and feed/forage programs.

The WGRF is currently investing in plant breeding programs designed to produce more economic value in livestock from less feed. Barley breeders are using WGRF funding to develop low-phytate barley, which reduces phosphorous levels in manure, and slow dry-matter-disappearance barley, which reduces the risk of acidosis in cattle. As of 2005, 22 percent of the Barley Check-off Fund was allocated to two-row feed barley, eight percent to hulless feed varieties and three percent to forage barley for a total of 33 percent allocated to livestock feed uses. This may be an underestimation of the value that the cattle feeding sector derives from the WGRF Barley Check-off Fund if it is assumed that the fate of all “failed” malt barley is to become feed barley. About 85 percent of barley seeded for malt is used for feed. With the WGRF contributing about one-third of its barley research funds to feed breeding research and with the development of dual-purpose two-row malt barley with enhanced feed and agronomic traits, the WGRF would like to see more stakeholders who feed barley to livestock become involved in research planning.

The WGRF feels that food barley may be one of the more exciting new areas for barley research. Barley contains a number of components of interest in the area of human health, including β-glucan, fibre and tocopherols. Hulless barley is becoming more important to the food industry and the industry is better equipped to handle “naked” grains. With this strong outlook for hulless food barley, funding allocations for food breeding uses were set at 10 percent.

The Wheat Check-off Fund was created at the same time as the barley check-off fund in response to similar challenges. The Wheat Check-off Fund receives $0.30/t deducted from CWB final payments to wheat producers in the prairie provinces. The fund invests over $3M annually in wheat breeding research. WGRF invests about 72 percent of its Wheat Check-off in wheat breeding programs at AAFC and about 20 percent with the CDC. The University of Manitoba (U of M), the U of A and the FCDC receive about two percent each from the Wheat Check-off Fund. The U of M fusarium nursery receives about three percent of the Wheat Check-off.

Between 2001 and 2005, AAFC received between about $2.3M and $2.5M per year from the WGRF Wheat Check-off fund. An analysis of the ICAR database in Section 1 suggests that most of the funding goes into research for milling and food applications. AAFC, however, has directed some of the funding towards feed grains research and feed production.

Between 2001 and 2005, CDC received between $610,000 and $690,000 per year from the WGRF Wheat Check-off Fund. The CDC invested about 30 percent of its share in bread wheat breeding; about 19 percent in durum wheat; about 19 percent in winter wheat development; the new CWGP class of wheat or CPS wheat (feed wheats) received about 9 percent; 12 percent was invested in pathology; 10 percent went into wheat quality research; and 2 percent was used for germplasm development.

Arguably, the livestock-feeding sector would derive the most value from CPSR wheat – which receives 12 percent of WGRF wheat funding. With nine percent of the wheat check-off devoted to germplasm and Fusarium genetics development, one could assume that livestock producers receive about 12 percent of the value of this investment, or slightly more than one percent. Thus, the WGRF contributes about 13 percent of the wheat check-off fund to wheat breeding for the benefit of livestock feeders. Since very little wheat is fed to cattle, feeders of monogastric livestock may derive the greatest benefit from this funding.

The WGRF Endowment Fund has contributed over $18M to agricultural research projects since its inception in 1983 when it received $9M from the discontinued Prairie Farm Assistance Act. For the 2004-2005 crop year, WGRF received over $300,000 in excess railway revenue under new Canada Transportation Act (CTA) legislation. In the 2005-06 crop year, Canadian Pacific Railway (CPR) was about $1.5 million over its revenue cap, paid these funds to WGRF but successfully appealed the CTA ruling and received a refund of $870,783. The CTA ruled that CPR again exceeded the federal grain revenue cap for the 2006-07 crop year. CPR must pay the excess of $3,760,353 plus a five percent penalty to WGRF. These funds are added to the principle of the Endowment Fund. WGRF uses
only the Endowment Fund’s annual interest to fund crop research projects in areas that are traditionally under funded. SVC has calculated WGRF endowment funds that have contributed to feed grains projects using this formula:

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\text{(Total value of all projects directly related to breeding feed barley or feed wheat + funding for projects that may support or provide some benefit to plant breeding efforts for these crops) \times \ (feed barley share of the Barley Check-off Fund + feed wheat share of the Wheat Check-off Fund)}
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SVC then summarized WGRF Endowment Fund allocations for all projects between 1985 and 2007 (Chart 1.6).

Feed grains and forage projects and funding levels for these projects have been compared with all other WGRF funded projects. Funding for all projects has been steadily declining over 22 years – reflecting declining interest on the invested principle. Feed grains and forage research has always been funded by WGRF at low levels – though funding levels are continually decreasing and few projects have been funded in these areas since 2001.

Looking at feed grains and forage funding relative to all project funding shows that these areas received more funding in 2007 than in all other years except 1998 (Chart 1.7).
Chart 1.7 – Percentage of feed grains project funding relative to all funding (1985-2007 - WGRF endowment fund)

Source: Western Grains Research Foundation, Strategic Vision Consulting Ltd.

The amount of funding allocated to feed grains research rose substantially in 2007 because of the volume of funding that the WGRF endowment fund allocated to research on Fusarium Head Blight (FHB). While cattle-feeders do not profit directly from FHB research in wheat, SVC is assuming that keeping wheat yields high is providing some value to those feeding barley to livestock – and that this benefit is in proportion to the percentage of funding that the WGRF allocates to feed barley breeding.

2.3 Canadian International Grains Institute

The Canadian International Grains Institute (CIGI) is a non-profit educational facility offering training in grain handling, marketing, technology and transportation. About 60 percent of CIGI core funding is provided by AAFC and the CWB covers the remaining 40 percent. Other agricultural sectors contribute additional funds. While CIGI cereal facilities are designed mostly for support of the food sector, CIGI also has a mandate to support the value of Canadian feed ingredients.

2.4 Alberta Agricultural Research Institute

AARI has funded livestock research opportunities that are focused on nutrient management systems and net feed efficiency. Between 1997 and 2007, AARI funded research in the areas of feed grains, forage, silage, pasture and range. Funding is allocated through the Agricultural Funding Consortium (AFC), an arm of AARI that includes sixteen different stakeholder organizations: AARI, Alberta Crop Industry Development Fund (ACIDF), Alberta Livestock Industry Development Fund (ALIDF), Diversified Livestock Fund of Alberta (DLFOA), Agriculture and Food Council (AFC), Alberta Value-Added Corporation Ltd. (AVAC), Climate Change Central (CCC), Alberta Barley Commission (ABC), Alberta Pulse Growers Commission (APGC), Alberta Canola Producers Commission (ACPC), Alberta Chicken Producers (ACP), Alberta Milk (AM), Alberta Pork (AP), Alberta Egg Producers (AEP), Potato Growers of Alberta (PGA) and Alberta Beekeepers (ABee).

Over 11 years, AARI allocated over $62.7M to agricultural research and development. The average level of funding each year was in excess of $5.7M, with a range of $316,000 to over $11.6M. Through this period, AARI invested over $960,000 in feed grains and feed research (Chart 1.8).
While little to no investment was made in six of eleven years, AARI invested over $230,000 in feed grains and feed research in 1999 and about $440,000 in 2007. At times, AARI has funded projects to the point that research teams do not have the resources to accept additional funding for several years – which may explain why funding appears to be sporadic. In addition, project funding is at the discretion of the members of the AFC – and each year, AFC members decide which projects to fund. This can also create funding discontinuities in specific areas.

Overall, the timing of research funding seems to be sporadic. These patterns in project funding are not unique to AARI. Unfortunately, this erratic timing of does not create an ideal environment for research continuity and does not allow for efficient planning or the efficient use of research infrastructure and/or human resources.

SVC has compared AARI investments in feed grains research to investments made in pulses and oilseed crops, non-feed wheat and non-feed barley as well as general agronomy (Chart 1.9).
AARI invested over $7.8M in oilseed projects, almost $3M in agronomic research, almost $2.7M in pulses and about $2.25 in non-feed wheat and barley projects between 1997 and 2007. As with feed grains and feed research, there is considerable variability in year-to-year funding for project areas. Oilseed projects for example, were allocated almost $3M in a single year, and yet in two of eleven years received little to no funding at all. Agronomic projects received almost $6M in funds in a single year, and yet received no funding at all in five of 11 years. Similarly, pulse projects were allocated over $850,000 in each of two years and received nothing for five of 11 years.

An analysis of functional food, human health and environmental projects illustrates similar trends – with all three areas becoming very popular with funders in the last two years (Chart 1.10).
Since 1997, AARI has invested over $10.8M in these three areas, however, over $9M of this total amount was invested during the last two years.

### 2.5 Alberta Crop Industry Development Fund

ACIDF, founded in 2002, is dedicated to the development of a globally competitive crop sector in Alberta.\(^{48}\) The organization is an independent, not-for-profit entity directed by the crop industry. ACIDF oversees three grants from the Minister of Agriculture, Food and Rural Development. Some of these funds are directed towards feed breeding and forage research. ACIDF invests with five goals:

- To increase the ability of farmers to manage risk
- To develop new businesses and markets
- To increase crop sector diversification
- To adapt and develop new technology through new research and development and commercialization
- To increase consumer confidence in the production of food

The Industry Development Initiative (Fund 2001), the Feed Grain Quality and Supply Initiative (Fund 2005) and Fund 2006 would be of particular interest to the beef cattle industry.\(^{49}\) From the Industry Development Initiative of 2001, ACIDF allocated an average of $97,300 to 121 projects.\(^{50}\) Most projects were in the areas of applied research and crop production, but also included some basic research and commercialization work as well as marketing activities. Projects were chosen for their potential to support the industry both financially and socially. ACIDF allocated over $3.3M to the cereal sector in this round of funding (Chart 1.11).
While ACIDF would have applied some of the cereals funding to feed grains projects, it is not clear how much of the $3.3M allocated to cereal research actually went to feed grains research.

The Feed Grain Quality and Supply Initiative has $10M designated for improvements in the production of feed grain energy. Part of this initiative is dedicated to improving the ability of the market to respond to the value in the grain. As part of this initiative, ACIDF, AARI and ALIDF have invested in Near Infrared Reflectance Spectroscopy (NIRS) rapid analysis technology to help improve price signals in the feed market.

Fund 2006 will target $18M towards research into integrated crop management, diversification and production. With Fund 2006, ACIDF funds need to be matched by industry funds. While matching funding has the advantage of leveraging research investments, $18M is a considerable sum of money to raise – especially for research in areas that traditionally attract little private investment. The need for matching industry funds could limit the impact of this investment if ACIDF cannot find sufficient industry funding to spend the entire $18M. In addition, the matching grant system may result in a shift in the types of projects receiving funding towards projects that have commercial applications at the expense of “public good” projects.

2.6 Alberta Barley Commission
The Alberta Barley Commission contributed $500,000 on behalf of barley producers to the development of the J.H. Helm Research Centre at the FCDC. In addition, ABC contributes funds to the FCDC each year (Chart 1.12).
ABC has also funded specific feed barley projects for beef, pigs, and poultry in all but one year between 2000 and 2007. Over eight years, ABC has contributed over $1.5M to the FCDC and over $200,000 to feed projects.

For 2008, ABC’s intent is to combine its $250,000 investment in FCDC with $250,000 from each of ACIF, Alberta Beef Producers and Alberta Pork; and $500,000 in existing funding from each of ACIF and AAF; to create stable and continuous funding for the FCDC at a level of $2.5 to $3M per year.

2.7 Other sources of funding for feed grain breeding

Other sources of funding for feed breeding projects include Manitoba’s Agri-Food Research and Development Initiative (ARDI), Saskatchewan’s Agriculture Development Fund (ADF), AVAC and federal funding made available through AAFC’s MII.53

Manitoba Agriculture, Food and Rural Initiatives (MAFRI) and AAFC, through the APF, have collectively funded the ARDI. ARDI has invested almost $31M to support innovative research of benefit to the agricultural sector and consumers.54 About 18 percent of this fund has been invested in cereal crops and some of this funding benefits the feed grains sector. Manitoba is Canada's fourth-largest cattle-producing province with about 10 percent of the cattle in the country.55

The ADF, under the jurisdiction of the Agriculture Research Branch of Saskatchewan Agriculture and Food (SAF) funds agriculture and agri-food research and development through three programs: 56

- Agri-Value Program (AVP)
- Research and Development Projects Program (RDP)
- Strategic Research Program (SRP)

SAF is funding four chairs in crop genetic improvement in cereal crops and is committed to providing salaries and benefits for each research chair for five years.57 The length of the commitment is designed to recruit and retain the
best research personnel possible. Saskatchewan is Canada's second-largest cattle-producing province with 22 percent of the cattle in the country.\textsuperscript{58}

2.8 Funding for feed grains research in western Canada

SVC has attempted to compile the funding allocated to the breeding of feed barley and feed wheat in western Canada. Data from a variety of funding sources, including AARI, ABC, AAFC and WGRF is most complete between 2001 and 2005. SVC derived barley feed funding for the governments of Alberta, Manitoba and Saskatchewan from data presented by Heisey \textit{et al.} in 1996.\textsuperscript{59} Feed wheat funding for AAFC was also derived from this same data set.

Funding for feed grain breeding remained steady at between about $2.5M and $2.6 M per year between 2001 and 2005 (Chart 1.13).

\begin{center}
\textbf{Chart 1.13 – Funding for feed grains research in western Canada (2001-2005)}
\end{center}

Source: Alberta Agricultural Research Institute, Alberta Barley Commission, Agriculture and Agri-Food Canada, Western Grains Research Foundation, Heisey \textit{et al.}, Strategic Vision Consulting Ltd.

* Calculated from data reported by WGRF as cited by Heisey \textit{et al.}\textsuperscript{60} (Prairie provinces only)
  US$1M (1996) x $1.37 = CD$1.37M x 33% (WGRF ratio of feed to malt barley research expenditures)

** Calculated from data reported by WGRF as cited by Heisey \textit{et al.}\textsuperscript{61}
  AAFC spent US$400,000 (1996) on barley breeding in western Canada – split about evenly between malt and feed programs at Brandon. This is a very rough approximation of AAFC A-base funding for feed barley research

*** Calculated as 80% of the ABC contribution to FCDC Lacombe

**** Calculated from data reported by WGRF as cited by Heisey \textit{et al.}\textsuperscript{62}
  AAFC spent US$3.9M (1996) on wheat breeding in western Canada (CD$5.343M) x 13.08% (WGRF expenditures on CPS wheat + CPS share of WGRF expenditures on germplasm and Fusarium research). This is a very rough approximation of AAFC A-base funding for feed wheat research.

The largest source of feed grain breeding funding is the WGRF – which contributes 50 to 56 percent of total funds each year. The governments of the prairie provinces contribute about 25 percent each year – and AAFC and ABC
contribute about 15 percent and 5 percent each, respectively. While AARI and ACIDF contribute substantial funds towards feed grains research, these organizations may not have contributed funds between 2001 and 2005 and/or SVC cannot attribute funds specifically to feed grains research during this period.

AAFC’s annual contribution of $972,865.00 to feed grains R&D based on the data of Heisey et al. is in line with the $800,000 in funding attributed to AAFC feed grains projects in 2007 (Chart 1.5).

When the federal government terminated the Western Grain Transportation Act (WGTA) subsidy in 1995, the cost of exporting barley from the eastern prairies increased. The termination of the WGTA subsidy, in turn, lowered barley prices in the Canadian prairie provinces and value-added cattle and hog production flourished. Barley feed use (including waste and dockage) recently reached 9.0 Mt and between 1997-1998 and 2007-2008, feed barley exports from Canada have averaged about 0.5 Mt per year. This suggests barley producers sell almost 86 percent of the barley produced in western Canada as feed.

Heisey et al. estimated annual expenditures on barley breeding in western Canada at $4.247M. If 86 percent of all barley produced in western Canada is sold as feed, one might expect that $3.668M per year would be allocated to feed barley breeding if funding were to be tied to the end use of the product.

Livestock producers use a substantial volume of Canadian wheat as feed for hogs and poultry; however, accurate data on feed wheat use are not available. The best information comes from the feed, waste and dockage (FWD) category of the Statistics Canada supply-disposition table. Even though dockage, which includes weed seeds, broken grains, and other extraneous material, makes up a large proportion of the total, it is often cleaned and used for feed – and FWD is accepted as a proxy for feed use. Between 1999 and 2004, FWD averaged 3.9 Mt per year.

Most Canadian wheat is milling quality. Each year, however, a portion is downgraded to feed because of adverse weather or disease. Livestock producers also use significant volumes of lower-quality wheat from classes such as CPS, Canada Western Red Winter (CWRW) and No. 3 CWRS as feed.

More accurate consumption statistics calculate the amount of wheat fed to beef cattle, dairy cattle, hogs, chickens, layers, turkeys, horses, sheep and lambs each year. Using this method, livestock feed volumes for Canada averaged 1.857 Mt between 1999 and 2000. Statisticians compile this data by assuming that each age group of animal consumes a specific ration. These estimates are significantly lower than FWD estimates, but are probably more accurate. Assuming that western Canada produces 23 Mt of wheat per year, livestock producers feed about eight percent of total production to livestock.

Heisey et al. estimated that annual expenditures on wheat breeding in western Canada were $13.837M per year. If eight percent of all wheat produced in western Canada is sold as feed, one might expect that $1.117M per year would be allocated to feed wheat breeding.

SVC estimates the feed breeding share of western Canada’s wheat and barley breeding budget should be $4.785M per year based on the calculations and assumptions in Sections 2.2.8.1 and 2.2.8.2. However, the total funding for wheat and barley feed grains research in western Canada between 2001 and 2005 only averaged $2.522M per year (Chart 1.13). These data suggest that barley and wheat feed breeding research is underfunded in western Canada by $2.263M year.

### 3. Feed barley registrations

An indirect means of measuring the contribution of research into feed grains is to measure the number of barley varieties developed specifically for use as feed and forage. Between 1908 and 2007 in Canada, 97 barley varieties were registered as feed varieties and seven were registered as forage barleys. In this same period, fifty-four barley varieties were registered as malt types and nine were registered for food uses.

Since few barley varieties were registered in any given year before about 1980, SVC summarized barley variety registrations from 1908 to 1980 and from 1981 to 2007. Twenty-three feed and 14 malt barleys were registered...
between 1908 and 1980. Between 1981 and 2007, the count for Canadian barley registrations was 74 for feed, 40 for malt, nine for food and seven for forage (Chart 1.14).

**Chart 1.14 – Barley varieties registered between 1981 and 2007 for feed, food, forage and malt end-uses**

The trend for feed types of barley is flat to downwards whereas the trend for malt types is a slow trend upwards. There are also seven registrations for forage barley types, specifically for livestock purposes – with six of those registered in the past eight years. Given the estimate that 86 percent of barley produced in western Canada is sold as feed, the number of new feed barley varieties relative to the number of malt barley varieties is low. Based on actual sale volumes for feed and malt barley, one might expect the registration of more than six new feed barley varieties for each variety of malting barley registered.

### 4. Feed wheat registrations

SVC also measured the contribution of research into feed grains by measuring the number of wheat varieties developed specifically as feed types. Historical wheat data classifies wheats according to grain class as outlined in Section 2 of the Canada Grain Act. Examples include CWRS, CWRW, CWAD, Canada Western Hard White (CWHW), CPSR, Canada Prairie Spring White (CPSW), Canada Western Extra Strong (CWES) and Canada Western Soft White Spring (CWSWS). Wheats are also referred to more generally as hard red spring wheat, winter wheat, durum wheat, hard white wheat, hard white spring wheat, utility wheat, soft white spring wheat or white winter wheat.

SVC grouped spring or winter CPSR (spring or winter) types of wheat and utility wheats as “feed” types because these classes were not developed for milling purposes or for specific end-uses for food processors. All other wheat classifications were considered “food” or milling wheat types.
Between 1885 and 1967, historical data include only four descriptions for wheat: CWRS and CWRW or general references to hard red spring or to winter wheat. There were only 25 varieties of wheat registered in Canada before 1968. From 1968 to 2007, 136 wheat varieties were registered: 76 were classified as CWRS, CWRW, hard red spring wheat or winter wheat; 18 as CWHW, hard white wheat or hard white spring wheat; 14 as CPSR (spring or winter) or utility wheat; 6 as CWES; and 12 as CWSWS, soft white spring wheat or soft white winter wheat.

In Chart 1.15, SVC graphed feed wheat and bread wheat registrations between 1968 and 2006.

**Chart 1.15 – Wheat varieties registered between 1968 and 2007 as feed and bread wheats**

![Chart 1.15](chart1.png)

Source: Alberta Agriculture Food and Rural Development, Crop Development Centre (Saskatoon), The Heritage Wheat Project, Western Grains Research Foundation, Strategic Vision Consulting Ltd.

The trend line for feed wheat registrations is flat to slightly up. For bread wheat registrations, however, the rise in the number of new varieties available each year is steep – and the number of new bread wheat varieties available each year increases substantially between 1986 and 2006.

SVC then compared feed wheat registrations to durum wheat and white wheat registrations (Chart 1.16).
In this case, the trend line for feed and durum wheat registrations is similar. In contrast, there is a distinct, upward trend in white wheat variety registrations, with more new white wheat varieties registered between 1999 and 2007 than in the 30 years prior to 1999.

Source: Alberta Agriculture Food and Rural Development, Crop Development Centre (Saskatoon), The Heritage Wheat Project, Western Grains Research Foundation, Strategic Vision Consulting Ltd.
Section 2 – Investment in forage research in Canada

Issues covered . . .
Forage research institutions in Canada
Organizations that fund forage research in Canada

In the context of this report, the term “forage research” is all-inclusive and refers to a wide array of scientific endeavours. Much of the research described as “forage research” is only peripherally related to livestock production.

Forages include annual or perennial, grassy or leguminous plant species grown traditionally grown as livestock feed, or any plant species – tame, native or otherwise – growing in a managed or unmanaged pasture or rangeland ecosystem. Forage research includes work in areas as diverse as agronomy, beef production, biotechnology, grazing, nitrogen fixation, plant breeding and genetics, pest management, physiology, pollination, production and management, regional adaptation, soil fertility, sustainability and variety assessment.

1. Investment in forage research in Canada

The Thomsen Corporation used the ICAR database and supporting public accounts to measure the total expenditure on forage R&D by federal and provincial governments, universities and industry in 1996 dollars. Between 1985 and 1998, research expenditures in forages had declined from $41M to less than $19M.

The number of Professional Person Years (PPY) dedicated to research reflects the overall level of research funding. Between 1985 and 1998, the total PPY dedicated to forage research in Canada fell from a high of 158.7 in 1985 to low of 72.4 by 1998 (Chart 2.1).

Chart 2.1 – Professional person years in forage research (1985-1998)

Most of the investment in forages has been made in alfalfa; followed by lower levels of funding for general forage projects; and then followed by even lower levels of funding for legume, grass, pasture and rangeland projects. As
funding levels decreased after 1985, funders contributed a greater proportion of funds to general forage, grass, legume, pasture and rangeland projects while the proportion of funds dedicated to alfalfa projects declined.

The average cost of forage research in 1996 dollars was estimated at $257,000 per professional research scientist. Multiplying average cost by PPY for 1971 to 1998 indicates that the total investment in forage research by federal and provincial governments, universities and industry fell from $33-40M in the 1970s and 1980s to less than $20M by 1998 (Chart 2.2).

**Chart 2.2 – Estimated annual expenditure on forage research in Canada (1971-1998)**

Source: Thomsen et al.

Chart 2.3 illustrates the relative contribution of federal and provincial governments, universities and the private sector to forage R&D.
As federal support for forage research started declining in Canada in the late 1980s, universities stepped up their forage research capacity. When federal support increased through the mid to late 1990s, university support for forage research declined. The federal government has traditionally been a strong supporter of forage research in Canada – as have universities. However, because the public sector has supported ICAR to a greater extent than the private sector, the database may underestimate the contribution of the private sector to forage research. Nevertheless, the ICAR database still presents the best long-term snapshot of forage research in Canada.

2. A history of forage research institutions in Canada

In the 1920s, Agriculture Canada Saskatoon (The Dominion Experimental Farm) and the U of S agreed that Agriculture Canada would be responsible for forage research. AAFC’s historical forage research responsibilities have included agronomy, breeding, species and variety testing and recommendations for the western Canadian forage-growing regions. By the 1980s, AAFC moved away from its extension responsibilities to focus on research – specifically in the areas of molecular genetics, physiology, the role of forages in environmental systems and range and pasture management. By the late 1990s, AAFC was again working informally in extension, but this time through partnerships with industry and commodity groups – with research targeted at the forage-beef interface.

Through the 1980s and 1990s, AAFC had to deal with reductions in its research budget and demands by management for an economic justification of its programs. At this same time, AAFC saw that industry and commodity groups were becoming more self-reliant. For this reason, AAFC felt justified in reducing the level of historical research support for many programs. At about the same time, AAFC chose to alter its Study Management System. Under the new system, AAFC started evaluating the economic potential of its research programs. Apparently, forage research scientists found it difficult to develop economic arguments that clearly demonstrated the value of forages to the economy. This is surprising given the value that the beef and dairy industries add to the Canadian economy. Forage and rangeland scientists eventually made better arguments and established the economic value of forage and rangeland research, but by then, these areas had been declared “low priority” – and AAFC Western Region forage research scientist numbers plummeted by 50 percent between 1990 and 1997. Unfortunately, no champion emerged from the livestock sector (or any other sector) during this period to help challenge these drastic staffing cuts.
In the early 1970s and into the early 1980s, short-term “applied” research funding became available through the Agriculture Development Fund in Saskatchewan, Agro-Man (1979) in Manitoba, Farming for the Future On-Farm Demonstration Program (1982) in Alberta and the New Crop Development Fund (1973), a federal project. These initiatives helped prevent more serious losses in forage research capacity. AAFC research scientists were also able to make up some of the shortfall in their A-base budgets through matching grant programs with industry. Unfortunately, with no means of collecting check-off funds, the forage and rangeland sector had only very low levels of matching funds available to support research projects and forage, and rangeland research in Canada continued to decline though the 1990s.

In 1995, CARC initiated the development of a strategy to address research and technology transfer for forages. CARC asked the Canadian Forage Council (CFC) and the Canada Committee on Crops (CCC) to form a steering committee. The steering committee organized a workshop for about 70 forage experts representing Canada’s forage growing regions and forage-related industries. Some key recommendations that came out of the workshop included:

- The establishment of a steering committee with a mandate to represent forage stakeholders and to include beef and dairy cattle interests, since most forages are used to produce meat and milk
- The acceptance of industry stakeholders of their proportionate share of responsibility in funding research – which included instituting a check-off fund
- Taking action to lower costs of production and increasing net returns for the value chain
- The development of new models for technology transfer

SVC could find no evidence that suggested CARC, the steering committee or the stakeholders implemented any of these recommendations. CFC was formed in the late 1980s but was plagued with problems due to lack of funding. Bill C-54, which had been designed to resolve at least some of the funding issues for organizations like CFC, proved impossible to implement by any national organization. CFC later disbanded, and in 2006, AAFC terminated its funding for CARC and the organization was disbanded.

In 2006, forage research was still ongoing at 10 Canadian universities and at AAFC research stations in Charlottetown, PEI; Swift Current, Saskatchewan; Ste. Foy, Québec; Lethbridge, Alberta; Lacombe, Alberta and Saskatoon, Saskatchewan. At the time, AAFC still had 25 Full Time Equivalent (FTE) scientists working on forages.

By 2007, only four forage breeding programs remained in Canada. These programs are located at AAFC Ste. Foy, AAFC Lethbridge and AAFC Charlottetown (with a co-location at Truro, Nova Scotia). AAFC, while still funding the forage breeding program in Saskatoon, has transferred the program and all materials to the University of Saskatchewan’s CDC in Saskatoon. CDC is not committed to continuing the forage breeding program because of the high cost of running breeding programs for perennial crops. AAFC forage breeders are nearing retirement and AAFC is not currently committed to filling these positions.

Overall, the funding situation for forage research is similar to that noted for feed grains research. Research capacity is declining, funding is inadequate and sporadic in nature, goals are short-term, there is no long-term strategy or long-term commitment to building or even maintaining infrastructure and smaller grants from more organizations are required to run the programs. In addition, new policies that charge research programs variable costs for the use facility infrastructure increases the cost of conducting research programs and can make it more difficult to obtain outside funding. At one time, variable costs were considered in-kind contributions from the institution conducting the research. Coupled with the imminent retirement of a number of key forage research scientists without a clear transition plan or even a commitment to filling these positions, the future for forage research in Canada looks bleak.

3. Other organizations that fund forage research in Canada

Organizations that fund forage research in Canada include: AAFC, AARI, ACIDF, ARDI, Alberta Riparian Habitat Management Partnership Office, Alberta Pork Producers Development Corporation, AVC Graduate Student Stipend Fund, Beef Cattle Research Council (BCRC), Canada-Nova Scotia Livestock Feed Initiative Agreement, Canon National Parks Science Scholarship Program, Ducks Unlimited Canada, Island Fertilizers, Manitoba Agriculture Eastern/Interlake Region, Manitoba Forage Council (MFC), Manitoba Milk Producers Cooperative, Manitoba Rural
Adaptation Council Inc. (MRAC), National Science and Engineering Research Council (NSERC), Nova Scotia Agricultural College (NSAC), Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), Primary Resources Development Agreement (PRDA), Ray Long Award, Saskatchewan Beef Development Fund (SBDF) and the University of Guelph (U of G). Grants range from $750 to $220,000 and as many as four grants are required to fund each research project. Median project value is in the range of $30,000-40,000 and most projects only run for one to four years.

The large number other organizations that fund forage research suggest that there is strong support from a diverse array of interested parties. However, these organizations lack the resources to make the large-scale contributions to forage research that were once provided at the federal level. Consequently, research projects tend to be small and regional in nature – and depend on these small groups of dedicated individuals for support. This situation has also forced forage research scientists to spend too much of their time applying for grant money and preparing progress reports from many smaller, special-interest groups as opposed to receiving support from one larger granting agency.

3.1 Agriculture and Agri-Food Canada

AAFC has been a strong supporter of forage projects – and between 1987 and 1995, according to ICAR, AAFC initiated about 40 to 70 new forage projects across Canada each year (Chart 2.4).

Chart 2.4 – Forage and rangeland projects (1987-2005)

A substantial proportion of this forage R&D falls into the realm of “public good” research. In Canada, there is a risk of losing public good research under the matching grants system because it is very difficult to connect public good to corporate funding. (Public good research does not usually increase corporate profitability). It is important to note that AAFC does have a mandate to maintain research capacity in areas that the private sector does not support – which may be an argument that the beef cattle industry could use in seeking additional funding for forage and feed grains research. SVC explores the issue of research for the public good in more detail in Section 4.

After the 1995 federal budget, the number of AAFC forage projects fell to just under 30 and then increased steadily until there were over 30 forage projects in each year in 2002 and 2003. By 2004 and 2005, with the move to
horizontal work management teams, the number of new forage projects dropped to less than five per year. ICAR estimates that its records represent a maximum of 50 percent of the ongoing forage research in Canada.108

AAFC has also supported rangeland studies – with the strongest support for range work occurring between 1994 and 2003. SVC found no rangeland studies in the ICAR database after 2003. On average, AAFC rangeland projects have been the responsibility of two scientists and the number of scientists working on each forage project ranged between two and five between 1987 and 2003 (Chart 2.5).

Chart 2.5 – Forage projects (1987-2005) – Scientists working on each project

<table>
<thead>
<tr>
<th>Year</th>
<th>Average number of scientists per project</th>
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<tbody>
<tr>
<td>1987</td>
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<td>2005</td>
<td>8</td>
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</tbody>
</table>

Source: Inventory of Canadian Agri-Food Research, Strategic Vision Consulting Ltd.

In 2004, the number of scientists per project increased to eight with the move to horizontal work management teams. At the same time, the number of new forage projects dropped from over 30 in 2003, to less than five in 2004 (Chart 2.4) – suggesting a precipitous decline in the number of forage professionals in AAFC after 2004. This cut in project and staffing levels, which occurred in addition to the 1995 budget cutbacks, left AAFC with little capacity to meet the needs of the forage industry in Canada.

3.2 Alberta Agricultural Research Institute

Over 11 years, AARI has allocated over $62.7M to agricultural research and development. With over $3.2M invested in forage, silage, pasture and range research, AARI has invested about five percent of its funds in these three areas (Chart 2.6).
There is considerable variability in year-to-year funding for forage, silage, pasture and range research. AARI has invested $500,000 to $700,000 in three of eleven years and $1.2M in a single year – but less than about $50,000 in each of four years. In one year, there was no funding allocated for research at all.

These funding patterns may suggest that there is limited research capacity in some areas. At times, AARI has allocated sufficient funding in a single area to fill research capacity for several years running – and research scientists have had no need to apply for additional funding after the first year. A better strategy for AARI to pursue, however, may be to establish a long-term commitment to consistent funding to help secure and retain highly qualified scientific staff.

3.3 Agri-Food Research and Development Initiative
MAFRI and AAFC, through APF, have collectively funded ARDI. ARDI has invested almost $31M to support innovative research of benefit to the agricultural sector and to consumers (Chart 2.7).
With about 6 percent of this fund (over $1.7M) invested in forage crops, MAFRI has been another strong supporter of forage research. While ARDI funding for forage research has dropped and was somewhat unstable in late 1990s to early 2000s, funding stabilized at around $130,000 to $180,000 per year from 2004 onwards.

3.4 Alberta Crop Industry Development Fund
Of over $12M in funds dispersed by ACIDF through the Industry Development Initiative of 2001, forage research received $620,300 (Chart 1.11).
Section 3 – The growth of the Canadian bioethanol industry and the shift in plant breeding focus from livestock feed to bioethanol feedstocks

Issues covered . . .
Shifts in types of crops grown in response to bioethanol feedstock demand
Shifts in research funding
Shifts plant breeding priorities and research resources

Larry Martin, Senior Research Fellow with the George Morris Centre, disagrees with analysts who feel that grain prices will remain high as a result of the expected growth of the global biofuels industry. The populations of developing countries are more sensitive to food price increases and because they tend to consume more raw grains, pulses and oilseeds, have been the first to notice the rising cost of commodities. Mexico has had to deal with riots over a 400 percent increase in corn tortilla prices and India has already developed policies aimed at augmenting food supplies. In contrast, a University of Iowa study noted that increasing grain prices by 30 percent in the US only increases food prices by about one percent. The impact of elevated commodity prices obviously has more of an impact in developing countries than in advanced industrial economies. Martin feels this reaction to rising food costs in developing countries, however, could be the catalyst that reins in rising commodity prices. Since the biofuel industry is heavily subsidized, consumers could pressure governments to reduce subsidies for grain-based biofuel production and to increase incentives for the development of cellulose-based biofuels – and this pressure may not just be limited to Third World countries.

Senior research analysts at the George Morris Centre have also warned that the Canadian plan for the development of bioethanol runs contrary to other agricultural initiatives and will not be positive for agriculture. Since Canada has positioned itself as a meat exporting country, analysts argue that converting Canadian feed grains into bioethanol instead of into meat and livestock for export makes little economic sense – especially when an increasingly prosperous world can afford to pay higher prices for meat protein. This strategic adjustment in Canadian policy is also taking place at a time when Canada’s livestock producers are least able to adapt to change.

Currently, the impact of the biofuel industry on the Canadian livestock sector seems to be due to changes in government policy. Crop producers are responding to increased demand for biofuel feedstocks and are optimizing gross margins at the farm gate in response to market signals from bioethanol producers. Plant breeders, in turn, are responding to crop producers’ needs, as outlined in research agreements with their funding agencies and in response to new market opportunities.

It may be simpler to try to understand the relationship between the demand for biofuel feedstocks and plant breeders’ initiatives by first considering how the biofuel industries in Canada and the US could shift Canadian crop acreages. This is important with respect to breeding feed grains because plant breeders could choose to follow shifts in crop acreage by expanding, contracting or changing the focus of their programs in response to market needs. The risk to the livestock sector is that these program changes could alter the attributes of new crop varieties, and these varieties may not meet their needs.

1. Acreage shifts
The reallocation of plant breeding resources in Canada may be reflecting changes in cropped acres caused by changes to Canada’s biofuel policy. Canadian plant breeding priorities, however, may also be changing in response to US biofuel policy. Changes in the acreage of various US crops could create shortages of US feed grain energy and protein for livestock feed. Canadian crop producers may choose to step in as suppliers of grain energy and protein to the US – creating an even more dynamic cross-border flow of commodities. If this happens, western Canada could see dramatic fluctuations in the acreage of crops as diverse as fababean, field peas, forages and triticale, in addition to barley, canola and wheat over the next 10 to 15 years.
1.1 Biodiesel

Biodiesel production in Canada could rise to between 0.3 and 0.4 B litres (L) to support a mandate for five percent biofuel content.\textsuperscript{114} Meeting this mandate will depend on securing an adequate supply of canola in western Canada and soybeans in eastern Canada. The government of Canada estimates that crop producer returns for canola will have to exceed the price of wheat in western Canada, in order to meet feedstock demands for biodiesel producers. In eastern Canada, the price of soybeans will have to be substantially higher than the price of corn to supply sufficient feedstock for biodiesel production. Studies suggest that canola production would have to increase six percent by 2010 to support this growth.\textsuperscript{115}

1.2 Bioethanol

The expansion of US bioethanol production from corn could open up new markets for Canadian feed grains south of the border.\textsuperscript{116} Ethanol analysts from Iowa State University's (ISU) Center for Agricultural and Rural Development have forecast that US ethanol production will rise from 18.5M L in 2006 to over 53M L by 2016. In this same period, ISU analysts predict corn acres will increase from 78.4M acres in 2006 to 92.5M acres by 2016. In that same period, soybean acres will drop from 75.5M acres to 68.4M acres.

The ISU model uses US Department of Energy oil futures forecasts. However, if oil prices rise by US$10 per barrel over current projections, corn acres could rise as high as 112.3M acres by 2016 while soybean acres would fall to 57.2M acres. The model also predicts that demand for Canadian wheat will rise from 4.8M t in 2007 to 5.8M t by 2016. With few acres of corn in western Canada, this could shift western Canadian acres to field peas (to make up the shortfall in the US soybean crop) and to feed wheat. As US livestock producers face rising corn and soybean prices, competition for Canadian feed wheat would increase, leading to higher prices. This study has led to speculation at CDC Saskatoon that crop breeders may wish to consider focussing their objectives on developing wheat for feed and fuel, instead of for food markets.

1.3 The development of triticale as a biofuel feedstock

Plant breeders are starting to put more effort into triticale as a biofuel feedstock because of the yield potential in this species. For a crop like durum wheat, as an example, there is less opportunity to increase yield because historically, yield has been climbing steadily for years. In Italian and Spanish varieties of durum wheat, yield per plant has increased at a rate of 0.36 and 0.44 percent per year, respectively.\textsuperscript{117} Because plant breeders have done so little to improve the genetics of triticale, increasing plant vigour in a focussed program could produce huge increases in yield in just a few years.

1.4 Field peas

In the US, producers are increasing corn acres at the expense of soybeans.\textsuperscript{118} If this trend continues, western Canadian producers may choose to grow field peas for export to the US to make up for the protein shortfall due to the reduction in soybean acres. Field pea acres could increase rapidly in western Canada, at the expense of cereal acres. Incorporating field peas into a cropping rotation provides an added competitive advantage for producers. With the cost of nitrogen (N) fertilizer rising rapidly, field peas offer crop producers the option of growing their own N.\textsuperscript{119} Since producer check-off funds provide direct support for plant breeding programs, any shift in acres from one crop to another could shift plant breeding efforts from one crop to another.

1.5 Fababeans

Fababeans are a good source of protein for livestock feed and are one of the better N fixing crops in western Canada.\textsuperscript{120} Acres of fababeans could increase in the near future as markets for this crop develop – particularly for the hog feeding industry. Recently, ACIDF chose fababeans as one of three crops that would share about $3.5M in feed development funding.

1.6 Forages

Forages make up more than 80 percent of livestock feed in Canada and most producers use seeded forages to produce tame hay or silage.\textsuperscript{121} Canada produces around 25Mt of tame hay annually on about 8M ha – with Alberta being the largest producer. In Québec, about 60 percent of the farmland is committed to forage crops and in Ontario,
producers grow forage crops on about 40 percent of all farmland. Canadian producers grow substantial volumes of forage crops in all provinces outside of the Maritimes and Newfoundland and Labrador.

Demand for biodiesel and bioethanol feedstock will have an impact on Canadian forage acres. There is an inverse relationship between forage yield and acres seeded to annual crops. As annual crop acreage increases, producers grow forages on increasingly marginal land and dedicate better quality land to annual and cash crops. As forage production moves to increasingly marginal land, maintaining yield and productivity becomes more difficult – and forage yield as well as total forage production would be expected to decline. This scenario could apply adverse economic pressure to already-struggling cow-calf operators.

1.7 Barley
The ISU report does not include barley because it is such a minor crop in the US. This is a concern given the importance of barley to livestock producers, especially in western Canada.

2. Funding shifts
The largest funders of wheat breeding research in western Canada are AAFC ($3.9M per year or 39 percent of all funds) and WGRF ($2.9 M per year or 29 percent). Royalties and grants account for 14 percent of the total, but these funds are difficult to track given the multitude of organizations that receive plant breeding royalties and the number of granting agencies. Provincial governments fund about 10 percent of the all plant breeding research – but the percentage contributed by any one province would be low relative to the funding of AAFC and WGRF.

2.1 Western Grains Research Foundation
WGRF is planning to invest in cereal grain varieties designed specifically for the bioethanol market because it sees the development of the bioethanol industry as a significant opportunity for wheat and barley farmers. One variety, AC Andrew, is particularly suitable for the production of bioethanol. This low protein, low gluten-strength soft white wheat was developed for use as a pastry flour. While these high yielding, high starch content, low protein grains make good bioethanol feedstocks, they can also be grown to supply livestock producers with large quantities of high-energy cereal grain.

2.2 Agriculture and Agri-Food Canada
AAFC’s allocation of research funds should mirror its priorities as outlined in the 2006 Science and Innovation (S&I) Strategy. The S&I strategy presents agriculture in terms of its connection to emerging national issues – which include, but are not limited to, climate change, energy supplies, health and terrorism. AAFC is addressing these national priorities through three themes, one of which is energy. AAFC has a goal of enhancing Canada’s ability to generate energy directly from biomass, and this includes the production of bioethanol from grain as well as the production of biodiesel from canola.

2.3 Changing institutional priorities
The Government of Canada and provincial governments will be making significant investments in the development of and support for the Canadian biofuels sector. The federal government alone has committed $673M to fund the development of biofuels in Canada.

2.4 Philosophical shifts
Plant breeders’ philosophical inclinations also play a role in shifting breeding program priorities. For example, some plant breeders feel that winter wheat, due to its potential for high yield, may have the most utility as a feed grain targeted for domestic use only. Others feel that this way of thinking caters to the lowest common denominator and choose to target the premium milling market. The reason is that winter wheat, since it is seeded in the fall and matures earlier in the season than spring wheat, has the potential to skirt environmental conditions that lower the quality of spring wheat. In these situations, winter wheat that meets Canadian milling wheat standards, offers a superior profit opportunity for the winter wheat producer.
Winter wheat, however, also needs to meet requirements for Kernel Visual Distinguishability (KVD) – and the probability of producing a milling quality winter wheat is low. For this reason, some breeders would rather focus on the feed market until the KVD issue is resolved. (SVC will cover KVD in more detail in Section 5). Since western Canadian plant breeders are sharing an average of $3.2M in producer check-off funds each year, they have a stake in creating a strong competitive advantage for western Canadian wheat growers.1 This includes keeping the options open for crop producers to obtain as high a price as possible for cereal grain crops such as winter wheat.

3. Shifting plant breeding priorities – the risk for livestock producers

Traditionally, western Canadian wheat classes have had to conform to specific end-use quality characteristics and protein functionalities designed for milling and baking.126 What has been marketed as feed wheat is typically a lower grade of grain that has not met milling standards due to frost, dockage or a series of other grade-lowering production setbacks.

Bioethanol manufacturers would like to have plant breeders develop a cereal grain with elevated levels of High Total Fermentables (HTF).127 This grain would also produce more ethanol per unit of feedstock. Currently, AC Andrew CWSWS wheat is in demand as bioethanol feedstock because of its high starch content. Some bioethanol stakeholders, however, are looking at hulless barley with low levels of undesirable, non-fermentable constituents for the manufacture of bioethanol in Alberta.128 In particular, these future stakeholders may have a specific interest in increased levels of β-glucan in hulled as well as hulless barley to supply a biorefinery.

Good milling and baking wheats and good malting and brewing barleys do not necessarily make ideal livestock feed. In the same way, good wheat or barley varieties for the manufacture of bioethanol may not make ideal feeds either. The cattle sector, for example, may want barley with high levels of energy or starch, improved feed intake and efficient conversion to protein. The dairy sector, on the other hand, might prefer barley varieties with high starch content, but dairy cows will need starch that is degraded more slowly in the rumen. Hog and poultry producers may be more interested in feed wheat than cattle producers; however, hogs and poultry may perform better if each class of livestock is fed a specific variety of wheat. What may be best for the livestock sector are varieties of wheat and barley bred specifically for livestock consumption rather than for milling, baking, brewing or the production of bioethanol.

4. Shifts in plant breeding research resources with the development of the biofuel industry

4.1 Wheat

Shifting wheat breeding resources towards the production of bioethanol may create varieties with higher energy levels and higher yield potential. Wheat yields will have to increase because grain producers in western Canada will find it challenging to make a profit growing CWRS at 32 to 35 bu/ac if they sell it as weathered low-grade wheat to bioethanol manufacturers.129 Some have speculated that farms may need wheat varieties that yield 45 to 60 bu/ac to be competitive. Two studies, one from Australia and one from Manitoba, have considered how much yield it would take to compensate producers for growing a lower quality wheat. If there is no economic justification for crop producers to grow lower quality wheat, it is unlikely that plant breeders would take this on as a project.

There are seven wheat breeding centres in western Canada: the U of Manitoba (CWHW and winter wheat), AAFC Winnipeg (CWRS), CDC Saskatoon (CWHW, CPS, CWRS, CWGP and winter wheat), AAFC Swift Current (CPS, CWRS and CWGP wheat), U of Alberta (CPS and CWGP wheat), FCDC Lacombe (winter wheat) and AAFC Lethbridge (CWSWS and winter wheat).130 AAFC also has a team effort dedicated to the development of CWHWS wheat. Plant breeders in all of these programs could shift resources into breeding wheat as feedstock for the emerging bioethanol market. Most of these wheat varieties would likely fall into the new CWGP wheat class. The extent to which resources shift may depend on the level of funding available for the development of CWGP wheat and the mandate of the institution responsible for the breeding program.

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1 SVC calculated the average wheat breeding contribution from WGRF at $3.2M per year between 2001 and 2005. In 2001, Heisey et al. have calculated this contribution to be about $2.9M.
In Australia, Brennan et al. investigated the trade off between yield and quality in plant breeding programs. They compared four classes of wheat representing the range from highest to lowest quality:

- **Prime Hard (PH)** – a top quality milling wheat with protein levels of 13 to 14 percent
- **Australian Standard White (ASW)** – a medium to low protein white wheat for milling or blending
- **General Purpose (GP)** – GP wheat fails to meet Australian Wheat Board (AWB) standards for major grade wheat. It is a general purpose milling wheat.
- **Feed** – feed wheat is high in protein and gluten and has good digestibility

Brennan et al. examined four scenarios (A, B, C and D) in which yield and quality were altered, and looked at the economics of breeding for changes in wheat yield and quality:

- **Scenario A** – An increase in yield with no change in quality – the specific scenario entailed increasing the yield of ASW by 10 percent.
- **Scenario B** – An increase in quality with no yield change – the specific scenario involved breeding projects aimed at producing PH instead of ASW wheat classes.
- **Scenario C** – A small decrease in quality coupled with a five percent increase in yield – this equated to increasing the yield of ASW wheat while reducing the quality of the wheat to GP
- **Scenario D** – A large decrease in quality combined with a 20 percent increase in yield – which translated to raising the yield of ASW by 20 percent but lowering the grade to feed.

Each situation was evaluated based on the economic value of the gain for the crop producer, the economic gain to the Rest of Australia (ROA) and economic gain to the Rest of the World (ROW). In Scenario A, increasing the yield of good quality wheat was the most profitable option for the producers with a benefit of AU$17.1M (Chart 3.1).

**Chart 3.1 – The financial benefit from increasing yield and/or lowering quality of Australian wheat**

<table>
<thead>
<tr>
<th>AU$M</th>
<th>Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scenario A</td>
</tr>
<tr>
<td>INCREASE YIELD</td>
<td>-20</td>
</tr>
<tr>
<td>No quality change</td>
<td>-15</td>
</tr>
<tr>
<td>INCREASE QUALITY</td>
<td>-10</td>
</tr>
<tr>
<td>No yield change</td>
<td>-5</td>
</tr>
<tr>
<td>Decrease quality (small)</td>
<td>0</td>
</tr>
<tr>
<td>Increase yield (5%)</td>
<td>5</td>
</tr>
<tr>
<td>Decrease quality (large)</td>
<td>10</td>
</tr>
<tr>
<td>Increase yield (20%)</td>
<td>15</td>
</tr>
</tbody>
</table>

Source: Australian Wheat Board
In Scenario B, increasing wheat quality while maintaining yield only returned AU$8.4M to the producers. In Scenario C, decreasing quality by a small amount and increasing yield by five percent returned AU$4.2M to wheat producers. In Scenarios A, B and C, the gain in benefit to the ROA and the ROW was about equivalent to the benefit to the wheat producer. In Scenario D, however, increasing yield by 20 percent while decreasing wheat quality to feed produced a loss to the crop producer of AU$18.7M; however, the ROA and the ROW received a benefit of AU$19.1.

Increasing yield and lowering the quality of wheat provided the greatest overall economic return (Scenario D). This is a sound economic option only for livestock producers who grow their own feed wheat – but would be of little interest to crop producers with no livestock to feed because there is no financial benefit for the operation. A better option for these producers is to grow another class of wheat, or better yet, a more profitable crop.

Kraft and Rude considered the economics of increasing wheat production to meet the demand for feedstock from bioethanol manufacturers. The researcher made several assumptions:

- Bioethanol plant needs, while putting upward pressure on local feed wheat prices, would have no effect on world wheat prices or the price of No.1 or No.2 CWRS
- Crop producers plant wheat targeted at the milling market
- No new acres of wheat will be seeded with higher price expectations for No.1 or No.2 CWRS

Based on these assumptions and on an analysis of western Canadian wheat grade distribution from 1980 to 2001, they concluded that wheat supply for bioethanol production would depend on growing conditions more than any other factor.

One means of increasing feed wheat production is to breed new high yielding varieties specifically for the feed and bioethanol market. This feed wheat would have no milling or baking attributes but would be very high yielding. However, farmers then need an economic incentive to grow feed wheat instead of milling wheat. Given the price of feed wheat relative to milling wheat, how much more yield would be required to offset the lower price of feed wheat?

Between the 1995-1996 and the 2000-2001 crop years, the Winnipeg feed wheat price was $130/t. Over the 20 years prior to 2001, the average HRSW graded 51 percent No.1 CWRS, 24 percent No.2 CWRS, 17 percent No.3 CWRS and 8 percent Feed. The average weighted market price for HRSW averaged $164/t. Using these figures, the revenues for feed wheat equalled HRSW when feed wheat yields exceeded HRSW yields by almost 30 percent. Crop producers will have to see the financial benefit in growing larger volumes of lower quality wheat in order for volumes of feed wheat to increase.

What the two previous examples illustrate is that even a 20 percent increase in yield is not enough to offset the lower value of lower quality wheat. Wheat producers may need to get yield increases in excess of 30 percent to offset lower wheat prices. The alternative is that wheat prices paid by bioethanol producers would have to rise if the bioethanol producers wish to encourage producers to grow lower quality wheat for bioethanol feedstock rather than higher quality wheat for export. The advantage of increasing wheat yield per unit area is that it would lower the cost of production and leave more acres open for the production of barley and other feed grains and forages.

Plant breeders are not only working to advance yields, they are steadily improving the complete “wheat package” which includes keeping agronomic traits such as days to heading, days to maturity and plant height within acceptable limits. It also means improving lodging scores as well as reactions to a range of diseases such as Fusarium, stem rust, leaf rust, bunts and smuts, among others.

According to the Canadian Seed Trade Association, wheat yields have increased around 22 percent in the last 30 years. Almost all of this increase has been due to improvements in crop genetics. Data from the Semiarid Prairie Agricultural Research Centre suggest that, using Neepawa as a check variety, yields of wheat varieties over the past 20 years have increased by about 15 percent (Chart 3.2). As a comparison, canola yields have grown by about 25 percent over the same period.
The rate of genetic gain over about 95 years has been in the range of 0.2 to 0.25 percent per year. In the last 30 years, the rate has been closer to 0.5 percent per year – which means that genetic gain should increase by an additional five or six percent over the next 10 years. According to wheat breeders, financial resources have the greatest positive impact on genetic gains.\textsuperscript{140} Given the trends in research funding for plant breeders and the regulatory obstacles in place in Canada, the fact that yields of CWRS wheats have continued to rise at all is very impressive. This data suggests that it should be possible for Canadian plant breeders to move wheat yields substantially higher with the creation of the new CWGP class of wheat. The lowering of regulatory barriers and the complete removal of KVD requirements for Canadian wheats could provide an even greater opportunity to raise wheat yields over the next 10 years. How long it will take to remove these regulatory impediments completely remains to be seen.

In the 1960s, the theoretical maximum yield for wheat was thought to be in the range of 10 to 12 t/ha (150 to 180 bu/ac).\textsuperscript{141} The theoretical maximum has since moved to 15 tonnes per hectare (225 bu/ac) and some speculate that the theoretical maximum for wheat could reach 20 tonnes per hectare (300 bu/ac) in western Canada.

Canterra Seeds is developing the first CWGP wheat varieties specifically for bioethanol production.\textsuperscript{142} The varieties Shiraz, Chablis and Ashby, which will be eligible for registration in 2009, will yield about 10 to 15 percent higher than check varieties such as AC Barrie, AC Superb and AC Crystal. This puts CWGP yields within the range of winter wheat yields.

These varieties are not milling wheats that did not meet grading standards, but are wheats that Canterra Seeds originally developed as feed wheats. Minor modifications to the germplasm created varieties ideally suited for bioethanol production. The company is also developing a management package for these wheat varieties that will allow producers to minimize protein and maximize yield. These varieties should also have some value as feed wheats, even though they are being bred to meet the needs of the bioethanol industry, because the energy (starch) content of the grain is high. Even though these varieties were not bred for feed purposes, their characteristics suggest that the varieties may also be well suited for use in the livestock industry.
4.2 Barley
The largest funders of barley breeding research are the provincial governments ($1M per year or 32 percent), WGRF ($800,000 per year or 26 percent) and AAFC ($400,000 per year or 13 percent). Royalties and grants account for 29 percent of the total but, as with wheat, these funds are difficult to track.

There are only three barley breeding programs in western Canada: AAFC Brandon, CDC Saskatoon and FCDC Lacombe. The principle barley breeders at all locations are in range of retirement – and retirement always leaves an institution with the option of closing the program. AAFC provides most of the funding for the AAFC feed barley program in Brandon; SAF contributes a large proportion of the funding for CDC Saskatoon; and AAF is responsible for the program at FCDC Lacombe. AAF has already decided to terminate the malting barley program at FCDC Lacombe. The loss of a malting barley program has negative consequences, not only for the malting and brewing industry, but also for the livestock industry, since grain that fails to meet malting standards is usually sold as feed. The malting barley breeder also adds additional value by contributing to the development of barley germplasm and by screening for resistance to barley diseases. All of this work benefits feed and malt programs equally.

The goal of AAF in closing the malting barley program (as it was explained to ABC personnel) is to put more resources into feed barley and bioethanol research. The resource allocation to feed research relative to bioethanol research, however, has not been made clear. The feed barley program has also been struggling with personnel issues as AAF shifts resources from one program to another. ABC has expressed its concern about a lack of commitment on the part of AAF to barley breeding in Alberta.

In 2007, ABC claimed that AAF was changing the focus of the FCDC and was reducing the size of the barley program. AAF has allegedly shifted funds away from agronomic programs and changed job descriptions and reporting structure to facilitate this change in program focus. In 1999, AAF added a molecular biologist to the FCDC barley breeding team, but later removed this position from the program – even though all of the equipment was purchased through the barley breeding program and the laboratory space was at AAFC. The FCDC barley program also lost a permanent germplasm development technologist when AAF moved this position to the biotechnology program. The technologist has since chosen to leave the biotechnology program and has moved back to the FCDC barley breeding program. ABC is now funding this position. ABC also funded positions in the FCDC NIRS quality laboratory and the biotechnology laboratory until these positions were made permanent in 2000.

On the surface, the FCDC seems to be in a good position to deliver value to producers and consumers of feed grains. However, ABC claims in a recent letter to the Honourable George Groeneweld, Minister of Agriculture and Food, that barley genomics staff have been reassigned by AAF to non-barley projects. ABC also claims that AAF has reassigned barley agronomics staff to non-barley projects, that feed barley staff and feed barley breeders are under pressure to work on other projects and that the feed barley program in at risk of being lost. In response, Minister Groeneweld noted that changes in the FCDC program have been minor and that staff reassignments have been made in response to recommendations made in 2006 by an international scientific review of the FCDC program. This shift in research resources, while not specifically related to the growth of biofuels, suggests that there may be many different reasons for a shift in resources from feed breeding programs into other areas. These types of changes occur frequently in large public research institutions and tend to be overlooked outside of the institution. Once these changes have occurred, however, the process is difficult, if not impossible, to reverse.

In 2007, ABC and the Alberta Barley Growers’ Commission (ABGC) received $262,000 from BOPI to assess the potential for barley as a biofuel feedstock. Industry partners contributed an additional $118,000 in funding to create a $380,000 commitment to barley-based bioethanol research. Barley growers would like to determine:

- How much bioethanol barley produces relative to wheat or corn
- The relative merit of hulled and hulless barley as bioethanol feedstock
- Which barley variety may be particularly well suited for bioethanol production
- The value of barley as a feed by-product of bioethanol production compared with corn
- The value of barley to the primary producer as an industrial feedstock
- The potential value of pre-distillation fractionation of barley to produce value-added by-products such as bran, β-glucans and germ
The goal of barley producers is to decrease their level of dependence on feed and malting markets. Currently, less than one percent of Canadian barley production is used for food or industrial purposes. Bioethanol manufacturers are expected to consume less barley than maltsters, but barley producers expect the bioethanol market value to be high.

5. Other issues
Livestock producers may also consider the potential impact that the development of cellulosic bioethanol (CEtOH) could have on plant breeding efforts in the areas of feed grains and forages. The concept of the biorefinery could also have an effect on barley breeding efforts in western Canada.

5.1 Cellulosic bioethanol
The best candidates for bioethanol feedstock may be vegetative biomass derived from tree waste or fast growing grassy species. There are a number of competing technologies in the lignocellulose-based bioethanol sector. Most require pre-treatment to alter the structure of the cellulose physically, chemically or physiochemically. Enzymatic hydrolysis, fermentation and distillation follow pre-treatment to produce cellulosic bioethanol (CEtOH).

Positive crop attributes for this industry include: high bulk density and yield; high “free fall” bulk density; low levels of “inhibitory” compounds; the ability to be stored for long periods of time without decomposing; low moisture, ash and silica content; and a straw with at least 60 percent carbohydrate. While some of these traits may be of benefit to the livestock industry, other traits, particularly those associated with increasing storage time without the risk of decomposition, could be developed through the enhancement of bioactive antimicrobial compounds in the plant. These varieties could prove to be quite toxic to livestock and may not meet livestock producers’ needs at all.

Drs. Mario Therrien and Bill Legge are developing high yielding forage barley for the livestock market at AAFC Brandon; however, the long-term goal is to have these barley varieties also meet the needs of the cellulosic bioethanol market.

5.2 Biorefineries and the vertical integration of bioethanol production
Bioethanol manufacturers are considering the extraction of value-added components from cereal grains before fermentation. Western Canada may soon see specialty grain processors creating business clusters in conjunction with the bioethanol industry. β-glucans are of particular value in some markets. One business option is to extract β-glucans as part of a value-added process and then to put the high starch waste stream through a fermentation process.

Plant breeders could shift programs towards creating enhanced levels of value-added cereal components, such as β-glucans, for specific manufacturing clusters. This has the potential to not only alter the feed value of hulled and hulless barley varieties for livestock, but pre-processing grains before fermentation may also alter the composition of dried distillers’ grains with solubles (DDGS). Livestock feeders using barley DDGS that has been processed before fermentation may need to determine the feed value of each specific DDGS by-product and make ration adjustments accordingly. Since there are numerous compounds that could be extracted from the grain, and with different processors each interested in a specific subset of compounds, barley DDGS could be nutritionally unique to each processor.
Section 4

Issues covered . . .
Public and private research in feed grains and forages in Canada
Limitations on investment in Canadian feed grains research
A comparison of the public and private plant breeding research sectors in Canada and the US
Canadian requirements for investment and infrastructure to meet end-user needs for feed grains and forages

We feel that the future of Canadian agriculture is in jeopardy, as we cannot continue to remain competitive under the current system.

— Charles Hubbard, M.P. ²

Canadian cattle producers have the ability and the resources to compete successfully in competitive global markets. To dominate world markets, Canadian cattle producers will need access to an abundant supply of cereal feed grains such as wheat and barley, at prices that are competitive relative to US corn. Western Canadian plant breeders have a vital role to play in helping Canadian cattle producers capture their share of the global market. SVC will look into competitiveness issues in feed grains by examining the differences between public and private plant breeding, the cost of plant breeding, the Canadian public-private funding model, private sector involvement in plant breeding and the return on investment in various feed grains crops.

SVC will then compare Canadian funding for agricultural R&D to other regions of the world, and more specifically, will look at Canadian funding for plant breeding compared to funding in the US. This section will end with a review of what Canadian breeders need in terms of research investment and infrastructure development to help meet future livestock sector needs for feed grains and forages.

1. Canadian agricultural competitiveness in a global context

Globally, the world’s population could reach 10B by 2035 ¹⁵³ and the consumption of protein is increasing rapidly in the developing world.¹⁵⁴ At the same time, annual gains in the global food supply have declined from three to one percent.¹⁵⁵ Increasing the global supply of food through the expansion of the cultivated land base may not be feasible — and could create environmental havoc in many regions of the world. A new “green revolution” is unlikely to solve the world’s food problems because additional production gains through chemistry or mechanization are forecast to be relatively small. With this scenario unfolding, what are the implications for Canada, a country that provides the world with over $24B in agricultural and food products each year? ¹⁵⁶

Wheat, barley and livestock make up a large proportion of Canada’s agricultural and food exports. With its sizable land base and its high level of agricultural productivity, Canada has a competitive advantage over most other nations that produce and export agricultural products. Canadian producers, however, depend on substantial investments in R&D in order to stay competitive. When the Canadian public invests in agricultural R&D, it receives a good return on its investment. Proof of that benefit is reflected in the growth in agricultural productivity over the last 40 years — with the agricultural sector outperforming both the manufacturing and business sectors of the Canadian economy.¹⁵⁷

² Report of the Standing Committee on Agriculture and Agri-Food, Registration of Pesticides and the Competitiveness of Canadian Farmers.

41 – Strategic Vision Consulting Ltd.
2. A competitive cattle sector

2.1 Plant breeders’ contributions to a competitive cattle sector

Plant breeders could help meet the demand for wheat and barley varieties with specific characteristics designed to meet the needs of the livestock sector. What is required are higher yielding feed barley and feed wheat varieties that produce more energy per unit of land. High levels of digestible energy, metabolizable energy and net energy and low levels of starch degradability in grains destined for beef and dairy cattle rations are all positive attributes of a good feed grain. Other needs to be addressed include good feed conversion to protein, good daily weight gain and high levels of feed intake. Even with Canadian wheat varieties, where yield has lagged due to regulatory constraints, producers have been able to increase yields an average of 22 percent between 1976 and 2006 – and almost all of this increase has been attributed to improved genetics. However, with a 10-15 year lag from the time of the first breeding cross until the release of a commercial variety, work must start sooner, rather than later for maximum benefit.

High grain prices also contribute to increases in the use of forages over feed grain in livestock operations – increasing the weight at which cattle go into feedlots. In these situations, forage and feeding systems research would help producers move seamlessly into different production alternatives and help maintain competitiveness.

Investments in plant breeding pay a good return on investment, both in terms of direct producer benefit and through the benefits that the seed sector passes on to the Canadian economy. Klein et al. used a multi-sector mathematical model of Canadian agriculture, the Canadian Regional Agricultural Model (CRAM) to calculate the rate of return on yield-increasing research on wheat between 1962 and 1991. The internal rate of return (IRR) ranged from 27 to 39 percent – with crop producers capturing 80 to 90 percent of the benefits of the research. Nagy has calculated the IRR for barley at 27 percent, with a range of 23 to 31 percent. These results for wheat and barley are in range of the estimated economic benefits for similar studies.

The seed industry itself is a strong contributor to the Canadian economy. Over 13,000 Canadians work in the pedigreed seed industry – and in Saskatchewan alone, the seed industry infuses $390B into the provincial economy. In fact, the seed industry, through the introduction of new varieties, is one of the key drivers of this economic productivity in the agricultural sector.

Globally, private sector plant innovators reinvest over 13 percent to R&D. This is in stark contrast to the automotive and food-processing sectors, with reinvestment rates of 5 percent and 1 percent, respectively. The pharmaceutical industry, as a comparison, reinvests 18 percent. Globally, private plant sector plant innovators invest about $1B in R&D and Canadian private plant breeding companies invest about $70M of this total.

Investments in plant breeding also produce cascading economic benefits through the value chain. The return on investment from plant breeding research is ten to one, which means that every $100 million in investment in plant breeding produces a benefit of $1B to the Canadian economy. As an example, feed barley breeding and disease resistance research funding at FCDC Lacombe between 1974 and 2001 produced 10-fold return on investment. More specifically, funders invested $8.6M in the FCDC feed barley program between 1974 and 2001 and the overall monetary benefit from that investment was over $109M between 1983 and 2001 alone. The IRR was 29 percent, which is an excellent rate of return for an agricultural research and development program. This type of public plant breeding research also adds value to the rural economy and these public programs collect additional funds from the private sector. For example, SeCan contributed almost $3M to AAFC – and research scientists used this research funding to leverage additional funds through matching investment initiatives.

3. What is the difference between public and private plant breeding?

There is a role for both the public and the private sector in the realm of plant breeding. Ideally, the goal may be to optimize the value of public funding, while encouraging the development of private plant breeding initiatives. But where does one draw the line between public benefit and private good? Some traits are under-researched in the private sector – including nutritional traits and plant adaptation to various environments. Methodology development, including the refining and testing of selection methodology has been, and will continue to be an important part of public sector work – especially as advances in biology continue to advance, creating the need for new tools. Both the public and private sector, however, see a need to increase the level of activity in the public sector.
sector for germplasm preservation and development. This includes the collection of germplasm from both cultivated and related wild species, and the incorporation of useful traits, including those with value added potential, into agronomically adapted varieties.

3.1 The public realm

There may be social returns from both public and private breeding programs, but furthering scientific knowledge is not necessarily profitable. Consequently, research in the public sector may produce societal benefits that the private sector does not. As an example, the role of the public plant breeders in the training of the next generation of plant breeders is considered essential and falls under the public good umbrella of human capital development. The risk of not having adequate development of human resources in the area of plant breeding is high. With flagging investment in public sector research, there are fewer opportunities for new plant breeders to acquire hands-on training at universities. Because skills in plant breeding are transferable, the private sector is not taking up the challenge of investing in human capital development because knowledge is mobile – and there is always the risk that highly trained private scientists could transfer newly acquired skills to a rival company.

Other areas that fit the public sector better than the private sector include research in high-risk areas. This type of research is required to support commercial breeding operations and is beyond the scope of the commercial realm. Technological problem solving is an important area for the public sector due to its ability to take a long-term view, as opposed to the short-term timeline of private industry. Technological bottlenecks can also be circumvented by the public sector because there are no issues regarding the private ownership of intellectual property. Private sector investment in more fundamental research areas such as genomics may tie up technologies in intellectual property ownership rules – and these types of projects may be more appropriate for the public sector to ensure that a limited number of commercial organizations do not have too much influence over the global food system.

At major international gatherings, plant breeders have divided responsibilities into the realms of public and private interest. Plant breeding responsibilities that could reside within the public system include breeding for low productivity crops, "minor" crops and small market crops, cereal disease control, conservation of genetic resources, variety selection methodology, germplasm preservation and development, grain science and technology, pre-breeding research and the training of plant breeders. The public sector could also excel in areas such as plant genomics (deciphering and understanding genetic information), proteomics (how the plant controls the chemistry that controls grain quality) and bioinformatics (using computers to solve problems in molecular biology). Output from all three areas could be made available to all private plant genetics ventures under reasonable commercial terms. There is also a need to for neutrality and transparency in the evaluation of field performance for all available varieties, and this area may be best handled by the public sector as well.

Public sector plant breeding in Canada once accounted for most of the new crop varieties. Funding cuts reduced the number of public Canadian plant breeding programs substantially and few crops still merit any public sector focus. Even where there is a focus on wheat and barley in the public sector, feed breeding is not a priority. Given the number of plant breeding priorities that plant breeders feel need to reside in the public sector, one has to question whether Canada even has the ability to support the needs of a private sector focused on the development of any new crop variety.

3.2 The private realm

Plant breeders have decided that the private sector, in a division of labour with the public sector, would be responsible for variety development, particularly hybrid crop development, and the search for patentable technologies in major crops for important markets. Annual global investments by private plant breeding institutions are about $1B. Private sector plant breeding investments in Canada are over $70M million annually – or about seven percent of what is invested globally.

3.3 The public-private hybrid experiment

Plant breeders have outlined areas in which the public and the private sector could excel by dividing up responsibilities. With pressure to cut government research program budgets in Canada, however, the funding model has been evolving into a “matching funds” effort, in the interest of increasing public sector “efficiency” in research. This system may not benefit livestock producers in need of feed grains because projects tend to focus on
shorter-term outcomes of immediate interest to the funding partner. This tends to reduce the amount of research conducted for the public good – and research for the public good often benefits primary producers.

The other disadvantage for livestock producers under this hybrid system is that without a source of private funding for research, the research will not occur. In Manitoba, all major funders have adopted this type of funding structure – and often require matching grants of up to 50 percent from private funders. The funding structure in the other provinces does not deviate substantially from this model.

Research scientists in agricultural fields have noted that it is very difficult to find funding in areas that may benefit livestock producers, including sustainable crop, range and pasture management; reductions in the use of crop inputs such as pesticides in crop production; or research in the area of agronomic practices.208 If we assume that Canadian livestock and crop producers provide the country with a secure and safe food supply, that Canadians want a secure and safe domestic food supply and choose to be exporters of safe food products to global markets, then we must conclude that a public investment in feed grains and forage research is worthwhile. If these issues are important to Canadians, then a shift back towards more public investment in agricultural R&D is required.

4. The check-off funds
The WGRF and ABC Check-off Funds have provided substantial support for plant breeding programs in western Canada. While the funding itself is important, producer support for public research is also required, and may become more important in the future, to demonstrate the importance of these programs to those who control the budgets within organizations such as AAFC, AAF and SAF.

WGRF and ABC Check-off Funds contributed $4.25M to $5.45M annually to Canadian agricultural research between 2001 and 2005. Crop producers support and direct these Check-off Funds, with most of the funding derived from wheat and barley exported from Canada. Between 1985 and 2006, the WGRF Endowment Fund contributed about $850,000 of $16M, or about five percent to feed breeding investments. From 2001 to 2005, the Wheat and Barley Check-off Funds contributed about $3.28M of $19.8M, or almost 17 percent of the funds to feed wheat and feed barley breeding.

Alberta barley producers support ABC by contributing 50 cents for each tonne of barley sold.209 ABC invests its check-off funds in projects that benefit the barley industry while contributing to the economic success of the province's barley producers. A substantial proportion of this funding found its way into western Canadian barley breeding programs.

4.1 Future trends in WGRF check-off funding
The CWB collects check-off funds for the WGRF on exports of wheat and barley. With a move towards greater domestic consumption of wheat, from the manufacture of bioethanol in particular, plant breeders could see a shortfall in check-off funding for wheat and barley breeding. SVC will discuss this issue using the Western Feed Grain Development Co-op (WFGDC) as an example. This co-op was created to fill the need for high yielding feed wheat varieties in western Canada.210 WFGDC believes that wheat breeders have been constrained by stringent KVD requirements in western Canada. The organization has proposed developing wheat varieties that will be exempt from licensing and KVD requirements because the seed will only be available to members and will only be used for feed or for the production of bioethanol.

The concept of a closed loop in crop production and utilization in western Canada is new. However, if this type of closed-loop system becomes more common, and exports of wheat and barley drop, then the CWB will collect lower levels of check-off funding for the WGRF. Will organizations such as WFGDC contribute to the WGRF check-off funds? It may not be fair to ask WFGDC members to pay into a check-off program since membership fees have already financed the research needed to produce wheat varieties. If the organization is already funding its own research, should members be asked to pay twice? These questions may point to a need to reconsider the means by which feed grain breeding is funded in western Canada.
5. What are the economic impediments that have limited private investment in Canadian feed grains and forage research?

Factors that influence private sector investment in plant breeding include the cost of research, market structure, seed industry configuration, the ability to reinvest corporate profits in research and farmer profitability. Profitability in the seed sector is also linked to profitable farm operations where the producer sees value in purchasing pedigreed seed.

5.1 The cost of research in plant breeding

Plant breeders have estimated the cost of developing a new variety of CWGP (feed) wheat, feed barley or forage barley at over $1.6M, with a range of $300,000 to $5M. The cost of producing CWSWS wheat or CWGP wheat may be less expensive than CWRS wheat because testing requirements are not as stringent; however, the quality requirements for CWGP have not yet been set. The shortest period of time in which plant breeders could develop a new variety may be as low as six years, but is typically in the range of eight to ten.

Estimates of the cost of variety development may be lower for established public breeders than those for new private plant breeding operations. Established public breeding programs have infrastructure and human resources in place. A new plant breeding operation would have capital costs associated with the development of infrastructure and the breeding expertise may not be in place. Private operations would also need to develop or procure an adequate supply of germplasm – and this could be extremely costly.

In 2000, Brennan and Singh estimated the cost of developing a new cereal feed variety in Australia. They assumed that R&D costs would run AU$250,000 per year for five years (AU$1.25M). Once plant breeders had developed their selection methods, the system would incur costs of AU$50,000 for 20 years to incorporate the selection into all Australian breeding programs (AU$1M). They also assumed that each new feed grain would have only an 80 percent probability of success and that the time required to produce a new feed grain would be about eight years. At an exchange rate of AU$1.16 to CA$1 in 2000, the cost of developing one Australian cereal feed variety was about CA$1.9M – which is in line with the Canadian plant breeders’ estimate of about CA$1.6M. The Australians took this analysis one step further and calculated that each new feed variety would have to provide an annual benefit of $400,000 per year for the investment to provide a benefit-cost ratio of 1.0.

Estimates for the cost of producing a malting barley can range from a low of $2.8M to as high as $10M per variety. Malting barley takes one year longer to register than feed barley, and it may take up to 5 years before a malting barley is accepted commercially – if it is ever accepted. Malting barley breeders may also need to compromise on yield and/or disease resistance to meet malting industry standards.

Malting barley registrations can also be sporadic. There were numerous registrations of two-row malting barley varieties between 2000 and 2002, but there have been no new varieties registered since. CDC Saskatoon has released a new six-row barley variety about every two years, but the malting and brewing industry have accepted none of these varieties and there is a definite preference in the industry for six-row malting barley varieties that have been registered in the US. Many of these varieties have originated from the University of Minnesota (U of M), North Dakota State University (NDSU)/North Dakota Agricultural Experiment Station (NDAES) and Busch Agricultural Resources, Inc. (BARI).

The development of malting barley varieties is expensive, time consuming and the risk of failure or non-acceptance by the maltsters and brewers is high. However, the malting and brewing industries have high standards, put substantial resources into creating varieties that meet their needs and pay a premium to producers for delivering malt-quality varieties. Seeded acres of two and six-row malting barley varieties combined, represent about 62 percent of barley acres, but malting barley selection rates are only 25-30 percent. The barley producer is assuming the risk of having barley accepted as malting grade in return for a premium of almost $50.00 over the international feed market price.
5.2 How do private (and public) plant breeders recover the cost of investing in cereal grains?

Private plant breeding companies cannot finance costly research and development programs if they are unable to charge a sufficiently high enough price for seed or if the producer does not have to purchase new seed each year. Public Canadian cereal breeders face a similar dilemma in that programs have been running with marginally sufficient or insufficient funding for years. Even if funding for public plant breeding institutions had not dropped, inflation would have reduced the size of plant breeding programs by over 62 percent over the last 20 years. This represents a decline in the output of plant breeding programs of almost three percent per year – even if budgets had not been cut.

Plant breeders can recover the cost of research in seed technology in a number of different ways. In some cases, there is an economic benefit to using certified seed – and the producer is willing to pay for new seed each year. In this case, the system returns royalties to the plant breeder. In other instances, the crop producer must make a compulsory royalty payment to the plant breeder, even if the producer has not purchased new seed. Sometimes the producer pays for the technology in the seed by signing a legal agreement when purchasing the seed. In some cases, however, the producer is not required to purchase certified seed (except for seed of a new variety), does not have to purchase the technology and the plant breeder receives no royalty. This is the situation with most self-pollinated cereal crops in Canada.

The use of certified seed can benefit producers in two situations: when crops are available as hybrids and/or when farming is profitable. Plant breeders produce hybrid crops by cross-pollinating two dissimilar lines of the same species. The progeny (the F1 generation), with half of its genetic material from each parent, exhibits an increase in productive capabilities which is known as hybrid vigour. Higher yield, superior disease resistance and improvements in other agronomic and quality traits are the result of hybrid vigour. In the next generation (F2) and in subsequent generations of farm saved seed (FSS), however, the benefits of hybrid vigour are lost and plants may even lose beneficial traits. Crop producers must purchase hybrid seed every year to maximize the commercial benefits of hybrid vigour.

Farmers purchase hybrid corn seed each year to extract the value from hybrid vigour, in part, because plant breeders have increased yields substantially using hybrid technology. Before hybrid technology was developed for corn, open pollinated varieties only gained about 2 bu/ac over the 70 years between 1860 and 1930. With the development of the double cross hybrid system, the genetic gain in corn yields averaged about 1 bu/ac/year from 1930 to 1960. Between 1960 and 2000, the rate of genetic gain in corn yields almost doubled, to 1.8 bu/ac/year.

Plant breeders have found it challenging to develop economically viable hybrids from self-pollinated crops like wheat, barley and soybeans. The creation of hybrid crop systems for open-pollinated crops such as corn and sorghum is much simpler – and this has attracted high levels of private sector plant breeding investment to open-pollinated crops. Canola and sunflower hybrids are also available commercially as are vegetable crops such as broccoli, cabbage, melons, onions, spinach and tomatoes – but the market shares of hybrid vegetable crops are marginal compared to corn. Producers growing most other major field crops such as wheat and barley depend on saved seed, and this limits seed industry growth and private sector involvement with these crops.

Research on hybrid wheat started in the 1970s with the first varieties commercialized in the 1990s. By 2000, France, Germany, India, South Africa, the UK and the US were growing hybrid wheat commercially. Only one variety was available in the UK and one in Germany, but as many as 10 were available in France.

Hybrid wheat never realized commercial success. While yield benefits ranged as high as 12 percent over the best self-pollinated varieties, in some years, it could also be as low as three to five percent. It was also difficult to obtain higher yields consistently and hybrid wheat had a tendency to have a high G X E response (an interaction between the variety and the environment). This attribute increases the risk of production substantially and producers tend to avoid growing varieties with high G X E values. In China, growers complained that hybrid wheat seed was of poor quality, yields were poor and higher seeding rates made hybrids too expensive to use. In South Africa, the development of hybrid wheat was even subsidized through a trust fund, however, the cost of developing hybrid wheat varieties was so expensive, Monsanto needed to consider adding some of the production costs to the price of the seed. This option was rejected because it would have made the seed so expensive that Monsanto would have priced itself out of the wheat-seed market.
In the end, seed production costs proved to be a major hurdle to the profitability of hybrid wheat. DuPont and Monsanto eventually sold their hybrid wheat businesses to German-based Saaten-Union GmbH. The production of hybrid wheat (and barley) is simply too expensive. Some predicted that hybrid wheat would take over in US but, producers grow neither hybrid wheat nor hybrid barley in the US today.

Canola in western Canada is available in both open pollinated and hybrid varieties. Because open pollinated varieties will produce progeny that are genetically similar to the parent plant, field performance of FSS should equal that of certified seed if germination and vigour are similar. Yet, most canola producers choose to purchase certified seed in Canada. This suggests that producers are willing to invest in profitable crops and are willing to support private plant breeders’ efforts – allowing private plant breeding organizations to recoup a fair return on their investment.

Producers have also purchased certified canola seed for convenience and safety. Certified seed is often purchased professionally pre-treated with insecticide for the control of flea beetles and fungicides for the control of seed-borne blackleg as well as the seedling root disease complexes caused by Fusarium spp., Pythium spp. and Rhizoctonia spp.

When hybrid canola became available to producers, the economic benefits justified the cost of the seed and hybrids have been slowly replacing open-pollinated canola acres in western Canada. Pedigreed seed prices have risen substantially with the introduction of canola hybrids and there are additional costs associated with the technology use agreement for Roundup Ready® (glyphosate tolerant) varieties. Despite increasing seed costs, hybrid market share increased from 35 percent in 2003 to 50 percent by 2004. Variety evaluation trials on the prairies have demonstrated a consistent yield benefit of 20 to 25 percent for hybrid canola over standard open-pollinated varieties. Producers gain additional value with hybrid canola due to lower dockage, more uniform crop stands, tolerance to environmental stress and reduced green seed. Clearly, the economics of hybrid crop use must be evaluated on a crop-by-crop basis.

Some would argue that crop producers should always use certified seed; however, when does the yield advantage associated with certified wheat seed outweigh the agronomic disadvantages of poor seed purity in FSS? A small grain drill box survey in Georgia measured a certified seed yield benefit of 3 bu/ac over FSS. In Kansas, a USDA Economic Research Service (ERS) study documented a yield benefit of between 1.2 and 3.5 bu/ac when producers used certified seed. In this study, certified wheat seed paid for itself with a yield advantage of 1 bu/ac and a price of US$3.50 per bushel. Because of environmental constraints on production, however, the use of certified seed does not always ensure an increase in yield.

New, low cost producers such as Brazil, Argentina and Ukraine are increasing grain volumes in international bulk commodity markets, causing downward pressure on commodity prices and threatening Canada’s export market-dependent producers. There is little to suggest that Canadian cereal producers will be in a situation to pay more for inputs such as seed – and experts suggest that Canada will be unable to compete solely on a cost basis with these new market players. Producers can gain value directly through improved yields, lower costs, reduced risk or indirectly through better market access or better delivery opportunities; however, there is no clear indication that Canadian producers are becoming significantly more competitive because of improvements in any of these areas.

Producers often see the use of FSS as a cost-cutting measure – even though the use of FSS may result in an overall greater cost to the producers’ operations. It is difficult to argue for greater expenditures on inputs when Canadian crop producers are faced with the prospect of little to no profit or even a loss. Often, producers may simply be growing cereals in the rotation for disease management, or because there are no other viable alternatives. Whatever the reasons for the high use rate of FSS for self-pollinated crops, the current reality is that wheat breeding is of limited profitability compared to other crops – as is the breeding of barley, in Canada, and in most other countries of the world. This is an important issue for the Canadian livestock sector because these crops are major sources of feed grain energy.

Other means for plant breeders in the public and private sector to recoup the cost of investment in feed grains research include Plant Breeders Rights (PBR) and the payment of royalties on FSS. Canada’s PBR system, introduced in 1990, gives plant breeders the exclusive right to produce and sell seed in Canada for 18 years.
Farmers may purchase the seed, which includes a royalty. However, producers have “Farmer’s Privilege” and can use FSS without paying an additional royalty – but the variety cannot be sold without the authorization of the owner. PBR protected varieties are in the minority in Canada, so royalties are not collected to any great extent – and protected varieties of wheat and barley are especially rare. The success of PBR for wheat and barley in Canada will depend on the extent to which growers are willing to pay for new varieties with superior grain genetics.

Australia introduced PBR in 1994 and created the End Point Royalty (EPR) as a means of containing seed prices and generating economic returns for plant breeders.243 There is some concern that Australian producers are choosing not to purchase PBR and EPR protected varieties; however, there are not that many PBR and EPR protected varieties to choose from in some areas of Australia. Crop producers may not be choosing PBR and EPR protected varieties simply because they do not like the varieties they have been offered for sale so far.

Countries such as the United Kingdom (UK) and South Africa collect royalties on FSS. Plant breeders can recover R&D costs from FSS of barley, field beans, field peas, flax, oats, oilseed rape, wheat and yellow lupins in the UK through a use agreement with the crop producer.244 A use agreement is a means of collecting royalties on FSS for the use of the technology contained within the seed. Producers can only use FSS harvested within the same farming business and, by law, cannot transfer seed between farming businesses. The scheme is run by the British Society of Plant Breeders (BSPB), which represents the UK plant breeding industry. BSPB represents over 50 members, including almost all of the public and private sector plant breeders in the UK. Royalties are collected as a means of protecting plant breeding by optimizing the return on investment in plant breeders’ intellectual property.

In South Africa, wheat farmers contribute a fee of 9 Rand (R) (US$1.25) per ton to the Winter Cereals Trust (WCT) to facilitate R&D for new varieties of wheat.245 In 2006, the WCT collected about R24M (US$3.3M). Beneficiaries of the trust include major multinational plant breeding companies as well as plant breeders in the public sector.

If growing wheat and barley is not “sufficiently” profitable, if hybrids are not an option, if using certified seed is not seen as providing an economic benefit and if producers can grow wheat and barley from FSS without the need to pay royalties on the use of the technology, it may prove difficult for plant breeders to extract an adequate return on investments in wheat and barley in Canada. This may leave Canada with only one option – feed grain breeding may have to be designated as a “public good” if Canada values the contribution of the livestock industry to the Canadian economy and wants Canada to be a globally competitive supplier of livestock and livestock products.

5.3 How do private plant breeders recover the cost of investing in forages?

In Canada, producers grow over 20 forage species – and species composition in forage stands varies by region. Major forage crops in Canada include both legumes and grasses. Major leguminous crops include alfalfa, the most valuable Canadian forage; red clover, which is suited to soils with poor drainage; as well as alsike clover and white clover.246 There are also at least a dozen more leguminous forages that are used in Canada in limited quantities. Of the grassy forage species, timothy is the most widely grown grass outside of the drier regions of the Canadian prairies. Crested wheatgrass is one of the more important forage grasses in western Canada. In British Columbia, orchardgrass and Russian wild ryegrass predominate. Producers grow bromegrass throughout Canada and Kentucky bluegrass is common in many areas as well.

Private sector plant breeders recover their investments in forage crops in much the same way as they do with all crops. Key factors include the ability to recover the cost of the plant breeding investment and the ability to sell seed to profitable forage producers who see value in purchasing pedigreed seed on a regular basis.247 It has been difficult to recover the cost of research investments in forages in Canada, and the public sector has been driving forage R&D. With public sector investments in forages tapering off, a recommendation was made in 1999 to collect a check-off for hay to help fund R&D; however, it proved to be impossible to collect and long-term Canadian research capacity in forages has essentially collapsed relative to where it once was. There is still some private sector capacity to produce forage seed in Canada and there is a need to address the challenges that this sector faces.

In the forage seed sector, seed industry representatives suggest that innovation is driven by public sector research scientists.248 Reduced bloat hazard alfalfa and grazing tolerant forage grasses such as meadow bromegrass and orchardgrass have been pointed out as three notable public contributions to the success of forage crops in Canada.
Public research scientists have also developed techniques for \textit{in vitro} manipulation and embryogenesis as well as the genetic transformation of forage species.

Forty to 85 percent of forage seed sold is a recommended forage variety\textsuperscript{249} Even if all of this seed were certified, however, the opportunity for the forage seed value-chain to capture value from the sale of seed is low because of the low frequency of reseeding of forage stands. Depending on the province or region, alfalfa may be reseeded as often as every three years in Ontario and in more productive areas of the prairies (Table 4.1).

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<th>Province</th>
<th>Alfalfa reseeding</th>
<th>Grass reseeding</th>
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<td>Low</td>
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<tr>
<td>Ontario</td>
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<td>Québec</td>
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<td>8</td>
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<td>Prairies</td>
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Source: Strategic Vision Consulting Ltd, derived from data summarized by Thomsen \textit{et al.}

In drier, less productive areas of the prairies, alfalfa is only reseeded every 10 years. There is even less of an opportunity to capture value from the forage grass value-chain with an average reseeding interval of six years in Quebec to over 10 years in some areas of the prairies.

US public sector and private sector plant breeders were jointly responsible for the development and commercialization of alfalfa with tolerance to potato leafhopper\textsuperscript{251} Most advances in the area of alfalfa seed production in the US, however, have been made by the private sector.

The research required to develop multiple pest resistance in alfalfa occurred predominantly in the US as part of private plant breeding programs.\textsuperscript{252} The US private sector spearheaded the development and commercialization of resistance to Anthracnose, \textit{Aphanomyces}, bacterial wilt, \textit{Fusarium}, \textit{Phytophthora} and \textit{Verticillium} wilt disease pathogens as well as to pests such as spotted blue pea aphid and stem and root knot nematode. The private sector also drove the commercialization of higher quality alfalfa varieties – including low neutral detergent fibre (NDF) varieties with better levels of intake and low acid detergent fibre (ADF) varieties that are more digestible.

Alfalfa is a profitable crop in the US and seed companies are able to recover their R&D investments in variety development through regular seed purchases by alfalfa producers. Alfalfa is a synthetic variety\textsuperscript{253} and synthetics are similar to open-pollinated crops. Producers could save seed from generation to generation, but alfalfa seed is difficult to harvest and requires specialized harvesting equipment. Alfalfa also depends on bee pollination and this random pollination tends to create inbreeding and loss of yield in commercial fields.

The US has a very large premium hay market for feeding dairy cows, horses and purebred cattle. The market is particularly strong in California and the market is “finicky” in terms of quality.\textsuperscript{254} This market has been particularly supportive of Round Ready\textsuperscript{®} alfalfa because there is almost no tolerance for weeds in California hay. The US alfalfa hay market is another example of a market rewarding producers financially for a superior product. The alfalfa growers, in turn, can extract value from purchases of certified seed, thereby compensating the seed companies fairly for the use of their technology. The seed company then reinvests its profits in newer technologies and the cycle continues.

In terms of breeding for higher yield, alfalfa is an open-pollinated crop and plant breeders have made little progress on yield over a long period of time.\textsuperscript{255} Alfalfa breeders describe yield progress with alfalfa as similar to that made with open-pollinated corn between 1860 and 1930 – little progress over a period of 70 years. In 1998, Wiersma \textit{et al.} from the University of Wisconsin reported no genetic gain for alfalfa yield in 17 years.\textsuperscript{256} In 1999, the USDA reported that alfalfa yield was actually declining.
6. What are the differences in research incentive structures between Canada and the US in terms of private investment in feed grains and forage research?

Before looking at agricultural research funding in Canada and the US, it may be constructive to compare Canada and other industrialized countries with other regions of the world. Then, SVC will compare Canada with the US in terms of agricultural research funding and will compare private and public sector funding for plant breeding research. SVC will also look at Australia, a country that has more in common with Canada than the US in terms of its population, its resources and the size of its economy.

6.1 R&D spending in agriculture – how does Canada compare globally?

A number of countries have seen major shifts in agricultural R&D funding.\textsuperscript{257} Between 1976 and 1995, 34 \textit{industrialized} countries of the world steadily increased their investment in agricultural research, from just over $7B to just over $10B (Chart 4.1). At the same time, 119 \textit{developing} countries increased funding from just under $5B to just over $11B.

\textbf{Chart 4.1 – Global public agricultural research expenditures in various regions between 1976–95} \textsuperscript{258}

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\caption{Global public agricultural research expenditures in various regions between 1976–95}
\end{figure}

Source: Morris \textit{et al.}

In the 1990s, the richest nations reduced the rate of growth in funding for agricultural R&D.\textsuperscript{259} In the US and other wealthy nations, agricultural R&D funding moved away from maintaining and enhancing farm productivity and into other areas.

In 1981, Canada directed 8.4 percent of R&D funding towards agriculture.\textsuperscript{260} By 2000, R&D spending in agriculture was down to 2.9 percent. While Canada’s R&D spending rose from $6.1B to $16B, the amount spent on agricultural R&D fell from $513M to $468M. In that same period, agricultural Gross Domestic Product (GDP) fell from $25B to $18B and the share of agricultural GDP relative to total GDP fell from five to 2.2 percent. One might argue that a declining industry does not merit an increase in funding; however, one might also argue that lack of funding for R&D makes it more difficult to compete globally against better-funded competitors.
6.2 R&D spending in agriculture – how does Canada compare to the United States and to Australia

In 2000, the US public sector spent over eight times more on agricultural R&D than Canada – $3.828B international dollars to Canada’s $468M (Chart 4.2).261

Chart 4.2 – Public and private agricultural research expenditures in 2000 in the US, Canada and Australia262

The US private sector spent almost 17 times more – $4.061B to Canada’s $241M. Overall, the US outspent Canada on agricultural R&D by a factor of about 11 – a total of $7.889B international dollars to Canada’s $709M. Alston and Pardey presented similar numbers for US investment in agricultural R&D in 1996, with public sector spending in the state and federal realms at US$3.1B and with private sector R&D at over US$4B.263

In 2001-2002, the population of Canada was about 23M and in the US, about 222M, or over 9.5 times higher.264 In 2007, US GDP was about 11 times that of Canada.265 These data suggest that the US investment in agricultural R&D is not out of line with Canadian investment in R&D in terms of population and GDP. The key difference is that the US private sector spends disproportionately more on R&D than the Canadian private sector.

Different data sets show similar trends in agricultural research spending between Canada and the US. Data for fiscal year 2003 put the budget for the Research Branch of the USDA Agricultural Research Service (ARS), the US equivalent of the Research Branch of AAFC, at US$1B.266 For 2001-2002, AAFC’s agricultural research funding was $252M annually. With the Canadian dollar trading at 61.76 cents US in 2001,267 the USDA/ARS research budget was just over six times larger than the AAFC research budget.

In 1992, US private investment in agricultural research reached US$3.8B and was almost four times more than that spent by the public sector.268 By 2000, data provided by Pardey suggested that private sector spending on agricultural R&D only exceeded that in the public sector by about six percent.269 This suggests that US public sector spending on agricultural R&D rose rapidly between 1992 and 2000.

Canada and Australia are more similar to each other than Canada is to the US – which may allow for a better comparison of spending on agricultural R&D. Australia and Canada are both net importers of production technology, most high-technology equipment is imported from the US, both countries are rich in natural resources,
the primary sector dominates both countries’ economies and GDP per capita increased at an annual rate of 3.0 percent in Canada and 2.9 in Australia between 1995 and 2000. In 2000, the Australian public sector spent about 1.25 times as much on agricultural R&D as Canada, but the Canadian private sector outspent the Australian private sector by about 1.25 times (Chart 4.2). Overall, Australia spent about eight percent more on agricultural R&D than Canada.

More recently, Canadian grain trade competitors have increased their investments in crop development research – in recognition of the importance of R&D to commodity production and success in global markets. Australia, as an example, has increased its investment in wheat and barley development to over five times the current Canadian investment. Growers spearhead this initiative and coordinate their effort through the Grains Research and Development Corporation (GRDC).

Historically, the US public sector has played an important role in agricultural R&D. The USDA was established in 1862. The passage of legislation, such as the Morrill Land-Grant College Act (1862) established colleges and universities dedicated to agriculture sciences. In 1887, the Hatch Act established a network of State Agricultural Experiment Stations (SAES) to work in conjunction with the land-grant institutions. The Smith-Lever Act of 1914 extended the land grant-SAES collaboration to include federal (USDA), state and county agencies through the Cooperative Agricultural Extension Service (CAES). This series of initiatives created a public system with deeper roots and considerably greater scope than the Canadian public agricultural R&D system. The US public system also puts more emphasis on production agriculture than the Canadian system and is more closely aligned with the needs of producers through its network of agricultural universities and colleges, CAES, SAES and the USDA. In Canada, on the other hand, the House of Commons Standing Committee on Agriculture and Agri-Food (HCSCAA) recently criticized AAFC for becoming increasingly disconnected from producers.

The first public to private shift in plant breeding resources in the US occurred in the 1930s with the development of commercially viable corn hybrids. By 1970, the private sector’s share of corn R&D was 50 percent and the share increased to 70 percent by 1989. For self-pollinated crops such as wheat, private sector involvement has been limited compared to corn – so US crop producers have relied on the public sector to provide seed for new varieties of wheat and minor cereal crops such as barley and oats.

Between 1966 and the late 1970s, the US public sector invested between two to five times more in plant breeding than the private sector (Chart 4.3).
In this same period, private sector expenditures on plant breeding increased five fold. From 1979 to 1996, private plant breeders increased their investment in R&D by almost three times while plant breeding funding in the public sector has declined slowly to about 90 percent of what it once was.

In 1994, financial resources for US public sector plant breeding decreased to US$291M or about 9 percent of all public R&D expenditures in agricultural R&D. This decrease in funding occurred even though data suggested that the rate of return on the investment in plant breeding was positive and despite the fact that this type of research needed government support. This situation mirrors the Canadian experience in terms of government support for cereal grain and forage breeding programs.

The trends in expenditures in the US in plant breeding between 1994 and 2001 in the public and private sectors is reflected in a decline in plant breeders in the public sector and a gain in the numbers of plant breeders in the private sector. The number of plant breeders in the SAES dropped by over 20 percent in the seven years between 1994 and 2001 (Chart 4.4).
During that same period, the number of USDA plant breeders dropped by almost seven percent while the number of plant breeders employed in the private sector increased by almost four percent.

In the US, the private sector dominates plant breeding in hybrid crops such as corn and forage sorghum (Chart 4.5).

Source: Morris et al.
Ninety-five percent of corn breeding is conducted in the private sector and only five percent in the public sector. SAES is responsible for three percent of the public program and USDA represents only two percent of the US corn breeding effort.

In self-pollinated crops such as wheat where producers use FSS to seed a large proportion of the US acres, SAES dominates the breeding program with 43 percent of the breeding effort (Chart 4.5). USDA accounts for 15 percent of wheat breeders, making the public sector responsible for 58 percent of the wheat breeding effort in the US. The private sector, however, has 42 percent of all wheat breeders in the US. This is in contrast to Canada, where almost all wheat breeding is the responsibility of the public sector.

As of 2004, most wheat seed in the US was FSS and there was little interest on the part of the private sector in wheat breeding. In fact, there has been little private sector interest in wheat in the US since hybrid wheat production was abandoned in 1970s. Even though the private sector has recently become more involved in wheat breeding in the US, the public sector still dominates.

At first, the previous statements may be difficult to comprehend. If the private sector has 42 percent of the wheat breeders, how can the public sector dominate in wheat breeding with only 58 percent of the breeders? The difference is that the public wheat breeding programs are well-established, have access to considerable volumes of high-quality germplasm and have a well-developed infrastructure that is staffed with highly-qualified professionals. While the public sector has only 58 percent of the plant breeders, most of the wheat produced in the US comes from public sector varieties. For example, in the 1980s, the University of Minnesota and the University of California at Davis supplied 56 percent of HRSW varieties to the US market; Purdue University supplied 65 percent of all soft red winter wheat (SRWW); and Kansas State University and the University of Nebraska supplied 60 percent of hard red winter wheat (HRWW) to US producers. Between 2001 and 2003, wheat producers used public sector varieties to produce 78 percent of all the wheat in the US.

In 1980, the private sector supplied 18 percent of wheat seed to US producers – with Northrup-King providing 14 percent of all HRSW. Coker supplied seven percent of all SRWW and North American Plant Breeders supplied five percent of the HRWW. Between 2001 and 2003, private sector varieties produced 22 percent of all the wheat in the US – suggesting that the public-private sector balance in wheat breeding has not changed much since the 1980s. What is different, however, is that the US seed industry has consolidated. Syngenta purchased Northrup-King and Coker in 1976 and 1989, respectively. Between 1965 and 2005, over 50 seed companies have been absorbed into four large multinational corporations: Pioneer Hi-Bred International Inc., Monsanto Company, Groupe Limagrain and Syngenta Group Company.

Forage breeding in the US is dominated by the private sector, which has 62 percent of all forage breeders (Chart 4.5). SAES and USDA have 29 and nine percent of US forage breeders, respectively. Most Canadian forage sector breeding in Canada is the responsibility of three forage breeders in AAFC.

Canadian and US public agricultural research structures used to be quite distinct. Traditionally, the US agricultural research system has been much more decentralized than the system used by AAFC in Canada. In the US, the government invests most of its public funding in state research centres and land-grant colleges and Congress exerts control over agricultural research priority by "earmarking" research funds.

Private sector influence over research priorities has increased in both Canada and the US. In the US this influence grew throughout the 1930s with progress in the development of hybrid corn. In Canada, the influence of the private sector over public agricultural research policy did not increase in strength until the 1980s (50 years later than in the US) with the development of genetically modified plants – especially canola. This difference in the timing of private sector influence over research priorities in Canada and the US is reflected in the crops that are adapted to the growing conditions of both countries. Corn is the most important crop in the US, whereas wheat has dominated Canadian agriculture. The opportunity to develop hybrid corn in the US in the 1930s jump-started private sector investment in the US agricultural seed industry – and led to the private sector having more influence over national research policy. In Canada, the private sector did not become involved in funding agricultural R&D to the same degree until the wider scale introduction of canola in the 1980s.
Some might argue that the US and Canada are not that different when it comes to facilitating agricultural research in the public sector. In 1982, The Rockefeller Institute’s report on Science for Agriculture accused the USDA of ineffective leadership and maintained that the organization had neither a sound strategy nor the capacity to conduct cutting-edge research. Science for Agriculture also blamed USDA for allocating funding in response to political demands rather than on a balanced assessment of needs. In Canada, AAFC has been criticized by the HCSCAA for some of the same reasons. AAFC has struggled with funding issues and personnel cutbacks in Canada as well. This cutback in public sector R&D affects Canada and the US differently in terms of the development of feed grains. While both countries have seen scientific research reduced in the public sector, the private sector in the US has the opportunity to step in and fill any gaps in the area of corn breeding. In Canada, there is little opportunity for the private sector to generate a profit by developing feed grains such as barley and wheat or forages.

7. What do Canadian cereal grain and forage plant breeders need in terms of investment?

The cost of developing a new variety of cereal feed grain or a forage variety may be in the range of $1-2M, and the cost of running a single mature program through a network of institutions could range up to about $7M per year. Some new private CWRS programs have taken 20 years to produce their first variety, only to have the company terminate the program. This emphasizes the value of keeping existing programs running and well funded. Even then, well-funded programs running at full capacity can take up to eight to ten years to produce a new variety. The message here is that it is much more cost effective to maintain research programs than it is to try to rebuild these programs after they have been downsized or terminated.

Plant breeders need a long-term commitment and sustained support for their programs. These operations require equipment, facilities, access to the latest technologies as well as experienced staff. Funding for most breeding institutions is insufficient and as a result, they are suffering from lack of operational efficiency. In Canada, there is also a need to link plant breeding with genomics, proteomics and bioinformatics, but funding is currently insufficient – especially in terms of hiring the highly skilled staff needed in these areas. Typically, funds are available for interesting and innovative project-based research, but there are shortfalls in funding for maintenance and the development of infrastructure.

7.1 Who pays for investments in cereal grain and forage research in Canada?

Businesses that supply agricultural inputs such as fertilizers and pest management products, the food and fibre industry and the retail food sector are highly concentrated organizations compared to individual crop and livestock producers. These industries, through concentration and size, have the ability to sustain higher levels of profitability than the individual producer – creating a situation in which the producer of a commodity has neither the incentive nor the capital funds required to fund an optimal level of agricultural R&D. This business structure suggests that producers need investment in R&D from outside sources.

Traditionally, federal and provincial governments have been solid supporters of investment in cereal feed grains and forage research and development, but times have changed. Public sector investment in plant breeding has been declining. The private sector has taken up some of the slack, but only for the most profitable crops and crops for which it is possible to extract value from funds invested in R&D. With few exceptions, feed grains such as wheat and barley and forages are not overly profitable, and there is little opportunity for the private sector to recoup its investment in plant breeding in Canada. For the near future, crop and livestock producers will need the support of the public sector for new varieties of feed grains and forages.

Many have noted that Canada lacks critical research funding. Though Blade and Slinkard wrote this about public funding for R&D on new crops, the same arguments apply for “old” crops. The bottom line is that federal and provincial governments need to take a long-term, consistent approach to the development of crops such as wheat and barley as livestock feed.
Who controls agricultural spending for the public good? The Canadian government established the Canadian Agricultural Research Council (CARC) in 1974 to be the primary advisor on Canadian agricultural research.²⁹⁹ The role of CARC was to improve the coordination of R&D and technology transfer as well as to oversee priority planning in agriculture. CARC, though it had private sector representation, had no funding authority and could not counter the dominance of federal research institutions. As late as 1985, a few individuals within AAFC and members of the Senior Management Committee still had considerable influence over federal research priorities.³⁰⁰

Some within the federal government have supported funding for public-good research; however, it is becoming more difficult to make a case for the public sector to conduct research where the private sector cannot generate a profit.³⁰¹ A former assistant deputy minister (ADM) in the AAFC Research Branch, noted that in the late 1980s, it was still possible to argue the case for public sector funding to the Treasury Board if the private sector was not providing a service. By 1998, this ADM said, "I cannot make that case anymore with a great deal of credibility, because the counter-argument that I get, and I accept it, because I think it is quite true, is if the private sector is losing 10 cents on the dollar and that is the reason why they will not make the investment, then that is not a case for the Crown to put a dollar in. It may be a case for the Crown to put in 15 cents, so that the private sector can do it and make 5 cents" ³⁰²

At some point, the beef cattle industry could argue that the strategic goals and objectives of AAFC’s Science and Innovation (S&I) Strategy outline AAFC’s responsibility in supporting the development of feed grains and forages for the Canadian livestock sector. Goal 1 (Item 2) of the S&I Strategy suggests that AAFC should “continue to provide sector support where no other science and research providers exist.” ³⁰³ This is clearly the case in the area of feed grain breeding – the private sector is not currently involved in the large-scale breeding of wheat, barley or forages in Canada.

Goal 3 outlines one of the key foundations of the S&I Strategy – to provide a “return on investment” to Canadians. Canadian cattle and beef exports were worth $2.1B in 1996, and were the second largest agricultural export product after wheat ($4.7B).³⁰⁴ Investments in feed grains and forages not only help keep the livestock sector competitive, they also help maintain sustainability and provide a high return on investment to Canadians. Since the S&I Strategy aims to “strengthen “Canada’s agricultural producers . . . the rural economies in which they operate, the knowledge base that is the foundation for innovation and our ability to sustain regional innovation clusters in the future” then AAFC should be making a considerable capital investment in feed grains and forage research in order to fulfil its mandate.

Goal 5 supports accelerating the adoption and commercialization of science.³⁰⁵ Item 2 proposes focusing “S&I programming on building value chains and supporting commercialization strategies.” The livestock industry is a significant contributor to the Canadian economy and the loss in competitiveness of its portion of the value chain could represent a significant reduction in Canadian GDP. The production of large quantities of livestock feed and forage provides a competitive advantage for producers. This is the cornerstone that supports an extensive and economically important value chain – and livestock producers need state-of-the-art feed and forage-breeding programs to keep their piece of the value chain competitive.

The June 2007 HCSCAA report recommending that AAFC emphasize farming and primary production ³⁰⁶ may present an opportunity for the beef cattle industry to make a case for increased funding for feed grains and forage research.

Goal 6 outlines the enhancement of leadership and stewardship. This Strategic Goal fosters stakeholder engagement to ensure more collaboration with domestic agricultural organizations. Strategic Goal 6 also meshes with one of the recommendations of the 2006 Forage Research Review; that AAFC scientists develop better lines of communication with producer organizations.³⁰⁷ The Forage Research Review specifically named the Canadian Cattlemen’s Association (CCA) as an organization to contact. The beef cattle industry could also help AAFC meet another objective of Goal 6 of the S&I Strategy – by helping AAFC increase stakeholder involvement in setting research priorities.

The consensus at the HCSCAA hearings was that investment in Canadian agricultural research lags behind its competitors ³⁰⁸ – and Canada would likely lose its competitive advantage if this trend continues. Stakeholders
suggested that the grain industry in particular had an ineffective R&D strategy. In response, the standing committee proposed increasing grain industry R&D funding by $40M.

There may also be some hope with a promise from AAFC to the HCSCAA that the Agricultural Policy Framework II (APF II) will better serve the industry value chain. HCSCAA had recommended in its committee report in June 2007 that AAFC put more emphasis on farmers and primary production. This does not mean, however, that crop and livestock producers should not play a more active and aggressive role in cereal grains and forage research in Canada. Some have noted that industries that use cereal grains, including the feed industry, do not support plant breeding financially. This same criticism was leveled at the baking (bread) and food industries. End-users of feedstock for bioethanol production have invested directly in plant breeding programs. Husky Energy, for example, has made a sizable contribution to the wheat breeding program at the University of Manitoba. A beef cattle industry investment in plant breeding would demonstrate to granting agencies the importance of plant breeding to the livestock sector. This may also put the beef cattle industry in a better bargaining position as it lobbies for additional plant breeding funding.

7.2 A reallocation of grain breeding resources for the Canadian livestock sector

Plant breeders are willing to design varieties to meet the needs of almost any market. Take wheat as an example. There is enough variability in the germplasm to move from high protein milling wheats to high starch wheats that are better suited to bioethanol production. Even within milling wheat, there seems to be considerable potential to increase yield – in spite of Canadian regulatory impediments. Some wheat programs are currently shifting resources towards the breeding of varieties more suitable to the production of bioethanol.

This shift reflects:

- The economic opportunities available to wheat producers who are contributing to the funding of the breeding programs through the WGRF Wheat Check-off Fund
- Funding from private corporations producing bioethanol from wheat in western Canada

Barley breeders are responding to market signals in the same way as wheat breeders – through the funders of their programs. The livestock sector, through breeding program funding, has the same opportunity to “sit at the table” and to help direct plant breeding programs towards meeting its own goals. Adding new funding to existing programs is extremely cost effective because plant breeders already have access to wide range of germplasm, the programs are already in place and every program has access to a substantial amount of core funding. Core funders are also looking for partners with a stake in these plant breeding programs to help support the programs financially. Future support for public plant breeding programs from a wide variety of interested stakeholders will be crucial to maintaining, and possibly even increasing core funding from provincial and federal governments. The WGRF has also extended an open invitation to livestock producers to play a more active role in WGRF research in the area of feed grains.

8. Other issues

8.1 Matching grants

Scientists spend a considerable amount of time selling their research proposals and filling out multiple research applications under the matching grant system. This work is required to meet the needs of research partners – and all tend to have a unique set of needs that must be met as part of the grant application process. In some instances, the researcher can spend more time coordinating funding than actually conducting the research. Once the scientist has lined up the grants and the work is in progress, there is often a need to produce multiple progress reports, in a multitude of styles, for the same project. Funding agencies with smaller amounts of capital to invest may wish to consider pooling funds or at least agreeing on a standardized application and reporting structure. One advantage of pooling funds and coordinating funding efforts is that there is less chance of duplicating research efforts.

8.2 Early project termination

Scientists must often terminate projects when graduate students take a job before completing their research or before writing their theses. This may be the result of closer relationships between graduate students and industry, dissatisfaction with the progress of the research project or conflict with the graduate student advisor or advisory
committee, among other issues. This is particularly problematic given the shortage of agricultural research scientists in Canada.

8.3 Forages – unique issues
AAFC and other public research organizations have realigned research objectives to help meet the needs of industry clients. Advantages of this approach include the ability to:

- More closely meet the needs of industrial partners
- Transfer research results directly to the client or partner
- Empower industry to control its own development

This strategy, however, does not work well in situations where:

- **There is no clear industrial partner** or where industry groups exist, but have no funds available for research and no means of raising money for research purposes through their members.

- **The public is not a major beneficiary of the research.** Thomsen et al. calculated the average annual return on public investment in forages and forage technology R&D at 5.2 to 8.5 percent between 1971 and 1998. While consumers (the general public) have derived a benefit from this investment in forages, most of the benefit is realized by the forage producer.

Some would argue, however, that cattle production maintains native rangeland and pasture lands, thereby increasing biodiversity and aiding species at risk. This contributes to the public good and is not a benefit only realized by the forage producer. Increasing research into forage productivity, grazing systems and the integration of higher levels of forage species into cropping systems can also relieve the pressure applied to native grassy species – which should also be seen as a public good.

- **There are no cash receipts for the commodity.** Because most forage producers use the crop to feed livestock on the farm on which it is produced, little value is seen in terms of cash receipts. If the 28 Mt of forage produced in Canada in 1996 were sold at 1996 market prices, forage production would have an estimated value of $2.4B. Actual cash receipts, however, only amount to $78M – and lack of cash receipts underestimates the value of forages to the Canadian economy.

- **Check-off levies are impractical.** It would be almost impossible to assure compliance for a check-off on the sale of a product like hay.

In 1997, there was a sense that the risk of losing forage and rangeland research, which had no clear link to a private sector funding agency, was very high. This concern was well-founded. As of late 2007, much of the capacity to conduct public good research in the areas of forage and rangeland has been lost in Canada.

9. Research infrastructure requirements to meet end-user demands for feed grains and forages
In a comprehensive review of cereal breeding programs and infrastructure in western Canada, GrainTek estimated that it would take an annual investment of tens of millions of dollars to eliminate the infrastructure deficiencies alone. What Canada needs, though, is to be world leader in the area of cereal grains breeding – and it would take a much higher level of investment to become a globally competitive leader in research.

9.1 Staffing Issues
A number of public sector plant breeders will soon have the option of retiring. Dr. Brian Fowler, the winter wheat breeder at CDC Saskatoon will retire within two years. Drs Brian Rossnagel (barley breeder, CDC Saskatoon), Jim Helm (barley breeder, FCDC Lacombe), Mario Therrien (feed barley breeder, AAFC Brandon), Réal Michaud (forage breeder, AAFC Ste. Foy), Suriya Acharya (forage breeder, AAFC Lethbridge) and Yousef Papadopoulos (forage breeder, AAFC Truro, NS), to name a few, are all within five to 10 years of retirement.
Compounding this issue of impending retirements is the knowledge that fewer and fewer students see plant breeding and agricultural research in general, as an attractive career choice. In order to attract new students to these fields of study, Canada needs to fund new career research positions in agriculture in anticipation of future retirements. This also ensures a smooth transition from the retiring research scientist to new scientists who will pick up the programs and keep them moving forward without interruption. AAFC has responded to the June 2007 HCSCAA report by claiming that it will aggressively recruit new scientists to replace retiring employees. This program includes pairing new scientists with retired managers in the interest of “retain(ing) corporate knowledge.”

Attracting students to careers in plant breeding is not only an issue for Canada. The number of graduate students in plant breeding has also declined in the US over the last few decades. The situation is getting so serious that seed companies have considered hiring students with Bachelor of Science degrees in the biological sciences and then training new hires in plant breeding through in-house corporate programs. In terms of capacity to train plant breeders, only universities in major agricultural regions of the US still provide training in plant breeding.

9.2 Organizational links

There is always an opportunity to build better links between feed grains and forage breeders and industry. Some programs, such as the one at CDC Saskatoon are focussed on market needs and trends, and have a good record of meeting the needs of end-users. Other links that plant breeders could develop might be with cow-calf operators and cattle feedlot managers. One example might be a formal link between the beef cattle industry and AAF’s FCDC in Lacombe. In a recent research review of the AAFC forages program, the panel recommended that AAFC scientists establish a formal link with organizations such as the CCA, Dairy Farmers of Canada or their provincial groups in the interest of sharing research results with Canadian producers.

9.3 Cereal Centres of Excellence

Cereal breeders depend on plant pathologists, molecular geneticists, plant physiologists and experts working in doubled haploidy and plant breeding methodology; however, specialists in these areas are overly dependent on short-term project-based funding. GrainTek has proposed the establishment of three western Canadian Centres of Excellence, one each at the Universities of Alberta, Manitoba and Saskatchewan, to help build capacity into the plant breeding infrastructure. The goal is to enhance the competitiveness of western Canadian producers by re-establishing Canada as a leader in cereal research and breeding.
I have been so frustrated over the years that I have been releasing varieties in the U.S. where they have been accepted without any penalty in the market place there. These same varieties are being penalized in Canada and in some cases, we couldn’t even register them in Canada. So the big winners in the winter wheat area right now have been outside of this country. If I’m going to run a breeding program, I have to be able to finance it and one of the ways that I finance it right now is through royalties. Given the choices, right now, I either dump all the genetic material that has taken years to develop or I look at marketing it outside and at least collecting the royalties from outside of this country.

– Dr. Brian Fowler, 
Canadian winter wheat breeder

1. Regulatory impediments limiting investment in Canadian feed grains and forage research and the registration and commercialization of new crop varieties

Canada has numerous barriers to investment in feed grains research – barriers that investors do not have to deal with in nations against which Canadian cattle producers must compete. The issues that are most detrimental to progress in Canadian feed grains research include KVD, Plant with Novel Trait (PNT), the CWB/CGC grade system and the protracted seed sector review. PNT regulations would apply to Canadian forage varieties in the same way as they apply to the development of new feed grain varieties.

1.1 Kernel Visual Distinguishability

KVD, a component of the quality assurance (QA) system, is used to distinguish CWRS kernels from all other types of wheat kernels. Canada is the only country in the world that uses KVD to identify wheat quality. Though KVD is a QA tool in Canada, it places a burden on wheat breeding while adding no value in terms of plant genetics or the plant breeding process.

KVD is a limiting factor for the improvement of yield and other traits in wheat classes other than CWRS because all other classes of wheats must be visually distinct from CWRS. Rather than removing KVD entirely, the new rules have created a de facto KVD. While the newly created CWGP class of wheat was designed to open up the options for plant breeders to work outside of the constraints of KVD, the new class of wheat has a zero tolerance to kernels that look like CWRS or CWAD. Plant breeders are now free to work on wheat unencumbered by KVD requirements – as long as the wheat they are producing has a kernel that is visually distinguishable from CWRS! Many would argue that this does little to introduce more flexibility into the regulatory system.

The impact of KVD depends on the origin of the material that the wheat breeder is sourcing. If a breeder is simply crossing two CWRS wheats or a CWRS and a DNS (Dark Northern Spring) wheat, the closest US equivalent to CWRS, KVD is a non-issue. However, the wheat class is unlikely to see much progress if the plant breeder is only rearranging traits within CWRS and DNS wheats.

The issue becomes more complex when a CWRS or CWAD breeder tries to incorporate traits from other classes of wheat or from wild relatives. Conforming to KVD requirements means that CWRS breeders cannot take full
advantage of the wider range of germplasm available from the International Maize and Wheat Improvement Center (CIMMYT) or from winter wheat lines from the European Union (EU). Wheat breeders working with minor classes such as winter wheat face similar problems when using CWRS or CWAD as a source germplasm. By using diverse sources of germplasm, Canadian plant breeders risk creating new varieties that do not meet existing KVD standards — and it may take six to 10 years before a plant breeder discovers that new lines with considerable value to western Canadian producers cannot be registered in Canada. This can be a considerable waste of time and money when 15 to 25 percent of all new lines tested in the western Wheat Cooperative (Co-op) trials fail to meet KVD standards after 10 years of research. In some cases, lines that initially appear to meet the KVD standard fail due to environmental stress causing a modification in kernel appearance. This barrier to commercialization is one reason why multinational seed companies have little interest in investing in Canadian wheat breeding.

KVD requirements set an optimal kernel size of 35 mg for CWRS, in contrast to modern wheat varieties in other countries where the optimal kernel size is 40-45 mg.334 This makes it difficult for a Canadian wheat breeder to select for higher yield because higher-yielding varieties tend to produce larger kernels or non-uniform kernels which do not conform to the look of a “classic” kernel. Varieties meeting CWRS-KVD guidelines tend produce kernels with an unresponsive “sink” for the production of seed volume — preventing the formation of larger kernels, in spite of favourable field conditions for the promotion of high yield. The evidence is in Co-op trials where, of 31 Western Bread Wheat Co-op lines with yields over 110 percent of Neepawa, only two lines produced kernels that were smaller than Neepawa while the other 29 lines had kernels that were larger.335 The risk is that plant breeders are faced with discarding the vast majority of high yielding lines when kernels must be uniform and only slightly larger than those of Neepawa wheat.336

Before examining wheat yield in more detail, consider two “truisms”:

- US Hard Red Spring (HRS) wheat lines have a yield advantage over Canadian CWRS wheats
- Canadian wheat yields are lower than US wheat yields because of the Canadian KVD requirement 337

Most Canadian producers would probably agree with these statements; however, others have chosen to disagree, and have put forward valid arguments to back their position. SVC will consider all points of view and will present arguments for both sides.

Most Canadian producers would probably agree that the yield of US HRS wheat is substantially higher than that of Canadian CWRS wheat. However, is this really the case? Scientists have examined two sets of yield data: summary statistical data and data from statistical tests.338 Summary statistics suggest a yield advantage for US HRS wheat over Canadian CWRS wheat, whereas statistical tests point to a negligible US advantage. However, the summary statistics demonstrate higher mean and median US yields at four out of five locations. The conclusion put forward was that US lines out-yielded Canadian lines by 3.68 percent or 1.83 bu/ac — which most would agree is not a large difference in yield.

Most Canadian producers would probably agree that Canadian wheat yields less than US wheat because of the need to meet requirements for KVD — and many wheat breeders would be inclined to agree as well. Putting the blame entirely on KVD for reduced Canadian yields may be an oversimplification.339 As a rule of thumb, plant breeders feel that lowering protein increases yield potential by about 10 percent in CWRS wheat. In a comprehensive study, yield comparisons between Canadian and US wheat suggest that Canadian wheat has a protein advantage of 0.417 percent over US wheat. Assuming a 10 percent yield penalty for each one percent increase in protein in hard red wheats, then the US HRS yield advantage of 3.68 percent is offset by the 0.417 percent protein advantage in Canadian CWRS wheat. The author of this report suggests that the high protein content of Canadian wheat plays a significant role in lowering yield and that it is difficult to resolve the exact relationship between KVD and yield.

Europe and the US typically produce wheat with higher yields than Canada — due in part to differences in climate, but also as a result of lower quality requirements.340 Wheat growing areas such as Australia and Argentina, which have rainfall comparable to that of western Canada, have similar wheat yields — suggesting that climate is much more important than KVD in limiting the yield of wheat.
The US has more flexible quality standards than Canada, which makes it easier for plant breeders to make yield improvements in the US than in Canada.\textsuperscript{341} Wheat breeders in North Dakota and Montana have made more progress in raising wheat yields than their Canadian counterparts, and this has been attributed to the US discontinuing the use of KVD in the mid-1960s. Though Canadian wheat breeders are making progress in raising the yield of wheat varieties, some feel that the US may be ahead of Canada by as much as 15 years.

Plant breeders listed the following crops as those with the greatest potential for use as feedstock for western Canadian bioethanol manufacturers or as animal feed: winter wheat, hulled barley, CWGP wheat, winter triticale, CPS wheat and hulless barley.\textsuperscript{342} Spring triticale is not on the list, despite research indicating its suitability for food or as a feedstock for bioenergy. Recently, the board of ACIDF chose to fund feed research for barley and triticale – but chose not to fund wheat until KVD issues have been resolved.

In summary, a complex array of factors are involved in determining the yield of wheat—genetics, environment (climate, soil type and fertility, quantity and timing of precipitation, disease and insect pressure) and politics (regulatory requirements). In terms of realizing yield potential, some factors are under our control and we can potentially change them; others are beyond our control and we have no choice but to live with them. We cannot control the weather or change our geographic location, but we have the ability to influence political issues such as KVD regulations. KVD may not be solely responsible for reduced yield in Canadian wheat, but may be one factor of several contribute to lower yields. The benefits of the current KVD system are questionable if Canada is the only country in the world that sees value in and continues to use such a system. The inability of plant breeders to incorporate traits from other classes of wheat or wild relatives due to KVD requirements provides a strong argument for the elimination of KVD, particularly in view of estimates that progress in raising yield of wheat varieties lags the US by as much as 15 years.\textsuperscript{343}

1.2 Plant with Novel Trait
The CFIA defines a novel trait as one that is: 344

- Not found in stable, Canadian populations of plants of the same species
- Found at a level significantly beyond the range of that trait in stable, Canadian populations.

A trait level beyond anything other than an “incremental” increase above historical trends is a trait significantly beyond the range of Canadian populations. The CFIA does not provide a measure for the term “incremental” and the term is subject to interpretation. The novel traits regulations apply to any new trait – and the regulators decide what triggers novelty.

Seeds Regulation Part V defines a novel trait by the environmental impact of the plant, in comparison with its counterpart, in five areas:

- Biodiversity
- Gene flow
- Non-target organisms
- Plant pest potential
- Weediness

The CFIA, however, has exclusive jurisdiction over the definition of “novelty.” The Canadian government outlines novelty under three Acts: the Feeds Act, the Food and Drugs Act and the Seeds Act.\textsuperscript{342} A number of different organizations enforce these Acts: the CFIA’s Plant Biotechnology Organization (PBO) and Feeds Section; and Health Canada’s Food Directorate. Environment Canada has authority over all products not covered under the previous acts through the Canadian Environmental Protection Act (CEPA).
A multitude of scientists and agricultural organizations have chastised the CFIA for using an inappropriate definition of Plant with Novel Trait (PNT) to regulate food and feed.\textsuperscript{346} Canada is the only country in the world using this term in a regulatory context. These Canadian regulations are scientifically arbitrary and, at times, the CFIA’s interpretation of the definition of PNT hinders the registration and commercial development of new technologies. SVC will use the introduction of low phytate barley into Canada to help explain the regulatory approval process for “novel” crops.

Low phytate barley, developed at CDC in Saskatoon had the potential to provide Canadian livestock producers with a competitive advantage. This technology would also have been beneficial in lowering the impact of livestock operations on the environment. Unfortunately, the benefit of this innovative technology to Canadian producers and the livestock sector has been delayed and the US, a major agricultural competitor, has already introduced a US version of this technology. Canadians will likely see little benefit from the investment they have made in low phytate barley. In addition, the US is building this low phytate innovation into other crops such as corn.\textsuperscript{347}

There are problems with the CFIA’s definition of PNT:

- Canada has a stand-alone regulatory framework that is out-of-sync with the rest of the world.\textsuperscript{348, 349} The PNT regulations do not distinguish between different breeding methods and most countries regulate plant breeding according to breeding method. In Canada, the technique used to produce the trait does not trigger novelty, only the nature of the trait triggers the assignment of novelty. This sets up an interesting situation in which a non-PNT plant in Canada could actually be a GMO elsewhere in the world. SVC will discuss this issue in more detail later.

- The government of Canada has not harmonized a working definition within its own system. ABC points out that this is particularly problematic when dealing with AAFC, the CFIA, Environment Canada and Health Canada.\textsuperscript{351}

- Multiple levels of “proof” are required from each government department to satisfy their own interpretation of novelty – with each department standing behind a unique set of standards, processes and procedures, slowing the process of innovation and hampering development and commercialization of unique technologies in Canada.\textsuperscript{352} This perceived lack of clarity is a concern because it may be hindering investment in plant breeding in Canada.\textsuperscript{353}

- Since the CFIA defines a novel trait as one that is not found in Canada, these regulations are snagging products of traditional plant breeding that pose no threat to food or feed safety or to the environment.\textsuperscript{354} Many feel that this “in Canada” clause does not reflect relative risk with regard to traditional plant breeding methods. If a trait exists in naturally occurring populations of the same species in other parts of the world, why should the trait be considered novel just because it does not occur in Canada? Since many genes for disease resistance in cereals come from wild grasses growing in the Middle East, almost every advance in disease resistance in wheat and barley in Canada triggers novelty – and delays the introduction of new varieties. Canada’s competitors do not experience these types of delays when introducing new traits into wheat and barley.

The PNT Technical Working Group of the National Forum on Seed put forward 14 names, mostly plant breeding experts from the public sector, to the CFIA, to advise the Agency.\textsuperscript{355} This group has not been convened as of March 2007 because the CFIA was still developing a draft guidance document. The PBO is working on the guidance document, but needs legal advice on a few issues and is seeking input from the horticulture and forestry sectors. This guidance document may not be ready for the public until sometime in 2008.

Even if the guidance document were available in 2008, PBO guidelines only deal with environmental safety.\textsuperscript{356} Novel feed and novel food issues will not be addressed. This is a key issue for the beef cattle industry since novel feed regulations have essentially made the commercial sale of low phytate barley impractical. This ruling may curtail the development of other new and innovative feed grains.
HB 379, a low phytate barley variety, illustrates the consequences of lack of PNT harmonization within the Canadian government. Dr. Brian Rossnagel created this innovative barley line at CDC Saskatoon through traditional plant breeding. HB 379 allows hogs to consume more phosphorus (P) while reducing their requirement for feed additives. HB 379 also reduces the P content of the hog manure, which is an environmental benefit. While the CFIA Seed Section ruled that HB 379 was not novel, the CFIA Feed Section ruled that HB 379 was a novel feed – stalling the registration process. The CDC argued that there was no scientific reason for labelling HB 379 a novel feed, but this ruling forced the CDC to spend over 15 months trying to convince the Feed Section of their error by providing a scientific rationale for their argument. Finally, in a letter dated September 18, 2007 the CFIA authorized the use of HB379 and CDC Lophy-I low phytate barley was registered for sale in Canada as a livestock feed.357

Drs. Brian Rossnagel and Gord Roland feel there are problems with the registration of CDC Lophy-I. They are concerned that the CFIA appears to understand neither the science used to create CDC Lophy-I, nor its own regulations. There are five issues:

- The CFIA seems to be applying regulations developed for products of recombinant deoxyribonucleic acid (DNA) transfer to conventionally-bred barley
- The CFIA has implied that because CDC Lophy-I is high in available P, it may not be as safe or as nutritious as conventional barley, while the CDC contends that it is every bit as safe and is actually more nutritious
- If CFIA feels that CDC Lophy-I is not as safe and nutritious as conventional barley, the onus is on the regulators to supply proof of lack of safety – and no evidence has been put forward
- By referring to CDC Lophy-I as a “high available P barley grain” the regulators have confused the release of a barley “variety” with a grain “type.” This alleged inappropriate labelling suggests that there may be a lack of understanding of the science of plant breeding and genetics.
- The CFIA Feed Section has restricted the use of HB379 and its descendants as germplasm. Since the CFIA Feed Section regulates “uses of livestock feed,” it may have overstepped its authority. Plant breeders have described this action as “bizarre!”

In addition, the CFIA Feed Section has created a new ingredient definition for high P barley that it will introduce into Schedule IV, Part I of the Feeds Regulations. Low phytate barley will now need to be labelled with a guarantee for minimum available P and minimum total P in Canada.358 **This labelling requirement makes the commercialization of low phytate barley for Canadian livestock feeders essentially impractical.** Even though this variety is registered, the labelling requirement makes it unlikely the cultivar will ever be widely adopted as a feed grain in western Canada. These types of issues within the Canadian regulatory system stymie innovation and set precedents that could also block the development of other innovative feed grain products for Canadian livestock feeders. In the meantime, the US, one of the Canadian livestock sectors largest competitors, has licensed low phytate barley for its producers – reducing the competitiveness of the Canadian agriculture sector yet again. The current Canadian PNT (and novel feed) regulations are inhibiting the competitiveness of Canadian producers, as well as the value-added food and fibre industries that rely largely on supplies of inexpensive primary products to meet consumer expectations, both domestically and internationally.

Canadian plant breeders have been dealing with the Canadian regulatory bureaucracy for over 15 months on the low phytate barley issue. While this regulatory debate has been in progress in Canada, low phytate barley was introduced into the US, with no restrictions, and is now available to US producers. In addition, Pioneer Hi-Bred International Inc. scientists have identified and silenced a gene controlling phytate production in corn.359 This transgenic mutant is very important for US livestock feeders using corn because corn germination and plant growth are not affected. Pioneer has plans to commercialize this low phytate corn within 10 years. Low phytate corn will contain a package of “stacked” traits designed to improve feed quality and increase the level of competitiveness of its livestock feeders globally.360 Based on the low phytate barley experience in Canada, major multinational corporations would be less likely to pursue the registration of similar innovative traits under current Canadian guidelines.
US agronomists and grains analysts have noted that new advances in corn genetics combined with good weather have raised corn yields to unprecedented levels in 2007. Exotic corn hybrids with “triple-stacked” traits are the key to these phenomenal increases in yield. High volumes of competitively priced feed give US livestock producers a competitive advantage over Canadian livestock producers.

Triple-stacking similar traits into wheat and barley would also benefit Canadian producers. The difficulty in realizing this competitive edge lies within the Canadian regulatory system. For example, even if each of these three, individual traits were available in three individual non-PNT plants, the process of triple-stacking these genes into a single plant could create a PNT. Even if a triple-stacked plant were not designated as a PNT, the situation may be similar to that of CDC Lophy-I, where the CFIA Feed Section could potentially declare the feed produced from the grain of the plant to be novel. Once these issues were resolved, the plant breeder would still have to establish that triple-stacking desirable traits into wheat or barley had not increased the competitiveness of the plant. Environment Canada would then have to rule on whether or not this potentially more competitive plant might have an adverse effect on the Canadian environment. Many regulatory hurdles will need to be overcome before the “triple stacked” traits currently available in the US become available in Canada. US crop and livestock producers will maintain a competitive advantage over their Canadian counterparts until these issues have been resolved.

The Alberta Barley Commission outlined to the Honourable Rona Ambrose, in a letter dated May 29, 2007, the problems Canadian producers are experiencing with PNT regulatory issues. ABC copied 15 additional politicians and members of the HCSCAA. Seven agricultural organizations signed the letter, in addition to ABC. This show of support by a range of agricultural organizations suggests that the complaints directed against the CFIA are not coming from a “lone wolf”; rather, it is a concern common to the agricultural sector as a whole and clearly illustrates the magnitude of the problem. This groundswell of opposition to an issue by a group of smaller organizations with common interests has been somewhat effective and may be a tactic that the beef cattle industry could also employ to its benefit. A greater coalition of agricultural organizations, however, may be required in order to achieve the desired outcome.

The EU defines Genetically Modified Organism (GMO) based on the technique by which a seed is produced. The CFIA, on the other hand, bases its definition on the characteristic of the seed – and does not consider the way in which the seed is produced. In Canada, the CFIA could designate both GMO and non-GMO feed grain and forage crops as PNTs. This situation puts Canadian producers at a disadvantage when selling products into global markets because most countries associate “novel” with genetically modified and assume that grains classified as PNTs are also GMOs.

This issue can become particularly problematic if the situation is reversed. What would happen if a feed grain that is not a PNT in Canada were actually a GMO? Moreover, what would happen if producers used this feed grain to feed cattle in Canada? The explanation is technically complex. Consider a situation in which a plant has no foreign DNA. This plant would not be a GMO according to the EU definition. In Canada, however, suppose that scientists use a GMO technology to insert DNA from a donor plant of barley into a host plant of barley. This new variety would not be subject to PNT regulations; however, European parliament Directive 2001/18/EC would classify the plant as a GMO based on the technique used to produce the plant. This lack of synchrony between the Canadian system and the system used by its trading partners has serious trade implications.

The development of polymeric, lipid-based and inorganic nanoparticles for human gene therapy is progressing quickly – and this technology has already been adapted to plant systems. Current Canadian regulations would permit scientists to use nanotechnological tools for the development of new crop varieties without regulatory oversight – as long as plant biotechnologists only transferred genes within the same crop species and as long as any foreign particles were not inserted into the plant. It appears that Canadian regulatory officials may be willing to accept this new technology – but the rest of the world may not. There may be considerable value in adopting a regulatory system that is consistent with what is acceptable to our most important global agricultural competitors – as well as to the customers who purchase our agricultural products.
1.3 The Canadian Wheat Board and Canadian Grain Commission grade system

Grades set by the CWB and the CGC may change on short notice. This disrupts the efforts of plant breeders since the varieties they develop must conform to the standards of approved grades. For example, plant breeders have found themselves in the process of developing a line of wheat to meet a particular grade, only to find the CWB and CGC change the grading – thereby disrupting the goal of the breeding program. Public plant breeders, employed mostly by the government, tend to limit their breeding objectives to conform to the current regulatory requirements and choose not to explore options for contract registration. Dwindling resources further reduce the likelihood of breeders looking for contract registrations for innovative crop varieties.

Market targets identified by the CWB may differ from those of industry. This may prevent industry (and breeders) from quickly reaching their target markets because of an inability to register innovative crop types that do not fit into the existing CWB/CGC grading system.

1.4 The Canadian seed sector and the seed sector review

The Canadian seed sector includes public and private plant breeders, pedigreed seed producers, commercial seed growers and the seed trade. The overall goals of the seed sector are to:

- Improve the agronomic performance of crop varieties
- Improve pest and disease resistance
- Respond to new and traditional needs of primary and end-use consumers in both domestic and export markets (which includes Canadian cattle feeders)
- Meet consumer demand for health, function and the environment through the use of new science

A number of areas of the Canadian seed sector are currently under review. This review includes the restructuring of the Prairie Registration Recommending Committee for Grain Cereal (PRRCG) as well as the Variety Registration Review process. The National Forum on Seed (NFS), the Seed Sector Advisory Committee (SSAC) and a number of other organizations have been contributing to the review of the seed sector in one way or another for about 10 years.

Reviewing regulatory systems creates uncertainty in the business world. Longer reviews are especially problematic. Businesses thrive in minimum risk environments where outcomes from the review of regulatory issues are, for the most part, predictable and of short duration. The regulatory review has left the Canadian seed sector in a state of flux for years. Meanwhile, competitor nations such as the US have continued to innovate and have commercialized a number of inventive new seed technologies on behalf of their end-users while those served by the Canadian seed sector continue to fall behind. SVC will present a short overview of the issues and the stakeholders involved in this process by describing the activities of three groups: the NFS, the SSAC and the PRRCG. SVC will also provide a short description of the progress of the CFIA’s review of the variety registration system.

The NFS was created as part of the Seed Sector Review to deal with regulatory and other policies of interest to the seed sector. Members include Canadian Federation of Agriculture (CFA), Canadian Seed Growers’ Association (CSGA), Canadian Seed Trade Association (CSTA), CWB, CropLife Canada, Grain Growers of Canada (GGC), l’Union des Producteurs Agricoles, National Farmers Union (NFU), private, public and university plant breeders, registered seed organizations and provincial government representatives from eastern and western Canada.

In 2004, the SSAC, which is made up of the CSGA, CSTA, GGC and the Canadian Seed Institute (CSI) published a strategic report on the future of the Canadian seed industry. The report outlined the strengths, weaknesses, opportunities and threats faced by the seed sector and provided recommendations for change.

The SSAC stated that international and domestic competitiveness is contingent on four conditions:

- Regulatory flexibility and the ability to meet timeliness
- An environment fostering science and innovation
- Profitability within the seed sector
- Consumer confidence in the seed sector

SVC will present a short overview of the issues and the stakeholders involved in this process by describing the activities of three groups: the NFS, the SSAC and the PRRCG. SVC will also provide a short description of the progress of the CFIA’s review of the variety registration system.
Specific recommendations of the report include: 375

- Implementation of an industry-led body to provide policy advice and to provide a forum for industry and government dialogue
- Changing the variety registration system so that there is greater flexibility in the information required for registration. Requirements would be based on crop kind.
- Creating an environment that supports and rewards innovation

All of these recommendations would likely help increase the competitiveness of Canadian cattle feeders.

To ensure a variety is adapted to a range of conditions, Co-op trials are conducted prairie-wide. 376 The administration of these trials for cereals is under the jurisdiction of the PPRCG. The trials include three years of field study at numerous locations in addition to screening for disease at AAFC research stations. Quality testing, if required, occurs at the Canada Grain Commission lab. A variety is then considered for registration at the next annual Recommending Committee meeting.

The PPRCG operates under the principle of collegiality and is the key decision-making body charged with licensing new grain varieties for western Canada. 377 The committee includes four subcommittees, one for each crop group:

- Wheat, rye and triticale
- Barley and oats
- Oilseeds (excluding canola)
- Special crops

Within each of these groups are three expert evaluation teams that evaluate the test data. After a review of the data, the committee recommends to the CFIA for or against the registration. An application package from the Variety Registration Office must be completed. If granted, the CFIA Registrar issues a certificate of registration.

For 2005, the PPRGC shifted all power to its four subcommittees, making them all independent recommending committees. 378 This gave more control to the subcommittees and allowed them to deal directly with the CFIA Variety Registration Office (VRO).

Some are concerned with the structure of PPRCG and the way in which it operates. Klein and Walburger conducted an econometric analysis of 19 years of PPRCG data collected on candidate variety characteristics and PPRCG member voting on wheat varieties. 379 Despite the means taken to assure objectivity, the decisions taken by committee members often had less to do with the characteristics of wheat varieties and had more to do with “other influences.” Klein and Walburger questioned the procedures followed for recommending new wheat varieties.

The variety registration system is under the jurisdiction of the CFIA, with a mandate to: 380

- Ensure that unadapted varieties do not enter the marketplace
- Meet current disease resistance standards against economically important pathogens
- Ensure that quality standards are met

The CFIA has been in consultations since 1998 and has been working towards major changes to the existing Variety Registration system. 381 The seed sector review is just one part of this consultative process. The CFIA has identified several areas of consensus that will form the basis for a new regulatory proposal:

- Merit and performance testing will be retained for some crops. For other crops, varietal recognition in some form will allow for seed certification.
- The capacity to deal with consumer confidence issues, especially in the area of health and safety will be retained
- The flexibility and responsiveness of the system will be improved with respect to regulatory amendments
Since October 2006, additional meetings, workshops and online input have contributed more information towards a proposal to “Facilitate the Modernization of the Seed Regulatory Framework.” The CFIA released a three to five year strategic action plan in the fall of 2007. SVC attended the Winnipeg November workshop on behalf of the beef cattle industry. This meeting gathered additional feedback to help develop a joint CFIA-stakeholder action plan for 2007-2008. The goal is to create a more flexible, tiered registration system and to strengthen the contract registration system. Another workshop is planned for March 2008. Unfortunately, the longer this regulatory review continues, the greater is the economic burden that Canadian cattle feeders must shoulder.

2. Economic losses incurred in Canada from regulatory constraints and impediments to registration
Canadian producers incur economic losses from regulatory constraints and impediments to registration. Two of the more important impediments to economic success include KVD and PNT.

2.1 The economic impact of KVD in Canada
The impact of KVD of on farm revenue will depend on whether or not Canada opts for full removal of KVD or decides only to partially remove the requirement for KVD in wheat. The restrictions imposed on wheat breeding through the requirement for KVD have a significant impact on producers. KVD regulations reduce income through lost yield and hinder the introduction of wheat varieties with beneficial agronomic traits.

Canada is the only country in the world using KVD, and many feel that the country needs to abandon this system. Canada has made a bit of progress on this issue with the partial removal of KVD on some classes of wheat. However, the bulk of the wheat produced in western Canada falls into classes of wheat that still have to conform to KVD requirements. A parliamentary report has recommended the full removal of KVD, but more pressure will be required before all of the recommendations of the parliamentary report are accepted.

Full removal of KVD restrictions could jump-start the wheat breeding industry. Removing KVD requirements would allow plant breeders to resurrect breeding lines they have shelved because of failure to meet KVD. Many of these lines have desirable traits such as high yield and better disease resistance. Plant breeders could re-introduce these lines into the registration system and quickly provide a wide selection of new varieties for crop producers.

Oleson estimated the impact of full KVD on farm revenue and examined nine possible yield/demand scenarios. He calculated that full removal of KVD would increase on-farm revenue (from baseline) by $60-171M annually. Oleson also conducted a similar analysis for the partial removal of KVD. In this case, CWRS wheat and CWAD would still have distinct kernels, but minor classes of wheat would not. The mid-point for partial removal of KVD fell to about $50M annually, or about half the benefit of full removal. Partial removal of KVD, however, still leaves plant breeders with a de facto KVD – and this situation does little to improve the situation from the perspective of the producer or the plant breeder.

Bole suggests that earlier studies, such as those of Oleson, have underestimated the cost of KVD. He estimates that lost yield, the inability to introduce resistance to Fusarium Head Blight (FHB) and the inability to introduce midge resistance into Canadian wheats have cost Canadian wheat producers about $200M per year. This scenario assumes a five to 10 percent increase in yield for Canadian wheat varieties if KVD were removed – which is worth about $150M per year. Bole also estimates that FHB resistance in CWRS/CPSR and possibly other wheat classes is worth, on average about $25M per year, but could range as high as $50M per year – and midge resistance in CWRS and several other classes of wheat is worth between $10 and $50M per year.

Thomas also suggests that Oleson underestimated the cost of KVD since he largely omitted pest resistance and agronomic traits from the calculations. For example, three CWRS lines with high levels of resistance to FHB (BW 330, BW 346 and BW 379) were rejected because they did not meet KVD requirements. Thomas also pegs CWRS yield loss due to KVD at 15 percent. Using this figure, multiplied by 14Mt multiplied by a price of $200/t suggests that producers lose $420M annually on sales of CWRS alone.

Canada can also calculate the cost of KVD to its producers in terms of access to genetic enhancements needed on the farm. Crop producers may see crop enhancements delayed for years or even decades as plant breeders attempt to maintain complex, multiple-gene traits like KVD while trying to introduce new, commercially important traits. Canadian plant breeders generally estimate that the value lost in existing varieties due to KVD restrictions is over
$3.75 per tonne of production. At western Canadian production levels of 23 Mt/year, the cost of KVD would equate to over $86M per year.

KVD requirements have also slowed the progress that plant breeders have made against FHB. As an example, the system rejected HY 644, a wheat variety with good resistance to FHB. Some have speculated that the cost of not registering HY 644 may be costing producers $5-10M per year until plant breeders can develop another variety with this level of resistance to Fusarium.

Dr. Brian Fowler has noted that winter wheat breeders have been unable to release high-yielding lines of winter wheat in Canada because they did not meet the requirements for KVD. The western Canadian producer and the Canadian taxpayer have paid the price. Plant breeders have been unable to register any new winter wheat varieties after an investment of over $11M in winter wheat programs.

Oleson also estimated the impact of KVD on yield. One scenario looked at a strategic direction called “going for feed.” In this scenario, plant breeders would be constrained by few limitations, outside of the requirement for good agronomic traits and disease resistance and would need to incorporate bread-making quality traits such as protein content and gluten strength into wheat varieties. Plant breeders and other scientists estimated the potential gain in yield at about 15 percent, plus or minus five percent for producers, and a yield gain of about 20 percent under controlled research conditions. The yield of winter wheat, with a higher yield baseline than CPS wheat and other minor classes of wheat, would rise by as much as 15 to 20 percent.

The problem with this scenario is that the conditions imposed by Oleson restrict yield. If the strategic direction were “going for feed,” why would feed varieties need bread-making quality traits? High protein content and good gluten strength have never been a requirement for a good quality feed wheat. Yields would be expected to rise even higher than 15 to 20 percent if plant breeders were not constrained by the need to maintain higher levels of protein as well as gluten strength in “feed” wheat.

KVD is not the only constraint on increasing wheat yields in western Canada. Yield can also stagnate as plant breeders attempt to maintain or improve quality characteristics. BW90 was up for registration with the PRRCG in 1989-1990. BW90 yielded 10 percent more than the check varieties; however, its gluten strength was too high. Plant breeders used the genetics of BW90 to create AC Barrie, a variety that had the yield benefits of BW90, and met the agronomic, disease, quality and KVD standards for CWRS wheat. This took five years, and not having BW90 represented financial loss to western Canadian producers. Assume that the quality differential of BW90 relative to AC Barrie represented a five percent discount on the price paid, but add in a 10 percent yield advantage. A quick calculation suggests that for every 1Mt of wheat produced, producers lost $5-10M at the farm gate when they lost the registration of BW 90.

2.2 The economic impact of PNT in Canada

Canadian citizens bear the regulatory burden of PNT regulations five ways.

- The actual cost of moving material subject to PNT regulations through the regulatory system
- The loss of access to technology for the number of years required to move innovative products through the regulatory system and on to market
- Losses caused when inventors abandon ideas due to perceived Canadian regulatory constraint
- Losses of technology and products that may provide a competitive benefit for Canadian producers
- Losses resulting from corporate flight as entrepreneurs move their research funds to countries with less restrictive regulatory processes

Corporations fear open-ended processes that increase the length of time new technologies are subject to regulatory scrutiny – especially when the type and amount of data required for product registration is not predictable. Three agricultural case studies estimated the cost of PNT regulations to Canada: the development of canola quality mustard (Brassica juncea), the introduction of Wheat Curl Midge (WCM) resistance into wheat and the introduction of low phytate barley to Canada. SVC will examine these case studies in more detail.
AAFC Saskatoon Research Centre and Saskatchewan Wheat Pool (SWP = Viterra) jointly developed canola oil quality *B. juncea* (Brown or Oriental mustard) through traditional breeding.\(^{397}\) SWP introduced Arid and Amulet, the first two canola oil quality mustards in 2002. *B. juncea* is suited to the hotter, drier areas of the southern prairies, particularly to the brown soil zone.

Field trials for this project were already in progress in 1987 – before SWP knew the CFIA would consider this a novel technology in Canada.\(^{398}\) All field trials initiated before 1988 were exempt from environmental, food and feed approvals; however, any lines tested after 1988 were subject to PNT regulations. SWP estimated the cost of registering canola quality *B. juncea* at over $3.5M. Project partners spent about the same amount for a total cost of over $7M – and the process took over two years to complete. SWP developed similar varieties for the US and Australia at no incremental cost and in considerably less time. For the size of the Canadian market relative to those of the US and Australia, many companies would turn down the business rationale for a $7M incremental investment for a Canadian registration of this type of product. Now that private businesses are aware of the additional costs they are likely to face when registering this type of product in Canada, the economics of the situation may lead them to abandon the Canadian market in favour of more lucrative markets in Australia or the US.

SWP is now working with BASF to register imidazolinone-tolerant (CLEARFIELD\(^\text{®}\)) *B. juncea*.\(^{399}\) Even though this trait is already present in canola (*B. napus*), the CFIA has classified this trait as a PNT in *B. juncea*. In addition, the CFIA Feeds Section requires a complete compositional analysis, even though the companies have already completed a considerable volume of testing in closely related species such as canola. Over $500,000 has already been spent on fulfilling the requirements for regulatory approval in Canada and it will take at least two more years to complete the regulatory process.

Much of the work on WCM resistance in wheat winter wheat occurred in the 1970s and 1980s.\(^{400}\) Plant breeders transferred the gene for WCM resistance to winter wheat from another species – but found the same gene for resistance later in another winter wheat variety. WCM is the vector for Wheat Streak Mosaic Virus (WSMV). According to the CFIA’s own definition of PNT, the trait was not novel. AAFC submitted for regulatory approval for WCM resistance in May 2001. The CFIA then asked for more information and the plant breeder complied. This started a four year, open-ended process in which the CFIA continued to request more and more information. When queried on the growing quantity of information required for a supposedly non-novel trait, the CFIA responded, “We don’t know (how much information we need) but we’ll tell you when we have enough . . . .” In June 2004, AAFC received approval from Health Canada and the CFIA’s PBO. The CFIA Feed section took one more month to grant approval. The plant breeder provided no estimate of the costs involved but noted that the introduction of WCM resistance was delayed by at least one year. Considering that the US or Australia would have released this variety immediately (and at no cost to the plant breeder) the incremental delay in registration in Canada relative to that of competing nations was over three years.

The USDA-ARS released Mace, a WCM resistant winter wheat, in December of 2007. This will give US growers the opportunity to start growing Mace in 2008.\(^{401}\) Pesticides have not been particularly effective in controlling WCM and winter wheat growers have had to use a combination of strategies. One option is controlling grassy weeds and volunteer wheat, which are both sources of WSMV, with herbicides, in broadleaved crops grown in rotation with winter wheat.

Mace winter wheat will benefit winter wheat growers on the US Great Plains, where yearly outbreaks of WSMV reduce crop volumes by about five percent and where damage has exceeded US$35M in a single state, as it did in Montana in 1995.\(^{402}\) Over two years of field testing, USDA scientists have noted that yields of Mace winter wheat equalled those of two of the top winter wheat varieties in Nebraska under disease-free conditions. In WSMV-infected fields, however, Mace out-yielded non-resistant winter wheat varieties by two to three times. Canadian wheat producers still have no access to this technology. Numbered lines have been registered in Canada but are still two to four years away from commercial production.\(^{403}\)

The low phytate trait in barley took about one and one-half to two years longer to bring to market in Canada than in the US.\(^{404}\) US plant breeders developed low phytate barley at the same time as Canadian plant breeders; however, this product is already on the market in the US and is being fed to hogs. US hog producers will likely export these hogs into Canada. The CFIA Feed Section has declared low phytate barley a novel feed in Canada and labelling
requirements may create a situation in which this type of barley is not commercially viable. Canadian hog producers
will suffer economically from this decision while US hog producers are free to capitalize on the competitive
advantage offered by this value-added feed.

These three case studies clearly suggest that the Canadian regulatory system is not working well and is in need of
modernization to keep pace with Canada’s agricultural competitors. Without change, Canadian feed grain producers
and the livestock sector will remain at a competitive disadvantage due to delays in the introduction of innovative
cultivars and will fall further behind every year. There appears to be little incentive for the agricultural research
community to invest in the development of innovative value-added traits in Canada because of the high cost of
navigating the Canadian regulatory system, the lengthy waiting period between the time of submission of the data
package and the registration of new technology and the uncertainty regarding the data required for registration.

3. Creating a competitive environment for Canadian feed grain end-users
What Canadian feed grain end-users may need is a regulatory climate that balances regulatory issues with the need
for Canadian producers to be competitive. The regulatory environment in Canada has denied primary producers
access to new technologies and innovations that are currently available to their competitors – putting Canadian
producers at a competitive disadvantage. There are solutions to problems associated with both KVD and with PNT.

Another barrier to regulatory competitiveness in Canadian agriculture is the Agricultural Policy Framework
(APF). Producers find the APF difficult to understand, burdensome and feel that it limits their business
opportunities. In March 2007, in a review of Canadian agricultural policy, the Canadian Federation of Independent
Business (CFIB) identified a reduction in regulatory burden as one of the four key areas to which APF does not
focus enough attention.

Canada needs to reconsider the nature of its regulatory system in light of a myriad of valid criticisms that been
brought forward by numerous stakeholders. What Canada needs is an efficient, science-based regulatory system that
includes consistency between the acts and regulations governing variety development and commercialization.
Canada may also be able to create a more competitive environment for feed grain end-users by considering the
advantages inherent in newer US regulatory initiatives as well as greater protection for intellectual property rights.

3.1 Cabinet Directive on Streamlining Regulation
In April of 2007, a Cabinet Directive on Streamlining Regulation replaced the Government of Canada Regulatory
Policy of 1999. Cabinet designed this directive in the interest of creating a more accountable, effective and
efficient regulatory system. There are also provisions for protecting the social and economic interests of Canadians.
Specific regulatory objectives include:

- Protecting and promoting economic interests, the environment, health, safety, security and social
  interests
- Promoting a system that encourages entrepreneurship, innovation and investment
- The development of science-based decision-making
- Creating accessible, comprehensible and responsive regulation
- Promoting efficient and effective regulations where the cost of meeting the regulatory requirements is
  justified in terms of the benefit
- Creating coherent policy that minimizes duplication and responds to clients in a timely manner through
  coordination and cooperation within the federal system, and through interaction with other levels of
  government in Canada, as well as internationally

The goal of this directive is to reduce repetitiveness in the federal regulatory system. The federal government has
also been tasked with developing a service-oriented approach to the regulatory system that reduces the
administrative load for Canadians. Producer groups such as the Grain Growers of Canada and the Alberta Barley
Commission support the Smart regulation initiative because it may represent an opportunity to speed up access to
new and innovative agricultural products.
The goals of the Cabinet Directive certainly represent a step in the right direction. The CFIA is starting a pilot project using this Smart regulation initiative. Whether or not the initiative results in any tangible improvements remains to be seen.

3.2 Alternatives to the KVD system

Analyses of the economic cost of KVD depend on the number of variables included in the study – which is why the cost of KVD ranges from $60M for all classes of wheat up to $420M for CWRS wheat alone. The bottom line, however, is that all of those who have studied the cost of KVD conclude that it is detrimental to the economic health of Canadian agriculture. A number of alternatives to the KVD system have been proposed. What is required is the political will to move towards a modern system that puts Canadian producers on an equal footing with their competitors.

The KVD system could be replaced with a statutory declaration system in conjunction with methodology that accurately determines the variety of grain. Another alternative may be a system based on the quality/functionality of the wheat. A 2006 HCSCAA report recommended abandoning KVD and replacing it with a system using a farmer’s declaration or affidavit in conjunction with a science-based system for quality control. This recommendation coincides with a CGC announcement to change western Canadian wheat classes. The CGC proposes eliminating KVD requirements for minor wheat classes, but CWRS and CWAD wheat must conform to the existing KVD requirements. This situation is referred to as partial removal, as opposed to complete removal of KVD. Because 80 to 90 percent of wheat is CWRS and CWAD, partial removal of KVD may not produce much benefit for producers.

3.3 Alternatives to PNT

The modernization of the regulatory system could provide a number of benefits to Canadians. A streamlined, efficient regulatory system would be less costly to operate and would have a greater capacity to review submissions. A reduction in the time required to review regulatory submissions would reduce the cost of each review and should encourage the development and release of new technologies in Canada – enhancing the competitiveness and self-sufficiency of the Canadian agricultural sector.

Numerous stakeholders have outlined the structure for an effective PNT-based regulatory process:

- **A system based on risk** – Most agree that “novelty” does not provide a reason for regulation. Regulations need to determine the level of risk that a technology or product poses and apply regulatory scrutiny accordingly. A tiered assessment of risk needs to be determined, and the experience of other countries should be considered.

- **A definition of novelty** – Canadian innovators need access to a clear definition of novelty and need to understand what triggers novelty. Public as well as private businesses need to know the costs as well as the time required to move a technology or product to market. Ag-West Bio Inc. workshop participants agreed that it is clear that transgenic technology would trigger novelty, but otherwise, the definition of novelty is unclear. This issue is complex and not well understood given the current definition of PNT. SVC has defined circumstances under which new technologies may not trigger the PNT process, even though at least one of the technologies would be defined as transgenic according to European regulations.

- **Harmonization with the rest of the world** – Canadian regulations need to be in harmony with the rest of the world. The goal is to shorten submission timelines, reduce the burden of evidence for approval and lower costs. Over-regulation in Canada will hinder innovation and Canada’s competitors are taking advantage of this regulatory hurdle to create a competitive advantage. Harmonization is also required to keep Canadian regulations consistent with those of its competitors to avoid issues associated with the imposition of non-tariff trade barriers.
A tiered risk assessment – the CFIA needs a two-tiered process to evaluate the need for a more detailed assessment. Plants that do not pose a risk to the environment should not be subject to further evaluation.

Taking advantage of scientific expertise – Canada should take advantage of its wealth of scientific experts who could help the regulators assess risk and novelty.

Interdepartmental coordination – the government of Canada needs more coordination between departments to reduce duplication of effort, conflicting requirements and regulatory overlap. The idea is for departments to share information and assessments through a single registration “window” for the assessment of human, feed and environmental safety.

Other issues highlighted include a need for regulatory consistency and accountability as well as an appeal process. The PBO is preparing a new directive document to facilitate streamlining of registrations; however, stakeholders have singled out the Feed Section as being particularly unresponsive to industry needs.

USDA’s Animal and Plant Health Inspection Service (APHIS) regularly reviews field releases to allow plant breeders to field test biotechnologically derived plants with which USDA has become comfortable and for which the regulatory burden may be excessive. If APHIS decides that the unconfined release of a GMO poses no risk to agriculture or the environment, the organism can be planted in US fields without APHIS authorization. Between 1987 and 2001, APHIS approved over 88 percent of 7,600 applications for the field release of plants produced using biotechnology. APHIS has since approved an additional 67 percent of 79 requests for deregulation. About 56 percent of these deregulated varieties are herbicide or insect tolerant and 19 percent have traits for improved product quality. This progressive USDA system has no equivalent in Canada.

3.4 Alternative to current Co-op testing approach

The Co-op testing system no longer functions efficiently due to reduced funding levels and the level of funding no longer supports the testing of larger numbers of varieties at the B-test level. As a possible solution to this situation, the government of Canada could form a system with a separate technical capacity governing the Co-op testing program through the creation of a new, independent testing agency. This agency would be responsible for the collection of agronomic quality and pathological data. Plant breeders would continue to contribute data but the agency would allow scientists more time to focus on their breeding programs. An added advantage of this system would be the elimination of any conflict of interest on the part of AAFC personnel regarding the registration of their varieties.

3.5 Intellectual property rights

Plant breeders protect new varieties of plants primarily through the Plant Breeders’ Rights (PBR) Act in Canada and through the Plant Variety Protection Act (PVPA) in the US. Other tools that plant breeders use to protect intellectual property include gene and plant patents and trade secrets. Trade secrets, as an example, might include the use of in-house, inbred parental lines to produce hybrid crops.

Despite the number of ways in which plant breeders can protect intellectual property, public and private plant breeders feel that returns on R&D in Canada do not justify making investments in a number of crops. Because public plant breeders still produce a wide range of new varieties of wheat and barley, this issue is not of great concern to many in the agricultural sector in Canada; however, a competitive market for new technology combined with customers who are eager to use the technology is one of the better ways to secure prosperity and build wealth. This scenario suggests that greater private sector involvement in barley and wheat breeding in Canada would be of value to Canadian producers.

Some have suggested that Canada has an outdated Plant Breeders’ Rights Act based on the older UPOV 78 convention. In contrast, the US has updated the PVPA to conform to UPOV 91 and has strengthened plant breeders’ rights through a number of successive legal rulings.
The Canadian PBR Act (1990) is administered by the CFIA. Its purpose is to provide a means for developers of new varieties to recover their research investment through the right to charge a royalty and to provide them with control over the multiplication and sale of their reproductive material. The Act grants rights when varieties are new, distinct, uniform and stable. There are two exceptions to the PBR Act:

- Plant breeders can use protected varieties for breeding without compensating the owner of the variety
- Farmers can save seed of protected varieties for their own use (Farmers’ Privilege)

Canada adopted PBR legislation long after most other developed countries. The delay may have occurred due to a combination of controversy over the legislation and low political priority. Even after its introduction in Parliament, Canada did not adopt PBR legislation for 10 years — handicapping the agri-food sector and reducing access to crop technologies that were not released in Canada because of lack of legal protection.

AAFC has attributed the increase in private sector investment in plant breeding, from $33.2M to $92M between 1987 and 2001, to the protection of intellectual property rights and to companies’ ability to capture sufficient financial return on their plant breeding investments. Unfortunately, cereals do not attract much of this private sector investment and cereal breeding continues to occur primarily in the public sector in Canada. The livestock sector would benefit from a greater interest on the part of the private sector in wheat and barley breeding.

In 1995, the US amended the PVPA, bringing the country into conformity with UPOV 91 and allowing the US to ratify the International Convention. The amendment extends the protection of most field crop varieties by two years, from 18 to 20 years. The amendment does not give crop producers Farmers’ Privilege and producers need permission from the owner of the variety to sell FSS of protected varieties. The amendment also addresses recent advances in biochemical and genetic engineering technology. Hybrid and non-hybrid varieties have equal protection under PVPA.

The US Supreme Court extended plant breeders’ rights further in its 1995 decision in Asgrow v. Winterboer. In this ruling, farmers could no longer sell protected seed that had been developed before April 1995 and was not covered by the PVPA’s 1994 amendment. This decision would keep US farmers from saving and reproducing non-hybrid seed for resale. Plant breeders received even more protection for their innovations in 2000 when Pioneer Hi-Bred received a ruling in their favour that gave plant breeders more control over their inventions.

The PVPA also gives Canadian plant breeders US protection for crop varieties that Canada does not protect. As a bonus, wheat varieties that do not comply with KVD requirements, or varieties that cannot be manoeuvred through Canadian PNT regulations can be registered in the US and can generate royalties. Consequently, US producers derive a competitive benefit from Canadian crop varieties bred by Canadian plant breeders.

The US Supreme Court further strengthened plant breeders’ rights in its 1980 decision in Diamond v. Chakrabarty. Though the ruling extended patent rights to genetically engineered (GE) microorganisms, this tool is important to plant breeders because plants produced using biotechnology received an additional layer of IP protection. After the Diamond v. Chakrabarty ruling, a succession of rulings by the Patent and Trademark Office’s Board of Appeals and Interferences expanded patent protection for GE organisms to include plants. This combination of legislative and judicial action in the US has helped create a wide-ranging series of incentives for developing new plant varieties.

While there may be some new market opportunities with creation of the CWGP class of wheat, many feel that Canada does not provide sufficient protection for plant breeders’ intellectual property (IP). While the full removal of KVD for all classes of wheat by 2010 could produce new screening programs for agronomic and end-use traits for wheat, private corporations will still find it difficult to generate a sufficient return on investment due to lack of sufficient protection of IP. Part of the problem is that the PBR Act is modelled after the older UPOV convention, UPOV 78, rather than the more recent UPOV 91. UPOV 91 prevents farmers from saving the seed of protected varieties and plant breeders may not use protected varieties in breeding programs to develop their own material. What is different in the UPOV 91 Act is that:
Plant breeders rights extend to the seed harvested from protected varieties. For example, if a farmer were to seed a protected variety without paying a royalty to the plant breeder, the breeder owns the wheat produced on that field as well as the flour, and any other product, produced from that seed.

Plant breeders using a protected variety to produce a new variety that is not substantially different from the original protected variety forfeit ownership of that variety to the first breeder.

UPOV 91 does not give crop producers “Farmers’ Privilege,” the right to use the harvested seed of a protected variety for planting. Each country that signs on to UPOV 91 must create its own special provisions for Farmers’ Privilege.

UPOV 91 essentially gives plant varieties protection that is closer to patent rights than did the older convention, UPOV 78. While Canada is a signatory to UPOV 91, it has not ratified UPOV 91. Under the 1994 North American Free Trade Agreement (NAFTA), Article 1701 requires that the parties only enforce UPOV 78, not UPOV 91. The seed industry and Canadian government, however, have both argued that not complying with UPOV 91 puts Canada at a competitive disadvantage and at “risk of losing investment and trading opportunities.”

In 1998, the federal government introduced a bill to amend the Plant Breeders’ Rights Act and bring it into conformity with UPOV 91. The bill died on the order paper, but the government has since been working with industry to re-introduce the proposed amendments. The original bill (Bill C-80) was based on UPOV 91 and provided for Farmers’ Privilege. The CSTA approved of the 1998 bill, but is now asking that farmers who save small quantities of seed pay royalties every time they do so. In the recently released Seed Sector Review, conducted by CSTA and CSGA, and supported by AAFC, the seed industry renewed its call for Canada to move towards UPOV 91. How the government will respond to the recommendations of the Seed Sector Review remains to be seen.
Section 6 – Forward looking competitors

Issues covered . . .
Feed and forage goals in Europe – toxins, anti-nutritional factors, feed quality and sustainability
Feed goals in Australia – higher yields and improved grain quality

Canadian livestock producers need to keep up with advances in research that may give a competitive edge to competing nations. The EU and Australia have a comprehensive set of research initiatives in feed grains and forages.

1. Europe
In its Stakeholders Proposal for a Strategic Research Agenda, the EU has a number of innovative initiatives in the area of sustainable livestock production.452 The EU has proposed several feed and forage goals:

- Produce livestock feed that is free of toxins and anti-nutritional factors
- Produce high quality feed
- Improve the sustainability of grass-fed cattle systems

1.1 Toxins and anti-nutritional factors
The most agriculturally important mycotoxins include aflatoxins, deoxynivalenol (DON), fumonisins, nivalenol, ochratoxin, patulin T-2 toxin and zearalenone.453 Governments regulate mycotoxins at the national level because they include molecules that are poisonous to animals and humans, and consequently pose serious risks to public health. The EU is also interested in mycotoxins because mycotoxin level restrictions can be used as non-tariff barriers to trade. In Canada and the US, annual losses due to mycotoxins in the feed and livestock industry alone are estimated at US$5B.

Anti-nutritional compounds in plants can affect animal behaviour, biology, growth and health.454 These compounds fall in four categories:

- Nutrient analogues that disturb animal metabolism such as dicoumarol and L-DOPA
- Digestive enzyme inhibitors such as anti-amylases and trypsyn
- Nutrient uptake blockers such as lectins, phytates and tannins
- Compounds produced from feed after hydrolysis such as cyanogenic glucosides, glucosinolates and gossypol

The EU is considering research into producing feeds that do not contain anti-nutritional compounds.455 One area of interest to the EU is the production of low phytate barley. The EU is particularly interested in more efficient utilization of feed P and a reduction in the anti-nutritional effects of phytate in livestock species. EU scientists will consider the use of tools in the area of proteomics and metabolomics to identify and manipulate plant genes that are responsible for the production of anti-nutritional compounds.

1.2 Quality feed
The EU has asked its animal nutritionists and physiologists to determine the optimal composition of macro- and micro-nutrients in livestock feed to ensure maximum palatability and digestibility.456 The goal is to optimize economic productivity, minimize the impact of livestock on the environment and enhance the quality of animal products for the consumer.

Macronutrients include carbohydrates, lipids and proteins.457 Cereals are the main source of carbohydrates, and oilseeds are the principle source of proteins. The EU is spearheading research into creating corn and wheat that accumulate abundant quantities of starch and oilseeds in combination with high levels of protein. The goal is to optimize the cost of feed and livestock production by concentrating feed energy and protein in the grain and by optimizing production volume per unit area of land.
Optimizing the concentration of micronutrients in feed grains is expected to lower the cost of livestock production.\(^458\) The EU is looking at optimizing amino acid composition in plant proteins to reduce the need for feed additives like lysine and methionine. While the EU is considering funding research in this area, Australia has determined that the benefit-cost ratio of this type of research is low and may be more reluctant to start large-scale plant breeding programs in this area.\(^459\)

The palatability and digestibility of feed increase feed efficiency and help reduce the impact of livestock operations on the environment.\(^460\) The EU is planning to increase feed digestibility by initiating research that brings together teams of animal nutritionists, plant breeders and plant technologists.

### 1.3 Increasing the sustainability of grass fed cattle systems

The EU is looking at grasslands, which represent about 40 percent of arable land in Europe, to improve agricultural sustainability.\(^461\) European grasslands are not that much different from Canadian grasslands – they all contain mixtures of forage species that vary in feeding value. The nature of the forage species and the proportion of each species inhabiting the grassland dictate the value of the grassland to livestock operations. Not only is the relationship between the ecosystem and the livestock complex, forages also have complex genetic systems such as allogamy and polyploidy which make breeding these species challenging. In addition, rangeland forage species are perennials and agronomy and breeding operations must be longer-term and require a larger land base than that used for annual crops. With this in mind, the EU proposes analyzing the function and dynamics of forage species mixes in a variety of grazed ecosystems. Their goal is to construct predictive models for better grassland management by 2015.

### 2. Australia

Australian scientists understand that biotechnology makes it possible to improve the efficiency of cereal grains as livestock feed through the introduction of specific genetic traits into crops such as wheat and barley.\(^462\) Research scientists and industry specialists in the areas of livestock nutrition and plant breeding, among others, have considered a number of options for increasing producers’ profitability in specific livestock sectors, including cattle feedlots. Agricultural economists have analyzed the options to produce a comprehensive set of recommendations for improving different characteristics of feed grains and have determined who in the value chain would be most likely to benefit economically from the research.

The study suggests that new feed types could provide greater benefits to cattle feedlot operators; however, livestock feeders would not derive any value from these potential benefits if grain producers did not receive sufficient compensation for growing the new types of feed.\(^463\) The most beneficial new crops included high seed coat digestibility barley, hulless barley and low seed coat content barley. The study also considered the value of raising the yields of feed wheat and feed barley.

#### 2.1 Increasing yield

Brennan and Singh first calculated the minimum price that cattle feeders would have to pay for a new grain to provide the crop producer the same gross return as a “standard” or older variety.\(^464\) For hulless barley, the assumption was that the crop would yield 20 percent less than the standard hulled barley. For feed wheat and feed barley, Brennan and Singh estimated that feed wheat and barley would yield 20 percent more than “standard” wheat and barley. They concluded that crop producers would need to be paid 10.4 percent more for hulless than hulled barley but could be paid just over 15 percent less for high yielding feed wheat or feed barley compared to standard wheat or barley. In this analysis, higher-yielding feed grains usually provided greater economic return than most new feeds with improved nutritional traits. High yielding feed barley provided a total benefit of AU$2.19M per year.

#### 2.2 Improving quality

In an Australian analysis, if a quality trait produced annual benefits $400,000 per year, the benefit-cost ratio equaled 1.0.\(^465\) High seed coat digestibility barley, hulless barley and low seed coat content barley all produced annual benefits of between AU$1.2 and AU$4M and had a cost-benefit ratio of between three and 10. The use of hulless barley provided a total benefit of AU$1.6M. The total benefit for low seed coat content barley was AU$1.40 million, and for high seed coat digestibility barley, the total benefit was $1.25 million. In all cases, the use of these higher...
quality barley varieties allowed cattle feeders to use alfalfa hay and hulled barley as a replacement for the more costly “millmix” and wheat.
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Appendix 1 – ICAR database download and sorting procedure

Ms. Trudy Devine, AAFC, Sir John Carling Building, Ottawa, ON downloaded AAFC projects in the ICAR database into Excel. The database included 69,764 lines of data.

Feed grains research

SVC retrieved the data for feed grains research by:

1. Selecting all data with the description "plants" from Commodity Level 1
2. Simultaneously selecting all data with the description "cereal crops, cereal crops and products, cereal products and field crops" from Commodity Level 2
3. Deleting all multiple references to the same project from the database
4. Deleting all lines where established researchers were recorded as:
   - Collaborateur industriel 1
   - Collaborating researchers
   - Collaborating masters students
   - Collaborating PhD students
   - Computer programmer
   - Other branch researchers
   - Other centre researchers
   - Other established researchers
   - Other PRC researchers
   - Manager 1
   - Professional(s)
   - Vacant
   - Vacant - CFAR

SVC deleted ambiguous references to established researchers to get a better picture of the number of full-time AAFC scientists working on each project. If deleting ambiguous reference to established researchers emptied all of the cells for a project, the data was not included in the summary. In these cases, there was no way to determine the actual number of AAFC scientists involved in the project. Only named AAFC research scientists were included in the count of scientists for each project.

This process of elimination may tend to underestimate the personnel complement working on each project between 1987 and 2003. In 2004 and 2005, however, the number of scientists working on each project is likely overestimated, since all of the scientific team members are included for each project – and it is unlikely that all members of a team contributed substantially to any one project, given that teams included up to 22 individuals.

5. SVC then classified projects into three categories:
   - Feed breeding and feed production
   - Feed breeding combined with other objectives
   - Food, nutraceutical and food quality

This process allowed a comparison of projects dedicated specifically or partially to feed to those aimed at improving the food, nutraceutical and food quality aspects of wheat and barley.

Forage research

SVC retrieved the data for forage research using the same first four steps as were used for cereal crops, except that "forage crops" was selected from Commodity Level 2.
Rangeland research
SVC retrieved the data for rangeland research using the same first four steps as were used for as for cereal crops, except that “land” and “soil and land” were selected from Commodity Level 1 and “grassland” was selected from Commodity Level 2.
Appendix 2 – Agriculture and Agri-Food Canada – 2007 projects

SVC downloaded Agriculture and Agri-Food Canada 2007 research project data from the AAFC website. Two databases were retrieved:

- Research projects at Agriculture and Agri-Food Canada – plant science research projects starting in 2007
- Research projects at Agriculture and Agri-Food Canada – environment and ecology research projects starting in 2007

SVC downloaded 163 projects, sorted the projects into 21 categories and tallied funds allocated for each project by category. Categories included:

- Agronomic benefit
- Health, environment and food safety
- Livestock projects
- Soil projects
- Insect management
- Disease resistance
- Plant breeding techniques
- Forages, fodder or range
- Feed breeding and production
- Feed breeding and other objectives
- Food, nutraceutical, biological products and quality
- Oilseed
- Pulse and legume
- Triticale
- Corn
- Potato
- Oat
- Fruit or vegetable (other than potato)
- Soybean
- Tobacco
- Other
## Appendix 3 – Abbreviations and acronyms used in this report

<table>
<thead>
<tr>
<th>Acronym or Abbreviation</th>
<th>Definition</th>
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<tr>
<td>AAF</td>
<td>Alberta Agriculture and Food</td>
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<td>AAFC</td>
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<td>Advancing Canadian Agriculture and Agri-Food (federal)</td>
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<td>ARS</td>
<td>Agricultural Research Service (USDA)</td>
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<td>ASW</td>
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<td>AVAC</td>
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<td>AVP</td>
<td>Agri-Value Program (SAF)</td>
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<td>AWB</td>
<td>Australian Wheat Board</td>
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<td>B</td>
<td>Billion</td>
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<td>Busch Agricultural Resources Inc</td>
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<td>CDC</td>
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<td>CEtOH</td>
<td>Cellulose-based Bioethanol</td>
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<td>Canadian Forage Council</td>
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<td>Canadian Grain Commission</td>
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<td>Canadian International Grains Institute</td>
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<td>CIMMYT</td>
<td>Instituto Nacional de la Maíz y Trigo (International Maize and Wheat Improvement Center, Mexico)</td>
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<tr>
<td>CPS</td>
<td>Canada Prairie Spring</td>
</tr>
<tr>
<td>CPR</td>
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<td>CPSR</td>
<td>Canada Prairie Spring Red</td>
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<td>CRAM</td>
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<td>CWAD</td>
<td>Canadian Western Amber Durum wheat</td>
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<tr>
<td>CWES</td>
<td>Canada Western Extra Strong</td>
</tr>
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<td>Canada Western General Purpose</td>
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<tr>
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<td>Canada Western Hard White</td>
</tr>
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<td>Canada Western Red Winter</td>
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<tr>
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<td>Canada Western Soft White Spring</td>
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<td>DDGS</td>
<td>Distillers’ Dried Grain with Solubles</td>
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<tr>
<td>DLFOA</td>
<td>Diversified Livestock Fund of Alberta</td>
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<tr>
<td>DNA</td>
<td>Deoxyribonucleic acid</td>
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<td>DON</td>
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<td>DNS</td>
<td>Dark Northern Spring wheat (US wheat class)</td>
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<td>EU</td>
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<tr>
<td>F1</td>
<td>The progeny of a cross between two parental crop lines</td>
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<tr>
<td>F2</td>
<td>The progeny of the F1 generation</td>
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<td>FCDC</td>
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<td>Farm Saved Seed</td>
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<tr>
<td>FTE</td>
<td>Full Time Equivalent</td>
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<tr>
<td>FWD</td>
<td>Feed, waste and dockage</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<tr>
<td>GE</td>
<td>Genetically Engineered</td>
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<td>GGC</td>
<td>Grain Growers of Canada</td>
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<td>Genetically Modified</td>
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<tr>
<td>GMO</td>
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<tr>
<td>Acronym or Abbreviation</td>
<td>Definition</td>
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<td>------------------------</td>
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<tr>
<td>GP</td>
<td>General Purpose (Australian wheat class)</td>
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<tr>
<td>GRDC</td>
<td>Grains Research and Development Corporation (Australia)</td>
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<tr>
<td>G x E</td>
<td>A genetic (G) interaction (x) between a crop variety and the environment (E)</td>
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<tr>
<td>ha</td>
<td>Hectare</td>
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<td>HCSCAA</td>
<td>House of Commons Standing Committee on Agriculture and Agri-Food (federal)</td>
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<tr>
<td>HRS</td>
<td>Hard Red Spring</td>
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<tr>
<td>HRSW</td>
<td>Hard Red Spring Wheat</td>
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<tr>
<td>HRWW</td>
<td>Hard Red Winter Wheat</td>
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<tr>
<td>HTF</td>
<td>High Total Fermentables</td>
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<tr>
<td>ICAR</td>
<td>Inventory of Canadian Agri-Food Research</td>
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<tr>
<td>IP</td>
<td>Intellectual Property</td>
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<tr>
<td>IRR</td>
<td>Internal Rate of Return</td>
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<tr>
<td>ISU</td>
<td>Iowa State University (Ames, IA)</td>
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<tr>
<td>KVD</td>
<td>Kernel Visual Distinguishability</td>
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<tr>
<td>L</td>
<td>Litre</td>
</tr>
<tr>
<td>M</td>
<td>Million</td>
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<td>MAFRI</td>
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<tr>
<td>Mt</td>
<td>Million tonnes</td>
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<td>N</td>
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<td>NDSU</td>
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<td>NIRS</td>
<td>Near-Infrared Reflectance Spectroscopy</td>
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<td>Ontario Ministry of Agriculture, Food and Rural Affairs</td>
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<td>P</td>
<td>Phosphorous</td>
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<tr>
<td>PBO</td>
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<td>PBO</td>
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<td>Prime Hard (Australian wheat class)</td>
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<td>PNT</td>
<td>Plant with Novel Trait</td>
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<td>PPY</td>
<td>Professional Person Years</td>
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<tr>
<td>QA</td>
<td>Quality Assurance</td>
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<td>RDP</td>
<td>Research and Development Projects Program (SAF)</td>
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<td>ROA</td>
<td>Rest Of Australia</td>
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<td>Rest Of the World</td>
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<td>SME</td>
<td>Small and medium-sized enterprise</td>
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<td>Strategic Vision Consulting Ltd.</td>
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<td>Tonne</td>
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<td>United Kingdom</td>
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<td>UPOV</td>
<td><em>Union Internationale pour la Protection des Obtentions Végétales</em> (International Union for the Protection of New Varieties of Plants)</td>
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<tr>
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<td>United States</td>
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<td>USDA</td>
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<td>Western Grains Research Foundation</td>
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<td>WSMV</td>
<td>Wheat Streak Mosaic Virus</td>
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</table>
References


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3 References note the location of the original research and may have been compiled from research summaries. References obtained from the World Wide Web include the original Uniform Resource Locator (url) and the date the reference was retrieved.


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