Feed grains and forage research and commercialization in Canada

Executive summary

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For:
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Introduction

The world's population is increasing by 78 million each year, and by 2030, more than eight billion people will inhabit the Earth.[1] 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.[2]

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 [3] 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.[1]

Annual gains in the global food supply have recently declined from three to one percent.[2] 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.[1] 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? [4]

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.[5]

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.[6] 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

This document is an executive summary of the full report.

Investment in research in Canada

Feed grains

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.[7] 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. With funding provided by a myriad of institutions, research tends to be project-based rather than program-based. This creates a situation in which a long-term strategy is sacrificed in favour of work directed at accomplishing short-term tasks.

With the movement away from long-term, sustainable investments in research, research funding has become institutionalized within a matching grant system.[8] In many cases, private-sector support is required before scientists can initiate new research programs. This need for private support tends to drive the research objectives towards a shorter-term, task-oriented approach. In addition, scientists need to spend a considerable amount of time selling their research proposals and filling out multiple research applications.[8] This complex array of comprehensive grant applications must be completed by the research community in order to meet the needs of the funders because each funding agency has a unique set of needs. Unfortunately, in order to comply with funders' needs, researcher scientists can often spend more time coordinating funding than actually conducting the research.

Over the very long-term, public funding for feed wheat and barley breeding has been declining slowly. Where federal sources have provided most of the investment in wheat breeding, provincial sources have been more important for barley breeding. [9] Compared to funding for wheat and barley breeding, public Canadian institutions have been investing about three times as much on improving canola varieties as they have on improving wheat and barley varieties – and this funding has been in addition to the private sector's already substantial commitment to canola breeding.

The public benefits in many ways from its investment in research and development. In 2003, Nagy calculated the economic returns based on the investments made in feed barley research at the Field Crop Development Centre (FCDC) between 1973 and 2001.[10] 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 has attributed about 52 percent of the benefit of the feed breeding program to increasing yield and 48 percent to disease resistance.[10] The overall Internal Rate of Return (IRR) for this program was 27 percent.

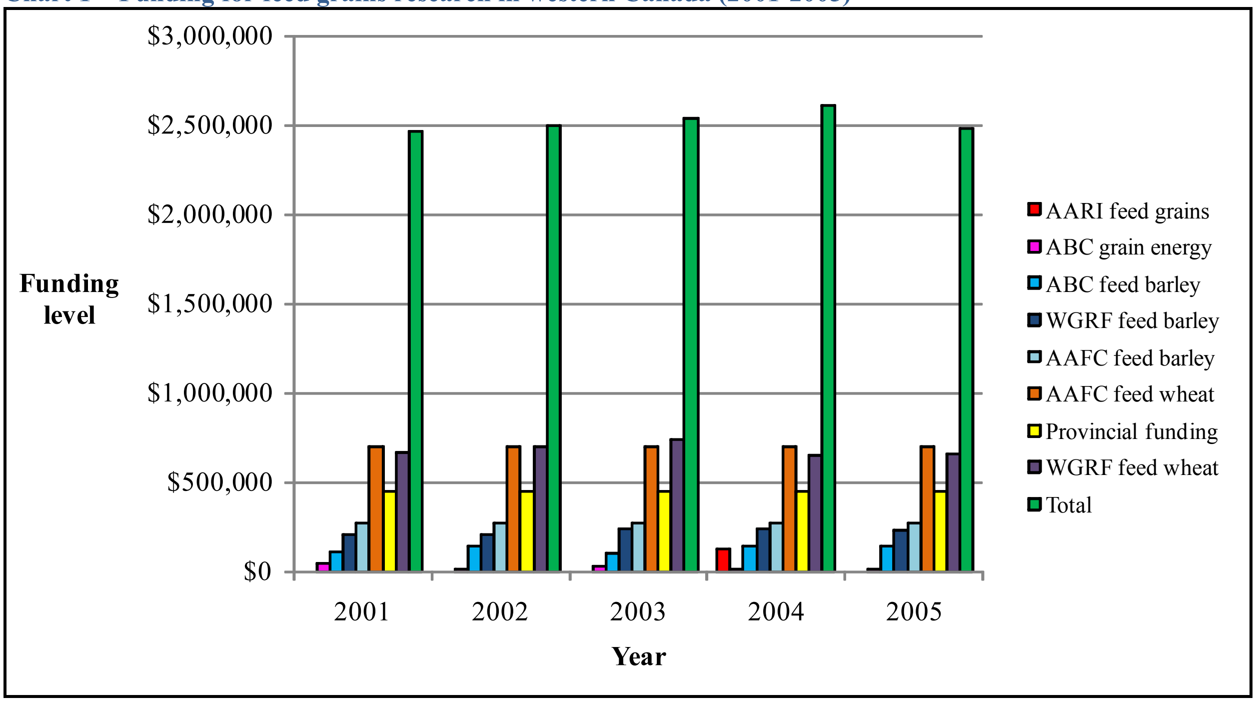
Historically, Agriculture and Agri-Food Canada (AAFC) has made the greatest contribution to feed grains and forage research of any organization in Canada. Other institutions that have made substantial investments in these areas include the Western Grains Research Foundation (WGRF) and the Alberta Agricultural Research Institute (AARI). The availability of public records makes it possible to track research investments made by these organizations; but in many cases, Strategic Vision Consulting Ltd. (SVC) could only track research investments indirectly.

In 2004, AAFC reduced the number of projects in its organization and increased the number of scientists per project 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 did not appear to be the case, although data was limited. What is notable is that by 2004 and 2005 some project teams had as many as 22 members!

SVC has estimated that barley producers sell almost 86 percent of the barley produced in western Canada as feed. With annual expenditures on barley breeding in western Canada estimated to be $4.247 million (M) [11] and assuming that 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.

With livestock feed volumes for Canada averaging 1.857 Mt between 1999 and 2000 [51] and 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*. have estimated annual expenditures on wheat breeding in western Canada at $13.837M per year.[52] 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. These data suggest that the feed breeding share of western Canada's wheat and barley breeding budget should be in the range of $4.8M per year. However, the total funding for wheat and barley feed grains research in western Canada between 2001 and 2005 only averaged slightly over $2.5M per year (Chart 1). These data suggest that barley and wheat feed breeding research is underfunded in western Canada by almost $2.3M per year.

Chart 1 – Funding for feed grains research in western Canada (2001-2005)



Source: Alberta Agricultural Research Institute, Alberta Barley Commission, Agriculture and Agri-Food Canada, Western Grains Research Foundation, Heisey *et al*.[11], Strategic Vision Consulting Ltd.

Another way of looking at investments in research is in terms of the products of research. 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. Currently, the ratio is about one-to-one – suggesting that malt barley research is being funded at a disproportionately higher level than feed barley research.

Forages

Between 1985 and 1998, research expenditures in forages declined from $41M to less than $19M.[12] 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. AAFC research scientists were 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.

As with feed grains research, forage research has been moving towards shorter-term, task-oriented projects. Funding tends to be piecemeal and of a short-term nature with little investment in infrastructure and no long-term vision. This approach has produced a research system in which the few programs left are barely able to survive.

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 Crop Development Centre (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 [13] and AAFC is not currently committed to filling these positions. If AAFC does not replace these positions, the capacity for forage research in Canada will reach new lows.

Over 20 organizations currently fund forage research in Canada.[14] Grants have ranged from $750 to $220,000 and as many as four grants have been 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 of 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 the projects depend on small groups of dedicated individuals for support. This situation has also forced forage research scientists to spend much of their time applying for grant money and preparing progress reports for many smaller, special-interest groups as opposed to receiving support from one larger granting agency.

A substantial proportion of Canadian forage R&D falls into the realm of "public good" research. There is a risk of loosing this type of public good research under the matching grants system because it is very difficult to connect public good to corporate funding and 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.

What do plant breeders need in order to be successful?

According to wheat breeders, financial resources have the greatest positive impact on genetic gains.[15] The cost of developing a new variety of cereal feed grain or a forage variety is in the range of $1-2M, and the cost of running a single mature program through a network of institutions could run up to $7M per year. 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 years.

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. Some new private CWRS programs have taken 20 years to produce their first variety, only to have the company terminate the program. The costs associated with starting new breeding programs or resurrecting old programs suggests that it would be more cost-effective to maintain existing plant breeding programs than to let the programs lapse and attempt to rebuild them later.

Plant breeders need a long-term commitment and sustained support for their programs. 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.[7] Typically, funds are available for interesting and innovative research, but there are shortfalls in funding for maintenance and the development of infrastructure.

A number of public sector plant breeders will soon have the option of retiring.[7] 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.

Who pays for investments in cereal grain and forage research in Canada? 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 for 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 from breeding these crops in Canada.

It is also important to note that the funding structure for wheat and barley breeding could change in the near future. Currently, the Canadian Wheat Board (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.

Many have noted that Canada lacks critical research funding and federal and provincial governments need to take a long-term, consistent approach to the development of crops such as wheat, barley and forages as livestock feed. For the near future, crop and livestock producers will need the support of the public sector for new varieties of feed grains and forages.

Shifting plant breeding focus from livestock feed to bioethanol feedstocks

Since Canada has positioned itself as a meat exporting country, analysts have argued that converting Canadian feed grains into bioethanol instead of into meat and livestock for export makes little economic sense [18] – 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.

Despite Canada's position as a meat exporting country and the current position of the Canada's livestock producers, Canada is moving quickly towards the development of a grain-based bioethanol industry. 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. The risk to the livestock sector is that these plant breeding program changes could alter the attributes of new crop varieties, and these newer varieties may not meet their needs.

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.[19] In this same period, ISU analysts predict corn acres will increase from 78.4M acres in 2006 to 92.5M acres by 2016 while soybean acres will drop from 75.5M acres to 68.4M acres. The model also predicts that demand for Canadian wheat will rise from 4.8 million tonnes (Mt) in 2007 to 5.8Mt 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.

Plant breeders are also starting to put more effort into triticale as a biofuel feedstock because of the yield potential in this species. 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.

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. 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.

Shifting wheat breeding resources towards the production of bioethanol will create varieties with higher energy levels and higher yield potential. Increasing wheat yields will be critical because grain producers in western Canada may not be able to make a profit growing current varieties of Canada Western Red Spring (CWRS) wheat that yield 32 to 35 bushels per acre (bu/ac) if bioethanol producers plan on purchasing only weathered, low-grade wheat.[20] Kraft and Rude have speculated that wheat yields will need to rise by at least 30 percent, to create varieties that would be economically viable as bioethanol feedstock.[21] Yield increases of this magnitude are required to offset the lower price paid for lower quality wheat. If plant breeders cannot increase wheat yields by about 30 percent, bioethanol producers would have to raise the prices paid to producers to encourage them to grow lower quality wheat for bioethanol feedstock rather than higher quality wheat for export.

It can be a challenge for plant breeders to raise wheat yields because 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.

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. Long-term wheat yield data suggests that it should be possible for Canadian plant breeders to move wheat yields substantially higher with the creation of the new Canada Western General Purpose (CWGP) class of wheat. The lowering of regulatory barriers and the complete removal of Kernel Visual Distinguishability (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.

According to the Canadian Seed Trade Association (CSTA), wheat yields have increased around 22 percent in the last 30 years.[22] Almost all of this increase has been due to improvements in crop genetics. Increasing wheat yield per unit area not only lowers the cost of production, it leaves more acres open for the production of barley and other feed grains and forages.

Barley breeding in western Canada will suffer with Alberta Agriculture and Food (AAF) closing the malt barley program at the FCDC.[23] The goal of AAF in closing the malting barley program, as it was explained to Alberta Barley Commission (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 has shifted 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. 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 Groeneveld, Minister of Agriculture and Food, that barley genomics staff have been reassigned by AAF to non-barley projects.[24]

Forages make up more than 80 percent of livestock feed in Canada and most producers use seeded forages to produce tame hay or silage.[25] Canadian producers grow substantial volumes of forage crops in all provinces outside of the Maritimes and Newfoundland and Labrador. 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.

Public and private research incentives

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.[22]

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.[26] As an example, feed barley breeding and disease resistance research funding at FCDC Lacombe between 1974 and 2001 produced 10-fold return on investment.[10] 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.[26]

Plant breeders could help meet the demand for wheat and barley varieties with specific characteristics designed to meet the needs of the livestock sector.[21] What is required are higher yielding feed barley and feed wheat varieties that produce more energy per unit of land.[25] 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.[26] 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.

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. There may be social returns from both public and private breeding programs, but furthering scientific knowledge is not necessarily profitable.[11] 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.[11] 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 for research that are a better fit the public sector than in the private sector include research in high-risk ventures.

Plant breeding responsibilities that could reside within the public system include breeding for low productivity crops,[27] "minor" [11] and small market crops,[27] cereal disease control,[28] conservation of genetic resources,[27] variety selection methodology,[11] germplasm preservation and development,[11, 28] grain science and technology,[28] pre-breeding research [27] and the training of plant breeders.[11, 28] 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).[29] Output from all three areas could be made available to all private plant genetics ventures under reasonable commercial terms.[28] There is also a need 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.

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.[11]

The public-private hybrid experiment

With pressure to cut government research program budgets in Canada, the funding model has been evolving into a "matching funds" effort, in the interest of increasing public sector "efficiency" in research.[8] 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. Research scientists in agricultural fields have noted that is it 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.[8] 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.

Return on research investment

Private plant breeding companies cannot finance costly research and development programs if they are unable to charge a sufficiently high enough price for seed,[11] or if the producer does not have to purchase new seed each year. There are jurisdictions in which 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. It presents a challenge not only for the private sector but also for Canadian public sector cereal breeders who have been running with marginally sufficient or insufficient funding for years.[7] 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.[30] 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 benefit when crop producers purchase certified seed. The use of certified seed, in turn, can benefit producers in two situations: when crops are available as hybrids and/or when farming is profitable. 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. Plant breeders, however, have found it challenging to develop economically viable hybrids from self-pollinated crops like wheat, barley and soybeans.[11] Hybrid wheat never realized commercial success on a global scale [33] and the production of hybrid barley is simply too expensive. 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.[31] Producers growing most other major field crops such as wheat and barley depend on Farm Saved Seed (FSS), and this limits seed industry growth and private sector involvement with these crops.[32]

Canada's Plant Breeders Rights (PBR) system, introduced in 1990, gives plant breeders the exclusive right to produce and sell seed in Canada for 18 years.[34] Farmers may purchase the seed, which includes a royalty. However, producers have "Farmer's Privilege" and can use FSS without paying an additional royalty. 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 [35] – not only in Canada but in most other countries around the world. Barley breeding is similarly unprofitable in Canada. This is an important issue for the Canadian livestock sector because these crops are major sources of feed grain energy.

In summary, 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.

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

Canadian grain trade competitors have increased their investments in crop development research – in recognition of the importance of R&D to commodity production and to success in global markets.[36] 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).

In self-pollinated crops such as wheat where producers use FSS to seed a large proportion of the US acres, State Agricultural Experiment Stations (SAES) dominate the breeding program with 43 percent of the breeding effort.[37] The United States Department of Agriculture (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.

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.

Forage breeding in the US is dominated by the private sector, which has 62 percent of all forage breeders. SAES and USDA have 29 and nine percent of US forage breeders, respectively.[37] Most Canadian forage sector breeding in Canada is the responsibility of three forage breeders in AAFC.

Regulatory impediments

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/Canadian Grains Commission (CGC) grade system and the protracted seed sector review.

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.[38] ***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.

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.[7] 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.

Conforming to KVD requirements means that CWRS breeders cannot take full advantage of the wider range of germplasm available.[39] Wheat breeders working with minor classes such as winter wheat face similar problems when using CWRS or Canada Western Amber Durum (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 significant 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 trans-national 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.[40] 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. 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.[41] 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.

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 that 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.[41]

The economic impact of KVD in Canada

The impact of KVD 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.[39] Canada is the only country in the world using KVD,[38] 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.[39] 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.[39] 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 calculated that full removal of KVD would increase on-farm revenue (from baseline) by $60-171M annually.[42] 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.[39] 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.

Thomas also suggests that Oleson underestimated the cost of KVD since he largely omitted pest resistance and agronomic traits from the calculations.[40] Thomas pegs CWRS yield loss due to KVD at 15 percent. Using this figure, multiplied by 14M tonnes (Mt) multiplied by a price of $200/t suggests that producers loose $420M annually on sales of CWRS alone.

With the removal of KVD, plant breeders and other scientists have 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.[42] 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.

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.[7] 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.

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.[40] 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.

Alternatives to the KVD system

The KVD system could be replaced with a statutory declaration system in conjunction with methodology that accurately determines the variety of grain.[7] Another alternative may be a system based on the quality/functionality of the wheat. A 2006 House of Commons Standing Committee on Agriculture and Agri-Food (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.[38] This recommendation coincides with a CGC announcement to change western Canadian wheat classes.[36]

Plant with Novel Trait

The Canadian Food Inspection Agency (CFIA) defines a novel trait as one that is: [43]

- 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 considered 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 trait regulations apply to any new trait – and the regulators decide what triggers novelty.

Canada is the only country in the world using this term in a regulatory context.[7] 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.

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 due to regulatory issues and the United States (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.[44]

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.[43, 45] The PNT regulations do not distinguish between different breeding methods [46] – 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.
- The Government of Canada has not harmonized a working definition within its own system.[45]
- 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.[45] This perceived lack of clarity is a concern because it may be hindering investment in plant breeding in Canada.[43]
- 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.[43] Canada's competitors do not experience these types of delays when introducing new traits into wheat and barley.

Low phytate barley

Dr. Brian Rossnagel created HB 379 low phytate barley at CDC Saskatoon through traditional plant breeding. HB 379 allows hogs to consume more phosphorous (P) while reducing the 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. The CFIA finally authorized HB 379 (CDC Lophy-I) low phytate barley in Canada as a livestock feed. However, low phytate barley will now need to be labelled with a guarantee for minimum available P and minimum total P in Canada.[45] ***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.

Because of the low phytate barley situation in Canada, most plant breeders, including those in major trans-national corporations, would be less likely to pursue the registration of similar innovative traits under current Canadian guidelines. Many innovative crop traits which are not available in Canada are currently reaching the stage of commercialization in the US. For example, livestock producers are now able to purchase corn grown from triple-stacked hybrids.[44] Hybrids produced from these new advances in corn genetics have helped raise corn yields to unprecedented levels in 2007 in the US. Triple-stacking similar traits into wheat and barley would also benefit Canadian producers. Many regulatory hurdles will need to be overcome, however, before these “triple stacked” traits that are currently available in the US become available in Canada – and US crop and livestock producers will maintain a competitive advantage over their Canadian counterparts until these regulatory issues have been resolved.

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.[46] 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.

The economic impact of PNT in Canada

Canadian citizens bear the regulatory burden of PNT regulations five ways: [47]

- 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

To summarize, 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.

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.[43, 46, 47] An effective regulatory process would provide:

- Assessments based on risk
- A clear definition of novelty which would allow stakeholders to understand what triggers novelty
- Harmonization with the rest of the world
- Shorten submission timelines that reduce the burden of evidence for approval and lower costs
- A tiered risk assessment that considers the need for a more detailed assessment. Plants that do not pose a risk to the environment would not be subject to further evaluation.
- The means of taking advantage of the scientific expertise available in Canada outside of the regulatory system.
- Good interdepartmental coordination that reduces duplication of effort, conflicting requirements and regulatory overlap.

Other important issues identified by stakeholders include a need for regulatory consistency and accountability as well as an appeal process.[46] The Plant Biosafety Office (PBO) is preparing a new directive document to facilitate streamlining of registrations; however, stakeholders have singled out the CFIA Feed Section as being particularly unresponsive to industry needs.

The seed sector review

A number of areas in the Canadian seed sector are currently under review.[48] 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.

The CFIA has been in consultations since 1998 and has been working towards major changes to the existing Variety Registration system.[48] The seed sector review is just one part of this consultative process. 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." [49] The CFIA released a three to five year strategic action plan in the fall of 2007. Another workshop is planned for March 2008. Unfortunately, the longer this regulatory review continues, the greater is the economic burden that the Canadian beef cattle industry must shoulder

Moving forward

The Canadian beef cattle sector needs to operate in a regulatory environment that balances regulatory issues with the need for Canadian producers to be competitive. The beef and beef cattle industry is a competitive, global entity, and Canadian producers are finding that competing against traditional as well as emerging competitors is becoming more of a challenge. The Canadian beef cattle industry needs to move forward with a number of initiatives in order to meet its international competitors head-on in a battle for global market share.

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. The Canadian beef cattle industry needs access to competitively-priced feed grains and forages in order to compete globally. In particular, the beef cattle industry will have to work to resolve a number of issues associated with both KVD and with PNT.

Canada, as a country, needs to reconsider the nature of its regulatory system in light of a myriad of valid criticisms that have 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.[5] 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.

Without a commitment to change on the regulatory front, funding organizations will continue to invest only in technologies that are currently acceptable within the Canadian regulatory framework. Investments in new technology that cannot be registered in a timely manner (or registered at all) in Canada will continue to drain both public and private funders' of their scarce resources. Until Canada shows a commitment to reducing the level of regulatory uncertainty, private sector research funding in agricultural technologies will continue to dwindle as corporations with global reach seek a return on their investments in more business-friendly jurisdictions.

The federal government has 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. [47, 50] The beef cattle industry would benefit from the development of alliances with these, and other, like-minded agricultural organizations with common goals.

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 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." [16] This is clearly the case in the area of feed grain breeding where the private sector is not currently involved in the large-scale breeding of wheat, barley or forages in Canada.

The consensus at the HCSCAA hearings was that investment in Canadian agricultural research lags behind its competitors [17] – and Canada would likely loose its competitive advantage if this trend continues. Stakeholders suggested that the grain industry in particular had an ineffective R&D strategy. HCSCAA recommended in its committee report in June 2007 that AAFC put more emphasis on farmers and primary production.

Barley breeders are responding to market signals in the same way as wheat breeders – by meeting the needs of 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.

In addition, 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.

References[1]

1 VOAnews. 2007. *Demand for animal products may double in 20 years.* The Poultry Site Latest News. Retrieved December 20, 2007 from http://www.thepoultrysite.com/poultrynews/13085/demand-for-animal-products-may-double-in-20-years

2 Leask, B. 2005. *Innovation and the seed sector*. Meeting Presentation from the National Forum on Seed. July 27, 2005. Winnipeg, Manitoba. Retrieved August 28, 2007 from http://www.nationalforumonseed.com/news-e.html.

3 Food and Agriculture Organization of the United Nations. 2001. FAOSTAT Database. Provisional 2000 Production and Production Indices. Retrieved November 1, 2007 from http://apps.fao.org/.

4 Meristem Information Resources Ltd. 2005. *The elephant in the room*. Perspective on crop development – January 2006. Retrieved November 1, 2007 from http://www.meristem.com/developRpt/CropDevelopmentReport05.pdf.

5 Canadian Seed Trade Association. 2006. *Innovation in agriculture*. *The contribution of the Canadian seed sector*. Submission to Honourable Mark Wartman, Minister of Agriculture, Government of Saskatchewan. Retrieved August 27, 2007 from http://cdnseed.org/pdfs/Submission%20to%20Sk%20%20Minister%20September%202006.pdf.

6 Mussel, A. and L. Martin. 2007. *Ethanol as public policy in Canada: understanding the broader policy context.* George Morris Centre. Retrieved December 19, 2007 from http://www.georgemorris.org/GMC/Publications/_PublicationPage.aspx?lID=295

7 GrainTek. 2007. *Improving the competitiveness of western Canadian cereal grain crops*. Retrieved October 14, 2007 from http://www.acidf.ca/files/focus/keith.pdf.

8 Van Acker, Rene. 2004. *Research of the public, by the public and for the public*. Manitoba Alternatives, published by the Canadian Centre for Policy Alternatives, 2004. Retrieved August 28, 2007 from http://www.forumonpublicdomain.ca/node/46.

9 Western Grains Research Foundation. 2007. *Barley check-off fund*. Retrieved September 4, 2007 from http://www.westerngrains.com/barley/b_check.html.

10 Nagy, J. G. 2003. *Economic returns to feed barley yield-increasing and disease resistance research at the Alberta Field Crop Development Centre.* Can. J. Agric. Econ. 51: 281-298.

11 Heisey, P.W., C.S. Srinivasan and C. Thirtle. 2001. *Public sector plant breeding in a privatizing world.* Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Agriculture Information Bulletin No. 772.

12 Thomsen, J., R. Ewing, K. Shukla. 2000. *Documentation and analysis of the economic benefits of public research of forages in Canada*. The Thomsen Corporation. Ottawa, CA.

13 Agriculture and Agri-Food Canada. 2006. *Forage research review*. *Briefing book.* Calgary, Alberta. February 6-8, 2006.

14 Canadian Cattlemen’s Association. 2004. *Beef and forage research in Canada*. Retrieved October 24, 2007 from http://www.wbdc.sk.ca/bfric/catlist.php.

[1] 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.

[15] Western Grains Research Foundation. 2004. *Wheat breeders aim high on yield*. Western Grains Industry Report. April 2004. Retrieved November 9, 2007 from http://www.westerngrains.com/news/ir_404a.html.

[16] Agriculture and Agri-Food Canada. 2006. *Science and innovation strategy*. Retrieved October 2, 2007 from http://www.agr.gc.ca/science-strategy.

[17] Standing Committee on Agriculture and Agri-Food. 2006. *Report on the review of the Canada Grain Act and the Canadian Grain Commission.* Compass Inc. Retrieved October 26, 2007 from http://cmte.parl.gc.ca/Content/HOC/committee/391/agri/reports/rp2564356/agrirp05/05-rev-e.htm.

[18] Mussel, A. and L. Martin. 2007. *Ethanol as public policy in Canada: understanding the broader policy context.* George Morris Centre. Retrieved December 19, 2007 from http://www.georgemorris.org/GMC/Publications/_PublicationPage.aspx?lID=295

[19] Pratt, S. 2007. *Ethanol industry may open new feedgrain markets*. The Western Producer. Retrieved September 15, 2007 from http://www.producer.com/free/editorial/markets.php?iss=2007-06-14&sec=markets&sto=31.

[20] Alberta Pork. 2006. *Expanded grain based biofuel production causes concern among livestock feeders*. Farmscape Article 2241. September 9, 2006. Retrieved September 15, 2007 from http://www.albertapork.com/news.aspx?NavigationID=2345.

[21] Kraft, D. and J.I. Rude. 2002. *Feed grains and ethanol processing in Manitoba*. Public consultation on expansion of ethanol industry. Manitoba Ethanol Advisory Panel. September 19, 2002. Retrieved October 29, 2007 from http://www.umanitoba.ca/afs/agric_economics/info/EthanolPaperSept2002.pdf.

[22] Canadian Seed Trade Association. 2006. *Innovation in agriculture*. *The contribution of the Canadian seed sector*. Submission to Honourable Mark Wartman, Minister of Agriculture, Government of Saskatchewan. Retrieved August 27, 2007 from http://cdnseed.org/pdfs/Submission%20to%20Sk%20%20Minister%20September%202006.pdf.

[23] Honourable George Groeneveld, Minister of Agriculture and Food, Alberta Agriculture and Food. 2007. *Letter to Mr. Terry Young, Chair, Alberta Barley Commission*. Retrieved October 18, 2007 from http://www.albertabarley.com/policy/2007%20docs/Groeneveld's%20response.pdf.

[24] Alberta Barley Commission. 2007. *Letter to Honourable George Groeneveld, Minister of Agriculture and Food, Alberta Agriculture and Food*. Retrieved October 18, 2007 from http://www.albertabarley.com/policy/2007%20docs/meeting%20request.pdf.

[25] Small, E. 2006. *Forage crops*. The Canadian Encyclopedia. Retrieved November 8, 2007 from http://thecanadianencyclopedia.com/index.cfm?PgNm=TCE&Params=A1ARTA0002890.

[26] Leask, B. 2005. *Innovation and the seed sector*. Meeting Presentation from the National Forum on Seed. July 27, 2005. Winnipeg, Manitoba. Retrieved August 28, 2007 from http://www.nationalforumonseed.com/news-e.html.

[27] Frankck, S.L. and P. Frannck. 2001. *The role of small and medium size private breeding companies in germplasm development*. ***In*** Z. Bedo and L. Lang (Eds.) Developments in plant breeding – wheat in a global environment. Proceedings of the 6th International Wheat Conference, 5-9 June, 2000, Budapest, Hungary. Klewer Academic Publishers. p. 117-124.

[28] Kent, T. 2003. *Wheat breeding – will commercial breeders be different? Commercial plant breeding and the role of public and industry funded R&D*. Retrieved November 1, 2007 from http://www.longreachplantbreeders.com.au/links/new_commercial_focus.pdf.

[29] C&N Partners Inc., GrainTek and Strategic Vision Consulting Ltd. 2007. *Cereal competitiveness in western Canada – executive summary.* Retrieved October 29, 2007 from http://www.acidf.ca/files/focus/exe.pdf.

[30] Bank of Canada. 2007. *Inflation calculator*. Retrieved November 8, 2007 from http://www.bankofcanada.ca/en/rates/inflation_calc.html.

[31] Fuglie, K., N. Ballenger, K. Day, C. Klotz, M. Ollinger, J. Reilly, U. Vasavada and J. Yee. 1996. *Agricultural research and development: public and private investments under alternative markets and institutions*. Agricultural Economic Report Number 735. USDA, Economic Research Service.

[32] McMullen, N. 1987. *An introduction to seed production.* NPA Report Series No 227. National Planning Association.

[33] Blom, N. 2007. *Monsanto struggles to recover costs of hybrid wheat seed in South Africa.* African Agriculture Friday, June 8, 2007. Retrieved November 8, 2007 from http://africanagriculture.blogspot.com/2007/06/monsanto-struggles-to-recover-costs-of.html.

[34] Canadian Food Inspection Agency. 2007. *Guide to Plant Breeders' Rights*. Retrieved November 9, 2007 from http://www.inspection.gc.ca/english/plaveg/pbrpov/guidee.shtml#a72.

[35] Frankck, S.L. and P. Frannck. 2001. *The role of small and medium size private breeding companies in germplasm development*. ***In*** Z. Bedo and L. Lang (Eds.) Developments in plant breeding – wheat in a global environment. Proceedings of the 6th International Wheat Conference, 5-9 June, 2000, Budapest, Hungary. Klewer Academic Publishers. p. 117-124.

[36] Meristem Information Resources Ltd. 2005. *The elephant in the room*. Perspective on crop development – January 2006. Retrieved November 1, 2007 from http://www.meristem.com/developRpt/CropDevelopmentReport05.pdf.

[37] Morris, M., G. Edmeades and E. Pehu. 2005. *The global need for plant breeding capacity: what roles for the public and private sectors?* Proceedings of the Symposium Plant Breeding and the Public Sector: Who Will Train Plant Breeders in the U.S. and around the World? Michigan State University, 9–11 March 2005.

[38] Standing Committee on Agriculture and Agri-Food. 2006. *Report on the review of the Canada Grain Act and the Canadian Grain Commission.* Compass Inc. Retrieved October 26, 2007 from http://cmte.parl.gc.ca/Content/HOC/committee/391/agri/reports/rp2564356/agrirp05/05-rev-e.htm.

[39] Bole, Jim. 2006. *KVD as an impediment to wheat development*. Appendix to report on the review of the Canada grain act and the Canadian grain commission. Compass Inc. Retrieved October 26, 2007 from http://cmte.parl.gc.ca/Content/HOC/committee/391/agri/reports/rp2564356/agrirp05/10-appd-e.htm.

[40] Thomas, Julian. 2006. *A technical critique of the western Canada Quality Assurance (QA) system in wheat*. Appendix C Parliamentary Report. Retrieved October 26, 2007 from http://cmte.parl.gc.ca/Content/HOC/committee/391/agri/reports/rp2564356/agrirp05/09-appc-e.htm.

[41] Western Grains Research Foundation. 2004. *Comparing Canada to the world.* Western grains industry report. April 2004. Retrieved November 9, 2007 from http://www.westerngrains.com/news/ir_404c.html#3.

[42] Oleson, B. 2003. *Variety eligibility declaration (VED) Update Report. Kernel Visual Distinguishability (KVD). Identifying the benefits of moving away from KVD*. Retrieved November 20, 2007 from http://www.grainscanada.gc.ca/Pubs/committee_reports/ved/oleson_sec2_a_01-e.htm.

[43] National Forum on Seed. 2007. *Meeting report*. Ottawa, March 26, 2007. Retrieved September 16, 2007 from http://www.nationalforumonseed.com/documents/Forum_Mtg_Report_March-26-2007.pdf.

[44] Nelson, S. 2007. *Corn yields soar thanks to stellar genetics*. Reuters UK Thursday October 4, 2007. Retrieved December 19, 2007 from http://uk.reuters.com/article/oilRpt/idUKN0435107520071004U.S.

45 Morrison, Linda. 2007. *Letter to University of Saskatchewan, Crop Development Centre re: HB379 barley variety.* Canadian Food Inspection Agency.

46 Ag-West Bio Inc. and U. of Saskatchewan. 2007. *Canada's regulations for novelty in plants, feeds and food. Final workshop report*. June 8, 2007. Saskatoon, SK. Retrieved November 20, 2007 from http://www.agwest.sk.ca/regulations/documents/070608%20AgWestBio%20Novelty%20Workshop%20Final%20Report.pdf.

47 Ravelli, Ross. 2007. *Presentation to the Standing Committee of Agriculture and Agri-Food*. *March 27th, 2007.* Grain Growers of Canada. Retrieved November 18, 2007 from http://www.ggc-pgc.ca/en/press_releases/2007/HoC_March_27_2007.pdf.

48 Agriculture and Agri-Food Canada. 2004. *Plant breeding in western Canada*. Bi-weekly Bulletin. November 26, 2004. Vol. 17. No. 17. Retrieved November 12, 2007. http://www.agr.gc.ca/mad-dam/index_e.php?s1=pubs&s2=bi&s3=php&page=bulletin_17_17_2004-11-26.

49 Canada Food Inspection Agency. 2007. *Overview and update of the seed program modernization initiative- fall 2007.* Retrieved November 13, 2007 from http://www.inspection.gc.ca/english/plaveg/variet/revetu/falaute.shtml.

50 Lesley, Mike. 2007. *Letter to Honourable Rona Ambrose, President, House of Commons Privy Council re: Regulatory issues involving plant novel traits (PNT) and their impact on innovation.* Alberta Barley Commission. Retrieved November 14, 2007 from.http://www.albertabarley.com/policy/2007%20docs/Treasury%20Board%20letter%20RE.%20PNT.pdf.

51 Agriculture and Agri-Food Canada Market Analysis Division. 2005. *Canadian feedgrain consumption*. Bi-weekly Bulletin. Volume 16. Number 8. Retrieved December 13, 2007 from http://www.agr.gc.ca/mad-dam/index_e.php?s1=pubs&s2=bi&s3=php&page=bulletin_16_18_2003-10-10.

52 Western Grains Research Foundation. 2001. Calculated from data reported by WGRF as cited by Heisey *et al*.[11]