Draft Background Document Only. Expect Summary Report in mid September.

Improving the Competitiveness of W. Canadian Cereal Grain Crops

An Initiative by ACIDF and AARI

Sub-project: Review of W. Canadian Public Sector Cereal Grain Crop Breeding Programs and Priorities, with an Emphasis on Bio-energy Market Requirements

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EXECUTIVE SUMMARY

In February, 2007 GrainTek was assigned the task by the Alberta Crop Industry Development Fund (ACIDF) and the Alberta Agricultural Research Institute (AARI) to develop an inventory of ongoing public cereal breeding programs and projects in Western Canada, to determine which breeding goals would be most important to make a significant difference to the competitiveness of Canadian cereals in the future. This task was a subset of a larger ACIDF / AARI project to set the stage for new investments in cereal genetic development, with the goal….'to improve Western Canadian crop production competitiveness for both livestock and renewable fuels industries'. GrainTek was also asked to prioritize breeding opportunities in relation to the two bio-energy market uses, in consultation with C & N Partners Inc., and Strategic Vision Consulting Ltd.. This report presents the findings of the GrainTek study.

Information to complete the task was obtained from all W. Canadiapubliccereal breeders and their institutions through personal and phone interviews, questionnaires, specially requested reports and annual reports, web pages, e dialogue, visits to research centers, and by attendance at plant breeding and bio-fuels meetings from February to May, 2007. A comprehensive inventory was developed, that includes all cereal breeding projects based on available information, and also includes market goals other than for bio-energy. Information about fall and spring rye programs was unavailable within the timeframe, and there are no public corn breeding programs in W. Canada. Forty two active, public, cereal crop breeding programs were identified, for different classes of spring and winter wheat, spring and winter triticale, barley, oat, and spring and fall rye. Within those programs a total of more than 120 specific breeding projects were inventoried. The review focused on identifying cereal breeding program goals that would really make a difference to the future competitiveness of W. Canadian grown cereals, and the identification of constraints to achieving those goals.

Thirty nine significant breeding opportunities or constraints were identified. Commentary about each was provided by GrainTek, including a special evaluation of the importance of Priority 1 disease resistances as a necessary constraint to cereal variety development. Items were categorized into 'Blue sky' (= visionary) opportunities (6), Regulatory constraints (4, but of major consequence, including KVD (kernel visual distinguishability) and PNT (plants with novel traits) issues), Breeding program infrastructure limitations (17, the largest category), and Specific genetic opportunities within programs (12). Listings organized by category are found in Section 6 of the report. A large majority of projects placed disease resistances, especially for Fusarium head blight and related DON toxin levels, at a high priority level in all cereal crops, because of potential productivity losses and loss of value in harvested grain. A number of the suggestions focused on opportunity for new crop types with improved varieties to emerge and / or be adopted on large acreage, or to be created through application of new crop technologies. Examples included: (a) Breeding investment in winter wheat and winter triticale improvement to bring W. Canadian acreages perhaps up to 30% of cereal acreage in the future; (b) Improved spring triticale and hulless barley varieties, to take advantage of high yield potentials and improved nutritional quality as feed; (c) Breeding support for

newly emerging cereal feed crop types , such as the CDC LLH-HOG (= low acid detergent fibre hull high groat fat). This new type is a hulled feed oat, with similar feed value to barley and lower production costs, of particular feed interest for use with high quality dairy, domestically and for export, projected to potentially reach 1m acres in production; (d) Completely new crops, created by application of all the newest breeding technologies, such as a perennial triticale for feed, forage and biomass production.

Estimates of likely rates of gain for yield for all cereals in the next 5 to 10 years were all optimistic, often better than rates of gain thus far, and especially for winter cereals, CPS wheat, forage barley and soft white spring wheat, especially if breeding budgets are increased. The caveat for yield improvement in wheat classes was that this would depend on removal of KVD as a requirement in high yielding wheat types. The following crops were ranked as a group (albeit with variable opinion) as having the highest potential for playing a significant role in the W. Canadian bio-energy sector in the future, either for feed and / or bio-fuels: Winter wheat, hulled barley, CWGP wheat, winter triticale, CPS wheat, and hulless barley. (Absence of spring triticale from this list was a surprise, as past W. Canadian research indicates it is very suitable for both uses). The absence of soft white spring wheat from this list was also a surprise, at variance with current interest of bio-ethanol plants in this low protein, high yielding crop type). GrainTek opinion is that both spring triticale and soft white spring wheat are important candidates for consideration for the emerging ‘grains for ethanol’ production industry.

Without exception, all responses emphasized the importance of long-term continuity of support for the core infrastructures of breeding programs, for breeder positions, career oriented technical staff, phenotyping and genotyping capacity, facilities and equipment. With strong infrastructures in place, new breeding traits or goals can readily be accommodated in response to new market demands. By contrast, short-term funding of narrow focus breeding targets may result in inefficiency and discontinuity for genetic progress, and does not promote development of long-term W. Canadian breeding capacity or competitiveness, even for the designated goal.

Annual investments in the tens of millions $ per year would probably be needed to remove all of the noted infrastructure shortfalls for cereal breeding in W. Canada. Several suggestions focused strongly on the need to develop human resources to staff public breeding programs in the future, especially to replace plant breeders now near retirement, and to replace positions recently closed. In one case a proposal was made to establish a multi-institutional W. Canadian Triticeae Excellence Center supporting cereal breeding, with three Chairs with related support to be placed one each at the Universities of Alberta (Plant Functional Genomics), Saskatchewan (Cereal Stress and Adaptation Physiology), and Manitoba (joint with AAFC, Cereal Pathology). Such an investment, supplementing other excellences found in existing breeding programs, would re-establish W. Canada at the forefront of international competitiveness in cereal research and breeding, for the benefit of Canadian producers.

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SECTION 1 PROJECT SCOPE AND DELIVERABLES

Project Deliverables, and Process, including GrainTek commentary re project expectations

1. Consult with all Western Canadian based public sector based cereals germplasm and breeding programs in wheat, barley, oats, triticale, rye, and corn

GrainTek commentary: GrainTek expected that individual breeders would readily respond to one-on-one contact from GrainTek for addressing and completing a series of questions that was prepared by the steering committee. A questionnaire approach to this gained almost no response from individual breeders, including negative response about the entire process and why it was even being undertaken, in some cases. An additional issue was the timing of the project start-up, which was just before breeders were presenting their materials for review at the February, 2007, Prairie Grain Development Committee meetings, and departure for winter breeding nurseries. Alternative approaches were thus put in place with the assistance of Alan Hall, so that Ms Dorothy Murrell (Research Manager of CDC, University of Saskatchewan) offered to provide collated information re CDC breeding program priorities, and Dr. Jeff Stewart (Science Director, AAFC, Crop Genetic Enhancement, Sustainable Production Systems) agreed to do the same for all W. Canadian AAFC cereal breeding priorities, the latter to be completed by April 15, 2007. The latter date presented cause for delay of project completion beyond the control of GrainTek.

Information from other programs was gained to the extent possible by one on one contact of GrainTek with breeders, including a visit with Alan Hall to the AAF breeding group at Lacombe, and a GrainTek visit to AAFC, Lethbridge. The level of detailed information that was made available from all sources was not necessarilyas complete as desirable for this process, especially in regard to staffing numbers and budgets. Such detailed information would have to be obtained in a follow-up process, in select breeding areas where this initiative identifies high priority.

Other methods of information collection included extensive web searches, review of existing project and program reports where available, and review of awards granted by research agencies, as available. Due to the scattered nature of the information needed for this review, it is possible that one or two breeding projects or initiatives may have been missed, especially as new projects are continuously being proposed and approved for funding. GrainTek also attended biofuels theme conferences held in Alberta during the project period, and the PGDC variety registration meetings in Saskatoon, in February.

Detailed project objectives for the review of public breeding programs (with GrainTek commentary)

a) Identify their program's most important germplasm and breeding objectives both now and in future with identification of the markets being targeted

   <u>GrainTek observations:</u> Whilst general breeding objectives were usually well described, the extent of detailed information made available about relationships to specific market needs was limited. In the case of wheat, program goals were set to respond to recommendations flowing from existing CWB and CGC marketing goals, which are well known and available on the web. AAFC and CDC priorities for breeding are substantially linked to the contractual requirements for use of checkoff funds made available through WGRF. GrainTek self-assessment of its achievement of this project goal is 'Very good' for program descriptions, but 'Patchy' with respect to the description of the linkages with the markets. GrainTek found no program where breeding goals / objectives were unrelated to general market needs. Several specialty cereal grain breeding programs for specialty markets were noted.

b) For their program, identify the most valuable future genetic step change for each crops competitiveness, why, and barriers to be overcome

   <u>GrainTek observations</u>: In investigations by GrainTek there appeared to be a reticence to identify 'step change' opportunity as a deliverable breeding goal. Most goals were set around solving genetic deficiencies of the moment, and any novel goals for future genetic delivery were seen as already captured in specific breeding projects already funded under special projects of the different programs. The comment 'there is no magic bullet to chase' was often heard. Most breeders indicated that genetic progress comes from incremental improvements of the entire program over time, not from 'step changes'. In terms of inputs received, project response to the review goal for this concept was minimal to zero, and even described by several as conceptually inappropriate.

c) Identify existing germplasm with most potential for major energy yield increase (yield and energy content)

   <u>GrainTek observations:</u> Only limited response was received to this very specific request for information, and identification of specific, named germplasm to build on was not generally provided. Useful information about differences between crop types, and general yield levels in different cereal grain types was received. A Phase II dialogue would be needed with breeders in crop types of priority interest to this project, to identify specific germplasm. This goal was generally not achievable at the

specifically identified germplasm level in the current project, but lists of the highest yielding registered varieties are provided.

(d) Identify other key trait changes that they are working on or will be working on in future within each crop in their program to significantly advance that crops competitiveness

GrainTek observations: GrainTek was able to complete a comprehensive review and analysis for this objective, and has compiled an up-to-date inventory.

e) Identify unique technologies and capacities that will make their crop breeding program successful in advancing cereals competitiveness

GrainTek observations: GrainTek was able to complete a comprehensive review and analysis for this objective, even though individual institutions did not necessarily highlight their own areas of strength.

f) Identify current resources, finances, and partners in their program

GrainTek observations: Following discussions with Alan Hall and with Carman Read, this part of the review was de-emphasized, as there was considerable resistance by breeders / institutions to take the time to develop this database within the timetable of the ACIDF / AARI project . Where project partnership information was received, it was included in the report, but it is fragmentary. Almost every breeder with a large program was found to have tens or dozens of individual collaborators, both national and international, but listings of these were not included as they contribute no clarifying insight into the project review objectives.

g) Identify special steps that they use to set their program goals to ensure program outputs will meet the priority needs of existing and future markets and industry end users

GrainTek observations: AAFC, AAF, CDC and the other Universities all have different methods for setting cereal grain breeding goals in relation to market needs, and most of these have well developed managerial systems / processes for determining their own institutional priorities. Much of what is done, especially in the University programs, is determined by access to external funds, especially check-off funds, and is fully accountable to the research agencies and to sponsoring industry. These dependencies are so strong, but also so patchwork in nature, that a separate, comprehensive review of the funding structure of all W. Canadian cereal grain breeding programs would be worthwhile.Such a review should include analysis of the influence of matching fund availability for influencing the nature of long-term plant breeding investments in relation to the industry oriented market needs of all of W. Canada. This review could also address overall and individual breeding program infrastructure and capacity for joint use by all W. Canadian cereal programs. The GrainTek review identified a strong but unsurprising link between breeding goals, end-user interests of industry, and ability to gain project based funding for those goals. This linkage expresses itself in approval or non-approval for specific breeding projects within programs. Decisions made at this level, not by the breeder alone, determine the future competitiveness of the particular grain crop. Notable exceptions to this linkage were the Canadian food and milling industry, and the feed and livestock industry, who are major users of domestic cereals. Access to information for completion of this project goal was variable in success, depending on the organization reviewed.

h) Identify intellectual property issues and possible solutions that are barriers to their program's germplasm and variety developments, and/or ability to partner with others in those developments

<u>GrainTek observations:</u> IP issues do arise, but are just another item that breeders have to consider in setting their work priorities and strategies. Information received by GrainTek did not reveal any insurmountable IP barriers to crop breeding progress. Solutions vary from establishing partnerships or licenses to capture the IP, to inventing around the IP barrier. An international trend in the direction of reduced germplasm exchange is evident, but was not flagged as a major issue in this review. Project review in this area was successful. AAFC has a fulltime office that looks after IP.

i) Identify barriers/issues they experience or anticipate experiencing in future in being successful along with possible solutions

<u>GrainTek observations:</u> Contributors and GrainTek indicated the presence of significant regulatory barriers to major increases in yield and energy production in cereals, as well as a number of infrastructure shortfalls that could limit genetic progress. Project completion in gaining information in this area was successful.

j) Identify gaps that exist in their capacity and capability that investments could address to improve cereal crop platform productivity for energy

<u>GrainTek observations:</u> From all the materials received and otherwise reviewed, GrainTek has been able to identify a number of gaps that can be addressed, as well as breeding opportunities that have not been fully grasped.

2. Provide an executive summary of findings along with a more detailed report that provides supporting analysis and recommendations. This to include identification and prioritization of short term genetic investment opportunities to

improve livestock feed and ethanol manufacturing competitiveness. Information and data collected in this project can be appendixed

GrainTek observations: Project completion in this area was successful and includes recommendations made directly by project collaborators, as well as by GrainTek directly.

3. Work with C&N Partners INC and Strategic Vision Consulting Ltd to merge findings, analysis and recommendations into one report on cereals competitiveness. Delivery is defined as professionally formatted electronic reports as identified above, in Microsoft Word and/or Corel Draw compatible formats. These, including supporting documentation, are to be provided to ACIDF and AARI.

   GrainTek observations: Completion of this phase is expected within 7 days of completion of and access to all three draft individual reports by GrainTek, C&N Partners INC and Strategic Vision Consulting Ltd

SECTION 2 W. CANADIAN CEREAL BREEDING PROGRAMS

Inventory of public Canada cereal grain breeding programs:

This section summarizes the institutional locations of public cereal breeding programs and special projects located in W. Canada, as funded March 2007. It should be noted that this breeding effort is generally further supported by other public and private institutional research programs and multi-institutional research networks, some directed to specific goals of the programs, others directed to genetic discovery at a more basic level. These include breeding for durable disease resistances, development of biotechnical and molecular approaches to improving selection methods for all traits, studies about future grain quality requirements, and physiological studies concerning stress tolerance and adaptability to variable biotic and abiotic stresses. Most of this kind of work now requires involvement of several institutions with complementary research capabilities. Research project teams to address particular breeding challenges are usually assembled according to the nature of the research project objectives, with the breeding program itself (the putative delivery point for successful findings) being a relatively small but vital part of the whole project. Some of the resultant teams are completely internal to an institution, and others include external members.

In the case of wheat breeding, programs up to 2007 have been typically very distinct from each other in the types of germ-plasm background used, with programs with different class and quality objectives being kept relatively separate from one another. Different Kernel Visual Distinguishability (KVD) requirements existed until 2006/2007 for every wheat class type. Registration standards for the new class Canada Western General Purpose (CWGP) were set at the February 2007 meetings of the Prairie Grain Development Committee (PGDC) held in Saskatoon. The CWGP class has no defined quality standards required as of March 2007, but has the KVD requirement of zero tolerance for kernels that resemble either the Canada Western Red Spring (CWRS) or Canada Western Amber Durum (CWAD) kernel type. CWGP can include both spring and winter types. Previous programs that were breeding for the classes Canada Prairie Spring (CPS, red or white), Canada Western Soft White Spring (CWSWS), winter wheat, or Canada Western Extra Strong (CWES) can still target those classes (although Canadian Wheat Board marketing and most breeding of the CWES class has now ceased). The products from such programs can also be marketed as CWGP as long as the KVD requirement is met. Revised target registration standards for disease response have also been prepared for all wheat classes including the new CWGP class, and standards for the latter class are expected to be soon added to the website at www.pgdc.ca

The above preamble to Tables 1 - 2, which indicate program locations and scope, is presented because the creation of the CWGP class has now resulted in some blurring of what were very distinctive wheat breeding classes, and separate programs. Program structures are now in transition as breeders respond to an opportunity to greatly broaden the germplasm base of CWGP in particular, particularly to seek a significant increase in yielding ability in this class, whether in the spring or winter types. KVD requirements are still in place for this new class, and were already shown at the 2007 PGDC meeting to be a significant barrier to yield progress even in this completely new class. This is especially the case for winter wheat, where Dr. Brian Fowler (CDC, University of Saskatchewan) has drawn attention to his opinion that, despite significant proven yield improvements in lines tested in the winter wheat Coop trials, no new winter wheat varieties have been released from the last $11m investment in breeding in this class, because every line offering significant yield increase has failed the KVD requirement. This restriction applies to any winter wheat designed for release as CW General Purpose wheat, where the tolerance for kernels that resemble CWRS or durum wheat is zero. It also continues to be a problem for any class or potential variety of high yielding spring wheat that is not CWRS or durum.

Table 1 Summary of all public W. Canadian cereal breeding programs, by institution and crop, April 2007

Abbreviations:

CW	Canada Western
CWRS, CWHWS	CW Red Spring, CW Hard White Spring
CWES	CW Extra Strong (mostly discontinued except for wind – down)
CWSWS	CW Soft White Spring
CWGP	CW General Purpose
HRWW	Hard Red Winter Wheat

		Winter wheat	**Special targets**
U of Manitoba	Brule-Babel (plus Lamari, Fernando)	Winter wheat	Genetics, mapping and breeding of disease resistance, including FHB, stem and leaf rust, and leaf spots; Genetics of herbicide resistance in weeds; Germplasm development – leaf spots; Evaluating wheat for feed; KVD issues; Use of doubled haploids; FHB genomics (with Germany); High yield, disease resistant winter wheats with FHB resistance, for bioethanol use in high moisture regions
U of S	Fowler	Winter wheat	High yield, low protein; Disease resistance; KVD issue; Semidwarfs for high yield areas, tall varieties for drought stress areas; Winter hardiness / cold tolerance studies; Collaborative molecular selection methods
AAFC / LRC	Graf	Winter wheat	1. HRWW with 5%> yield than AC Buteo, winter hardy, drought tolerant, strong straw, high test weight, CWRW Select quality; Resistant to at least 2 of stem rust, leaf rust, wheat curl mite, common bunt and Russian wheat aphid; 2. High yielders for feed grain if agronomics and disease resistance OK
FCDC / Lacombe	Salmon	Winter wheat	Improved winter hardiness, high yield, semidwarf types; Diseases resistance (snow mold, tan spot, rusts, take-all root-rot), milling quality (red and white), sprouting resistance = best spring wheats, drought tolerance, broadening germplasm base, forage yield, KVD issue
		Spring wheat	
U of Alberta	Spaner	CPS / CWGP	Low protein, high yield for biofuels / feed; Weed competitiveness / Organic production; KVD requirements as

			legislated; FHB resistance for biofuels; leaf spot and stripe and other rust resistances; N use efficiency; N use efficiency
U of Manitoba	Brule Babel, + Humphreys, Somers (A	CWHW	New genetic sources for sprouting resistance in hard white wheat, including identification of QTL molecular markers (MSc research, Mr. Rasul)
U of S / CDC	Pozniak	CPS / CWGP	Program is 90% red and 10% white CPS, including targeting of the ethanol and feed industry. Need high yield, acceptable end-use quality traits, and improved disease and pest resistance; KVD requirements as legislated
AAFC / Swift C.	DePauw	CPS / CWGP	1. By 2009 10%> yield than AC Crystal, with strong gluten and good milling and end use quality, OK KVD, pre-harvest sprout resistance, resistance to leaf rust, stem rust, common bunt, leaf spots, FHB (Score 33%< AC Crystal), and orange blossom midge. 2. By 2014 15%> yield AC Crystal, plus everything same as above, FHB scores = HY644 or better than AC Barrie
AAFC	Team	Hard white spring wheat	Yield 15% > Katepwa with equal protein, improved strength and better noodle making, resistant to leaf rust, stem rust, loose smut, bunt, leaf spots, FHB and wheat midge, grade protection = Katepwa.
AAFC / LRC	New staff	SWS	By 2009 Yields 15% > AC Reed plus resistance to diseases (stripe rust, powdery mildew, leaf rust, blackpoint), plus pre-harvest sprouting and superior end-use quality. Transfer Sumai 3 and Frontana FHB resistance genes into soft white wheat genetic background.
AAFC / CRC	Team	CWRS, Eastern Prairies	1. 10%> yield than AC Barrie, same protein, resistant to leaf rust, stem rust, loose smut, common bunt, leaf spots, FHB (scores 75% < AC Barrie), and Orange blossom wheat midge;, + improved grade protection; 2. By 2014 15%> yield than AC Barrie, plus all above and durable midge and leaf rust resistance
AAFC / SPARC	Team	CWRS, Semi-arid Prairies	1. 10% (12%)> yield than AC Barrie, same protein, resistant to leaf rust, stem rust, loose smut, common bunt, leaf spots, FHB (scores 75% < AC Barrie), and Orange

			blossom wheat midge, + improved grade protection; 2. Solid stem sawfly resistant with 8% (12%) > yield than AC Abbey with disease resistance package + drought tolerance and FHB scores 25% better than AC Abbey.
AAFC / CRC	Team	CWRS, Northern Areas	2 days earlier than Katepwa, with improved grade stability (weathering resistance, staining, retention of kernel color, test weight and sprouting resistance), yiled increased by 10% with same protein content
AAFC	Team	CWES	Further development discontinued
U of Alberta	Spaner	CWRS	Early maturity; Low input production; Weed competitiveness; Organics; Baking quality; FHB resistance, leaf spot and stripe and other rust resistances; N use efficiency
U of S / CDC	Hucl	CWRS	Midge resistance; Stress resistance; Sprouting resistance; Out-crossing studies; Organic production; CLEARFIELD resistance
U of S / CDC	Hucl	CWHW	Markers for white seed; Selection methodology
		Alternative wheats	
U of S / CDC	Hucl	Spring spelt	Earliness; Niche food market
U of S / CDC	Hucl	Puffing wheats	Large seed, semi-dwarf; Niche market
		Durum wheat	
U of S / CDC	Pozniak	Durum wheat	1. Conventional quality type, 5% > yield than AC Avonlea, stronger gluten than Commander; 2. Extra strong gluten durum + higher protein; 3. High pigment and reduced Cd in all types; 4. Improved resistance to orange blossom wheat midge, wheat stem sawfly, leaf spots (especially tan spots) and FHB resistance in all types; Novel FHB resistance sources; 5. Novel quality types in durum – Waxy durum, high amylase durum, durums with rheological traits suitable for baking markets
AAFC / Swift C.	Clarke	Durum wheat	1. Grain yield 10%> AC Avonlea, same protein; 2. Sawfly resistant with yield 5%> AC Avonlea; 3. Strong gluten type like Commander with yield 5%> AC Avonlea;

		Oat	
U 0f S / CDC	Rossnagel	Oat	Milling and feed types for SK, domestic and export; High groat fat and low hull fibre; Appropriate fat, beta-glucan and protein content; Disease resistances as needed and good agronomics; Also 1. Milling oat, high beta glucan food type; 2. Feed oat, low acid detergent hull high groat fat (LLH-HOG) oat for ruminants, similar feed value to barley; 3. High oil groat oat for non-ruminant feed; (NB Oat + barley PY now >16)
AAFC / CRC, Wpg.	Jennifer Mitchell-Fetch	Oat	MII Prairie Oat Consortium (9 partners); Goal – Competitiveness of oats; germplasm development and breeding for the Eastern Prairies; High yield and kernel size, high % plump kernels, milling quality (high beta glucan, total dietary fibre, low oil, high protein), lodging resistance, good test weight, and durable disease resistance genes (stem and crown rust, smut, BYDV, FHB and leaf spot resistances); (8.7 PY staff, $455,000 public funds + $166,000 private funds per year)
AAFC / CRC, Wpg.	J. Chong	Oat	Monitor oat disease, identify new resistances, breed varieties with disease resistance, good quality, high yield, good agronomics, and good milling quality
AAFC/ Lacombe	na	Oat	Discontinued, now run from Winnipeg
		Barley	
U of S / CDC	Rossnagel	Hulled 2 row malt barley	High yield + good agronomics; High test weight + plumpness + malt quality traits; Disease (smut, scald, FHB, spot blotch) and shattering resistances; Low phytate malt type collaboration
U of S / CDC	Rossnagel	Hulless 2 row malt barley	High yield + good agronomics; High test weight + plumpness + malt quality traits; Disease and shattering resistances
U of S / CDC	Rossnagel	Hulless 2 row food / other; Includes waxy types and high amylase types	Better threshability, low embryo damage, increased and lowered viscosity and beta glucan according to market, lower phytate, specialty starches and industrial types
U of S / CDC	Rossnagel	Hulled 2 row	High yield + good agronomics; High test

		feed barley for non-ruminants	weight + plumpness
U of S / CDC	Rossnagel	Hulled 2 row feed barley for ruminants, with slow rate dry matter disappearance	High yield + good agronomics; High test weight + plumpness;
U of S / CDC	Rossnagel	Hulless 2 row feed barley for non-ruminants, with low phytate	High yield + good agronomics; High test weight + plumpness;
AAFC / Brandon	Therrien, Legge	6 row malting barley	Priorities: Yield (high, FHB resistance (high), malt quality (very high, mainly for export) and Overall agronomics (medium); Best step change: FHB resistance + 50% reduction in DON (requires functional genomics and/or GMO approach); 3 PY, $101K /yr public funds + $60K grants + $20K /yr royalties
AAFC / Brandon	Therrien, Legge	Forage barley	High yield for cattle, and a cellulosic ethanol market that will emerge later; best step change would be 30% in crease in biomass, = or > open pollinated corn in W. Canada; 1st variety 2008 $80K /yr public + $40K /yr grants + $40K /yr royalties Need better link with industry and potential funders in this area
AAFC / Brandon	Therrien, Legge	2 row hulless food barley	Very high priority for Domestic market, High for export, for defined / desired quality types. Re-establish the nutritional primacy of barley in modern diets; 7 PY, $90K /yr public + $40K /yr grant + $5K /yr royalties
FCDC / Lacombe	Helm, Juskiw, Nyachiro, Zantinge, Xi	Barley	High yield, hulled and hulless feed, 2 row malt types; Disease resistance (scald, net-blotch, FHB, surface-borne and losse smut, root rot, stripe rust); Early maturity, post-harvest sprout tolerance / dormancy; Special purpose barleys – Strong straw (including semi-dwarf) types for irrigation and high fertility, and direct combining; Hulless for high energy feed, high quality feed types, food types and nutraceuticals; Annual

			forage barley; Stress tolerant types – drought, salinity, acid soils; Broadening genetic diversity in barley
		Spring triticale	
FCDC / Lacombe	Salmon	Spring triticale	High yield, straw strength, reduced height, earliness, high protein and quality, high yield forage types, awnless for green feed, post-harvest sprouting resistance, high test weight, improved disease resistance and drought tolerance, broadened germplasm base
AAFC / Swift C.	Clarke	Spring triticale	No information received (mainly screening?)
AAFC / LRC	New staff	Spring triticale	Possible new small breeding effort ?
		Winter triticale	
FCDC / Lacombe	Salmon	Winter triticale	Improved winter hardiness, High yield, drought tolerance, disease resistance (snow mold, leaf diseases, FHB); High protein content and quality for feed, low protein for ethanol market; Sprouting resistance; Forage potential (spring and fall seeded), Base plant type for bio-industrial applications; Broaden genetic base by making new primary triticales;
		Fall rye	
U of S	Fowler	Fall rye	No information received
AAFC / Swift C.	McLeod	Fall rye	No information received
		Spring rye	
AAFC / Swift C.	McCleod	Spring rye	No information received
		Field corn	
None W. Canada	na	Field corn	AAFC / Ottawa has corn breeding research; W. Canada acreage is all private varieties; AAFC / LRC runs a cost recovery adaptation trial testing system for private lines / hybrids

Table 2 AAFC / Cereal Research Centre, Winnipeg. Major research areas supporting breeding programs (From web, March 2007, including past dated content; Some content appears to be significantly our of date)

Institution	**Main cereal activity area**	**Leader**	**General research areas**
AAFC / CRC Winnipeg	Pathology	Menzies	Screen cereal varieties for resistance to rusts, smuts, foliar and viral diseases. Monitor races in W. Canada
AAFC / CRC Winnipeg	Pathology	Chong	Crown rust
AAFC/ CRC Winnipeg	Pathology	McCallum	Leaf rust
AAFC/ CRC Winnipeg	Pathology	Conner (Morden)	Cereal pathology
AAFC/ CRC Winnipeg	Pathology	Fetch	Cereal stem rusts
AAFC / CRC Winnipeg	Pathology	Gilbert	Wheat leaf spot and FHB
AAFC / CRC Winnipeg	Pathology	Haber	Cereal viruses
AAFC / CRC Winnipeg	Pathology	Tekauz	Cereal leaf spots and FHB
AAFC / CRC Winnipeg	Protein biotechnology	Bykova, Ranpitsch	Protein biotechnology
AAFC / CRC Winnipeg	Genetics	Fedak (Ottawa)	Cereal genetics
AAFC / CRC Winnipeg	Genetics	Thomas	Cereal genetics
AAFC / CRC Winnipeg	Molecular genetics	Somers	Cereal genetic maps, gene identification and location, marker development; DNA micro-array technology to ID varieties; Marker technology lab
AAFC / CRC Winnipeg	Molecular genetics	Somers + multiple collaborators and Agrogene consortium	Markers for: FHB, leaf rust, breadmaking quality, kernel color in wheat; Barley stem rust , scald, malt quality; oat crown rust, seed development traits
AAFC / CRC Winnipeg	Molecular genetics	Procunier, Somers, Scowcroft (CGC)	Genomic expression biochips for multiple genes by RNA profiling; SNiP technology for wheat variety ID
AAFC / CRC Winnipeg	Molecular genetics	Xing	Molecular plant pathology, to discover mechanisms of plant disease resistance;

			Proteomics; Broad spectrum disease resistance
AAFC / CRC Winnipeg	Molecular genetics	Somers + Automated Quality Testing Inc.	SNP use with bioinformatics, to map gene rich areas of the wheat and barley genome
AAFC / CRC Winnipeg	Molecular genetics	Cloutier	Molecular sequencing laboratories, with LRC, (Lethbridge), PAFRC (Summerland), ECORC and Morden
AAFC / CRC Winnipeg	Molecular genetics	Cloutier + Xing	Gene cloning laboratory; Bacterial artificial chromosome construction (BAC), to learn gene functionality, all traits
AAFC / CRC Winnipeg	Molecular genetics	Banks	Bioinformatics, including open-source, free for non-commercial use software development for molecular analyses
AAFC / CRC Winnipeg	Molecular genetics	Jordan	Genetic transformation lab for wheat and barley; Main emphasis on wheat quality and diseases
AAFC / CRC Winnipeg	Quality	Ames	Cereal grain composition and functionality; ID of novel quality traits and new market uses; Nutritional quality
AAFC / CRC Winnipeg	Quality	Ames, Lukow, + CGC + others	Cereal quality laboratory; Functional characteristics of cereal grains and derivatives re market needs; Main place for early generation testing of W. Canadian breeders lines, with full lab capability, wheat oats and barley (>30,000 samples processed between October and March each year)
AAFC / CRC Winnipeg	Quality	Ames, Lukow, + CGC + others	Protein functionality, dough and baking studies in wheat; Starch functionality in wheat; Durum and pasta quality;
AAFC / CRC Winnipeg	Quality	Ames, Lukow, + CGC + others	High yield feed wheat quality – for pork and poultry industry; Energy value, fibre, starch and protein quality
AAFC / CRC Winnipeg	Quality	Ames, Lukow, + CGC + others	Oat quality research; Food oat; Optimization of hull removal; Lab production of flakes and oatmeal; G x E effects on oat quality; Effects of heat / moisture treatments
AAFC / CRC Winnipeg	Quality	Ames, Lukow, + CGC + others	Development of new lab procedures for measuring oat quality parameters
AAFC / CRC Winnipeg	Quality	Ames, Lukow, + CGC + others	Food barley quality research: development of new food barley products (including tortillas and

			noodles; Tocopherols, betaglucan, phenolic acid content in barley grain and flour; G x E variation in barley quality for nutraceuticals etc; Starch components in barley and their functionality; Variety variation in phenolic compounds in relation to antioxidant activity
AAFC / CRC Winnipeg	Quality	Ames, Lukow, + CGC + others	Suitability of W. Canadian bread wheats for Asian noodle and pasta production
AAFC / CRC Winnipeg	Quality genetics	Ames, Lukow, + CGC + others	Strength characteristics in different varieties and classes of W. Canadian wheats; Knowledge development and method development

SECTION 3 W. CANADIAN CEREAL BREEDING PROJECTS

Inventory of public W. Canadian cereal grain breeding projects by cereal grain crop type

Table 3 Public Spring Wheat Breeding Projects Inventory, W. Canada, April 2007

Projects are grouped as far as possible according to

- Core breeding for adaptation / productivity / yield
- Disease and insect control by resistance, and related research
- Breeding for grain quality market oriented factors
- Other breeding traits / methodologies

NB GrainTek lacked access to current funding decisions by grant agencies, so there may also be recently approved grants of significance which have been missed in this list.

AAFC projects started in 2007 are also listed in the Appendix

	Spring Wheat specific breeding projects			
Institution / Leader	**Spring Wheat – Core Breeding Projects**	**Duration**	**Agency**	**$ Award**
U of A, Spaner	CPS biofuels, low protein, high yield	2006-2011 2007-2012	WGRF ACIDF, ALIDF, AARI	
U of A, Spaner	CWRS, early, organic systems	2006-2011	WGRF	
U of A, Spaner, Good	Spring wheat – N use efficiency	2007 - ?	? New	?
CDC, Hucl et al	CWHW Hard white wheat improvement	2005-2009	SADF	
CDC, Hucl	Novel improved hulled wheats, niche market	2006-2012	SADF	
CDC, Hucl	Organic spring wheat breeding / production	2004-2009	SADF	
CDC, Hucl / McCartney	Wheat breeding core program, check-off	2005-2010	WGRF	
CDC, Hucl	SWP joint spring wheat development	1995-cont.	SWP	
CDC, Hucl	CLEARFIELD spring wheat development	2003-cont.	BASF	
CDC, Pozniak	Breeding durum and high yielding wheats	2005-2015	WGRF checkoff	2,014,050
CDC, Pozniak	Proprietary breeding project	2003-2011	BASF	Proprietary
CDC Royalties	CDC Infrastructure (35%), contributing programs (65%)	2006-2007	CDC	
	Spring Wheat – Diseases, insects res.			
CDC, Hucl et al	FHB resistance, spring wheat and durum	2006-2009	SADF	
CDC, McCartney, Pozniak, Hucl	Leaf spot resistance, spring and durum wheat	2006-2011	SADF	170,500

CDC, McCartney	Cereal disease resistance evaluation: Leaf and stem rust, Common bunt, Leaf spots, FHB	2004-2008	SADF	
CDC, McCartney et al	Combining resistances to the SK leaf spot complex in spring and durum wheat	2006-2010	SADF	
CDC, McCartney et al	Disease resistance breeding, spring wheat breeding at the Univ. of Saskatchewan	2004-2009	SADF	246,900
CDC, McCartney	*Triticum-Stagonospora nodorum* pathosystem studies (leaf and glume blotch)	Pending	NSERC	
CDC, Pozniak	Breeding FHB resistance in wheat	2004-2007	SADF	
CDC, Pozniak, Hucl, McCartney	Enhancing FHB resistance, novel approaches	2006-2010	SADF	260,567
	Spring Wheat – Market quality traits			
CDC, Hucl et al	Pigment control in hard white wheat	2004-2007	SADF	
CDC, Pozniak, Knox, Clarke, Ames	Genetics / genomics of yellow pigment, durum wheat	2004-2007	WGRF	
CDC, Pozniak, Phelps	Evaluating wheat varieties for ethanol production	2006-2007	Husky Oil,SADF	15,000
CDC, Taylor / Pozniak	Genomics, mapping and cloning low cadmium genes in durum	2007-2010	NSERC Strategic	388,705
U of M, Brule-Babel + Humphreys, Somers (AAFC)	CWHW genes and QTL markers for pre-harvest sprouting tolerance	2005-2007	?	?
	Spring Wheat – Other traits / methods			
CDC, Hucl	Mitigating out-crossing, spring wheat	2005-2007	CSGA	
CDC, Fowler, Chibbar, Pozniak	Genomics approach for low temperature stress tolerance, cold hardiness, spring and winter wheat, and rye	2006-2010	Genome Canada III	
CDC, Pozniak, Somers, Clarke	Novel QTL methods for use in cereals	2005-2010	NSERC Discover	
CDC, Suprayogi, Pozniak	QTL maps and physiology of high protein durum wheat	2005-2010	NSERC Discover	
Pozniak	Genomics in durum wheat	2006-	NSERC, U of AB	
AAFC	**All Cereal Grain Crops Genetics projects** See Appendix VII : AAFC Reviewed and approved Science and Innovation Research Projects, starting 2007	2007-		

Table 4 Public Oat Breeding Projects Inventory, W. Canada, April 2007

Projects are grouped as far as possible according to
- Core breeding for adaptation / productivity / yield
- Disease and insect control by resistance, and related research
- Breeding for grain quality market oriented factors
- Other breeding traits / methodologies

	Oat Breeding specific projects			
Institution / Leader	**Oat - Core Breeding Projects**	**Duration**	**Agency**	**$Award**
CDC, Rossnagel	LLH-HOG oat	2006-2010	SuperOats Canada Ltd	
CDC, Rossnagel	General oat breeding at CDC	2006-2011	FarmPure Seeds	
CDC, Rossnagel	Evaluate CDC oats in N. Zealand	2006-	Plant Research, NZ	
CDC, Rossnagel et al	Milling oat R&D	2004-2008	Quaker + Cargill Can.	
AAFC, CRC, Winnipeg, Mitchell-Fetch	Comprehensive breeding program, backed by strengths of entire CRC capacity. Production related goals: Yield – Very high priority Lodging resistance – Medium priority Market type priorities: Biofuel – Zero – very low priority Feed – Medium – low priority Food – Very high priority	Ongoing	MII + oat industry consortium	
	Oat – Diseases, insects resistance			
CDC, McCartney	Oat and barley assessments for diseases	2006-2012	SADF	
CDC, McCartney et al	Research / deploy new oat crown rust resistance	2006-2012	SADF	
CDC, Tekauz, Rossnagel et al	ID and transfer FHB resistance to oat	2005-2007	WGRF	
AAFC, CRC, Winnipeg, Mitchell-Fetch	Production related goals: Disease resistance – Very high priority (Area of program strength)	Ongoing	MII + industry consortium	
	Oat – Market quality traits			
CDC, Rossnagel et al	Optimizing oat use for feedlot rations	2006-2008	SADF	
AAFC, CRC, Winnipeg, Mitchell-Fetch	Market use oriented goals: Milling quality – Very high priority Feed / forage quality – Med-low priority Starch changes – Zero priority	Ongoing	MII + industry consortium	

	(Could respond to new desirable nutraceutical traits found by industry)			
	Oat – Other traits, methods			
CDC, Rossnagel	Collab., NAMA oat mol. mapping project	2006-	NAMA	
AAFC, CRC, Winnipeg, Mitchell-Fetch	Funding is desirable for transformation work in oat, and for expanded molecular marker work, but has not been available so far. Also need funds to develop new quality tests for oats	None	None	

Table 5 Public Barley Breeding Projects Inventory, W. Canada, April 2007

Projects are grouped as far as possible according to

- Core breeding for adaptation / productivity / yield
- Disease and insect control by resistance, and related research
- Breeding for grain quality market oriented factors
- Other breeding traits / methodologies

Institution / Leader	**Specific Barley Breeding Projects**	**Duration**	**Agency**	**$Award**
	Barley - Core Breeding Projects			
CDC, Rossnagel	Specialty starch hulless barley	2004-2007	Agricore United	
CDC, Rossnagel et al	Specialty starch barley	2004-2014	InfraReady Products Ltd	
AAFC, Legge, Rossnagel, Edney	Low phytate malting barley	2006-	BMBRI	
CDC, Rossnagel	Joint malting R&D, Sapporo Breweries Ltd + Prairie Malt Ltd.	2006-2010	Sapporo, Prairie Malt	
CDC, Rossnagel, Scoles	E. Prairie core breeding project, check-off	2006-2014	WGRF	
CDC, Rossnagel, CWB, U of Man.	Low phytate hulless barley evaluation	2006-	On hold due to CFIA	
CDC, Rossnagel	2 row malting barley development	2005-2008	SeCan	
CDC, Rossnagel	2 row standard quality hulled feed breeding	1999-2009	SeCan	
FCDC, Team	6 row feeds for Alberta:Strong straw semidwarfs, drought tolerance with scald and net blotch tolerance, early types with high yield and scald tolerance, silage yield	1973-	AAF, ABC	
FCDC, Team	2 row feed, multiple disease resistance (scald, net blotch, smut, FHB, root rot), high digestible energy and protein, and yield > Xena	1973-	AAF, ABC	
FCDC, Team	Hulless high feed quality barle;. High energy, strong straw with high DE and digestible protein, and high test weight; Sprout tolerant; Low phytic acid	1973-	AAF, ABC	
FCDC, team	Hulless for food and nutraceutical industries, including Japanese markets	Ongoing	AAF, ABC	
FCDC, Team	2 row malt – strong straw, multiple disease resistance (scald, net blotch, smut, FHB, root rot), yields > AC Metcalfe	1992-	AAF, ABC	
AAFC, Brandon	6 row malt – High malt quality, FHB resistance, low DON, good agronomics,	Ongoing	WGRF, AAFC	
AAFC, Brandon	Forage barley, high cellulosic biomass (= OP corn = 5.5 T/ha DM, 6-7 possible);	Ongoing	AAFC	

	1st high starch type possible in 2010, 1st 90% fermentability type in 2012			
	Barley - Diseases, insects resistance			
CDC, Rossnagel, Steffenson (Univ. of Minnesota)	*Hordeum spontaneum* disease resistance introgression	2006-		
CDC, Rossnagel +n AAFC Lacombe	Scald gene pyramiding. Requested	2006-2010	ACIDF	
CDC, Legge et al + Rossnagel	Enhanced FHB screening at AAFC Brandon	2006-2008	CWB	
CDC, Rossnagel	FHB screening, barley breeding program	2006-2011	SADF	
CDC, Rossnagel et al	Genes and markers for net blotch resistance for W. Canada	2004-2008	SADF	
FCDC, Team	Germplasm development / introduction, disease resistance and other traits	1973	AAF, ABC	
FCDC, Team + AAFC	Molecular marker selection for disease resistance (scald, FHB)	2004	AAF, AAFC, ABC	
FCDC, team + AAFC	Root rot resistance field screening / selection for barley	Ongoing	AAF, AAFC, ABC	
FCDC, AAFC, Lacombe	Scald resistance screening (and net blotch), breeding program + W. Canadian varieties	Ongoing	AAF, AAFC, ABC	
FCDC, AAFC, Lacombe	Breeding line and genetic resistance studies, surface-born smuts and true losse smut	Ongoing	AAF, AAFC, ABC	
FCDC, AAFC, Lacombe	Surveying barley diseases, Alberta (leaf diseases and root rots; FHB in 2005)	Ongoing	AAF, AAFC, ABC, Others	
FCDC, AAFC, Lacombe	*In vitro* techniques for screening FHB resistance / tolerance and DON levels	Ongoing	AAF, AAFC, ABC	
	Barley - Market quality traits			
CDC, Leterme(PSC) Rossnagel	Functional properties, hulless barley for swine	2006-	ABC	
CDC, Yu et al + Rossnagel	Variety differences in ruminant nutrition	2006-2009	SADF	
CDC, Rossnagel et al	Improved slow dry matter disappearance for beef and dairy cattle	2002-2007	SADF	
CDC, Chibbar et al + Rossnagel	Study starch granule size distribution to improve barley grain quality	2006-2009	SADF	
FCDC, Team	Improved hull adherence vs AC Metcalfe	Ongoing	AAF, ABC	
FCDC, Team	NIRS methodology development, for grain quality determination, breeding and commerce	2004-2007	ACIDF, Rahr Malting, ABC	
FCDC, Team	Post-harvest sprout tolerance screening	1982	AAF, ABC	
AAFC, Brandon	Commentary: High starch barleys of CDC need to be put in high yield background; Some hulless barleys are reaching 85%	na	na	

	fermentable product (by weight), which could be moved to 90% for ethanol production; Biomass = Easy to breed, higher starch = Medium ease, and 90% fermentability = Hard;			
	Barley - Other traits, methods			
CDC, Chibbar et al + Rossnagel	Molecular markers for beta glucan content	2004-2007	SADF	
FCDC Team	Drought tolerant 2 row malt type	Ongoing	AAF, ARC, ABC, Funding Consortium	
FCDC, Team	DNA fingerprint database for AAF varieties	Ongoing	AAF, ABC	
FCDC, Team	Improve DH barley breeding methods	2002-cont.	AAF, ABC	
FCDC, Team	Genetic studies and selection methods for sprouting resistance in hulless and other barleys	1997-cont	AAF, ABC	
FCDC, Team	Drought tolerance, water use efficiency, and genetic mapping (6 row, 2 row, hulless barley; Triticale)	2005-	AAF, ABC, ARC, Funding Consortium	
FCDC, AAFC Team + GRL / CGC, AAFC lethbridge	Improvement of malt barley quality and seed homogeneity through optimization of agronomic, genetic and environmental factors Includes calibration of NIRS measurements with micro-malt data.	2005-	AAF, ABC, AAFC, CGC	
FCDC, Team + Good (University of Alberta)	N use efficiency in barley and triticale	2007 - ?	ACIDF, In-kind industry	1,600,000

Table 6 Public Winter Triticale, Fall Rye and Winter Wheat Breeding Projects Inventory, W. Canada, April 2007

Projects are grouped as far as possible according to
- Core breeding for adaptation / productivity / yield
- Disease and insect control by resistance, and related research
- Breeding for grain quality market oriented factors
- Other breeding traits / methodologies

	Specific Winter Cereal Breeding Projects			
	Winter Triticale - Core Breeding Projects			
FCDC, Salmon	Adaptation to high yield areas and traditional winter wheat areas	Ongoing	AAF, Progressive Seeds Ltd	
FCDC, Salmon	Early maturing, shorter stature, with disease resistance for black soil zone	Ongoing	AAF, Progressive Seeds Ltd	
AAFC (LRC) + FCDC, Salmon	Triticale biorefinery initiative	2007 - ?	AARI	3,000,000
	Winter Triticale - Diseases, insects resist.			
	No information received			
	Winter Triticale - Market quality traits			
FCDC, Team	Evaluate advanced lines for grazing potential, including reduced awn approach	Ongoing	AAF, Progressive Seeds Ltd	
FCDC, Team	Post-harvest sprout tolerance screening	1982	AAF	
FCDC, Team	Forage production – fall and spring seeded winter cereals	Ongoing	AAF	
	Winter Triticale - Other traits, methods			
CDC, Fowler, Chibbar, Pozniak	Genomics approach for low temperature stress tolerance, cold hardiness, spring and winter wheat, and rye (Cross listed in these tables)	2006-2010	Genome Canada III	
AAF, Team	Improve DH triticale breeding methods	2002-cont.	AAF	
AAF, Team + Good (Univ of Alberta)	N use efficiency in barley and triticale	2007 - ?	ACIDF, In-kind industry	1,600,000
	Fall rye - Core Breeding Projects			
	No information received			

	Winter wheat - Core Breeding Projects			
U of S, Fowler	Winter wheat, semi-dwarf and tall types; Disease resistance; KVD barrier to registration (18% yield increase of DH99-37-100 CHRW over CDC Osprey denied due to KVD)		SADF	
FCDC, Salmon	Adaptation to high yield areas and traditional winter wheat areas	Ongoing	AAF, WGRF	
FCDC, Salmon	Early maturing, semi-dwarf, with disease resistance, for black soil zone	Ongoing	AAF, WGRF	
FCDC, Salmon	Improved winter hardiness and seed colour	Ongoing	AAF, WGRF	
U of M, Brule-Babel	Disease resistant, semi-dwarf, high yield , cold hardy, hard red winters for high moisture areas, including Coop and Regionals testing	Ongoing	WGRF + ?	
U of M, Brule-Babel + Van Acker	Study of herbicide resistance genes in weeds (MSc Ms Karlowsky)	Ongoing	?	
	Winter wheat - Diseases, insects resist.			
U of M, Brule-Babel + Lamari (AAFC)	FHB, leaf rust, stem rust, tan spot, and Septoria leaf blotch incorporation into winter (and spring) wheat, and germplasm development, and genetic mapping	Ongoing	WGRF, ARDI, S + ?	
U of M, Brule-Babel + Graf (AAFC)	Joint rust nursery testing at U of M	Ongoing	WGRF + ?	
U of M, Brule-Babe + Fernando, Gilbert	Coordinator, joint W. Canada FHB nursery at Carman (13,000 plots in 2006)	2000 – cont.	?	
	Winter wheat - Market quality traits			
U of S, Fowler	CDC Ptarmigan supported in 2007, with 9% yield increase over CDC Kestrel, and +2% starch content	2006-	SADF	
FCDC, Team	Post-harvest sprout tolerance screening	1982	AAF	
FCDC, Team	Forage production – fall and spring seeded winter cereals	Ongoing	AAF	
U of M, Brule-Babel	Develop high yield winter wheat for the ethanol market, with enhanced fermentables. Targets 5 – 15% grain yield increase. Includes phyiological components in the research	2006 – cont.	NSERC / Husky	
	Winter wheat - Other traits, methods			
U of S, Fowler, Chibbar, Pozniak	Genomics approach for low temperature stress tolerance, cold hardiness, spring and winter wheat, and rye	2006-2010	Genome Canada III	

FCDC, Team	Improve DH winter wheat breeding methods (including putative stripe rust resistant line)	2002-cont.	AAF, WGRF	
FCDC, Salmon	Germplasm broadening, including use of strong gluten types from spring wheat, cold tolerance, and FHB resistance sources	Ongoing	AAF, WGRF	

Table 7 Public Spring Triticale and Spring Rye Projects Inventory, W. Canada, April 2007

Projects are grouped as far as possible according to

- Core breeding for adaptation / productivity / yield
- Disease and insect control by resistance, and related research
- Breeding for grain quality market oriented factors
- Other breeding traits / methodologies

	Specific Spring Triticale and Rye Breeding Projects			
	Spring Triticale - Core Breeding Projects			
FCDC, Salmon	Move wheat earliness into triticale	Ongoing	AAF	
FCDC, Salmon	Awnless / near awnless types for forage	Ongoing	AAF	
FCDC, Salmon	Move wheat solid stem trait into Triticale (for disease resistance, and for industrial straw use)	Ongoing	AAF	
	Spring Triticale - Diseases, insects resist.			
FCDC, Salmon	Screening for stripe rust resistance	Ongoing	AAF	
FCDC, Salmon	Incorporation of FHB resistance	Ongoing	AAF	
	Spring Triticale - Market quality traits			
FCDC, Salmon	Move wheat sprout tolerance into triticale	Ongoing	AAF	
FCDC, Team	Post-harvest sprout tolerance screening	1982	AAF	
	Spring Triticale - Other traits, methods			
FCDC. Salmon	Collaboration with AAFC biorefinery project	2006-	AAF	
AAFC	**Spring rye – No information received**			
AAFC	**Triticale – No information received**			

Table 8 Responding breeder estimates of achievable % yield increase potential in W. Canadian cereal classes, 5 year and 10 year time frame.

Source of estimate	**Cereal crop class**	**5yr % increase**	**10 yr % increase**	**Notes**
University of Alberta	CPS / CWGP	20 (25)	20 (40)	Subject to KVD release
University of Alberta	CWRS	5-10 (15)	10 (15)	(NB Exceeds historic)
CDC	CWRS	2-3 (5)	5-6 (10)	Historic levels continue
CDC	CWAD	2-3 (5)	5-6 (10)	Historic levels continue
CDC	CPS /CWGP	2-3 (5)	5-6 (10)	Historic levels continue
CDC	Winter wheat	4-6 (10)	8-12 (15)	Subject to KVD release
CDC	Malt barley	2-3 (5)	5-6 (10)	Historic levels continue
CDC	Feed barley	2-3 (5)	5-6 (10)	Historic levels continue
CDC	Hulless barley	2-3 (5)	5-6 (10)	Historic levels continue
CDC	Hulled oat	2-3 (5)	5-6 (10)	Historic levels continue
CDC	Hulless oat	na	na	na
FCDC / AAF	Spring triticale	5 (5 + starch and feed quality)	10-15 (10-15 + starch and feed quality	With extra tech. staff could do target starches plus larger seed type
FCDC / AAF	Winter triticale	5-10 Yield now is <5% of spring types, but closing gap	10-15	Hardiness is limiting winter triticale yields. W. triticale is great choice for cellulosic ethanol
FCDC / AAF	Bio-refinery triticale	1-5	3-6	Adding traits to chosen (fixed) yield type
FCDC / AAF	Winter wheat (feed type)	10-15 (15-20)	15-20 (25-30)	Extra resources could add 5% more through molecular + DH work. W. triticale is great choice for cellulosic ethanol
FCDC / AAF	Winter wheat (Select type with quality)	5 (10)	10 (15)	Extra resources could add 5% more through molecular + DH work
FCDC / AAF	Malt barley	5-10	10-20	Historic levels continue
FCDC / AAF	Hulled feed barley	5-10	10-20	Historic levels continue
FCDC / AAF	Hulless feed barley	5-10	10-20	Historic levels continue
University of Manitoba	Winter wheat	5	15	
Source of	**Cereal crop**	**5yr % increase**	**10 yr %**	**Notes**

estimate	class		increase	
AAFC	CWRS	3.5 = Historic (5)	7.1 = Historic (5)	1946-1981 rate was 0.29%/yr, became 0.71%/yr 1982-2006, due to technology + increased resources
AAFC	SWS	15	15 + multiple disease resistances	Quality suitable for domestic and export end-use markets
AAFC	CPS	10	15	CPS Red will require IP, and may not survive
AAFC	CWGP	3.5 Now 20% over CWRS. Any gains will be by lower protein + later maturity	7.1	CWGP is a very narrow focus with limited opportunity. Class depends on future of ethanol market
AAFC	CWAD	10	10 + Low Cd, and insect = disease resistance	2 quality types; Midge + sawfly resistance; east vs western prairie objectives
AAFC	Winter wheat	5?	10?	CWRW will require IP
AAFC	Winter triticale	No information	No information	
AAFC	Spring triticale	No information	No information	
AAFC	6 row malt barley	5 (7)	7 (9)	
AAFC	Forage barley	10 (15)	20 (30)	
AAFC	Hulless food barley	5 (7)	10 (12)	
AAFC	Hulled oat	5 (10)	10 (20)	Extra funds would improve quality as well
AAFC	Spring rye	No information	No information	
AAFC	Fall rye	No information	No information	

Notes:
1. Values in brackets indicate the yield increase estimate with extra breeding resources
2. Breeders reiterated that yield is not the only point of value in new varieties. In the case of cereal feedstocks for bio-energy use yield is a main driver
3. The livestock sector, the major beneficiary of high yielding feed grains, should improve their past meager investment in cereal breeding if they want higher yielding varieties (CDC comment)
4. CDC estimates reflect historical yield trends, and are conservative, reflecting no perceived changes in regulatory constraints to registration (GrainTek comment)
5. Blank indicates no estimate available.

SECTION 4 AREAS OF POTENTIAL BREEDING INVESTMENT

Areas of potential investment in the W. Canadian cereal grain crop breeding area, to improve competitiveness

Written submissions about future priorities were received from CDC, University of Saskatchewan, and from AAFC. Reports as received can be found in the Appendix. Notated summaries from these, and other comments from other institutional discussions and responses, are presented in this section, as well as independent observations by GrainTek.

I. CDC, University of Saskatchewan

(A) Regulatory constraints:

- CFIA uses an inappropriate definition of Plants with Novel Traits PNT's re novel food and feeds, that limits the ability to grow and market novel plant based products in Canada (e.g. Low phytate barley) because of the Canadian regulatory requirements linked to PNT's
- The KVD standard is a continuing impediment to registration of non CWRS spring and winter wheat varieties with significantly higher yield levels, or with other improved traits
- Market goals and the associated grades set by the CWB / CGC limit wheat breeding scope. Also, the approved grades into which varieties must fit change with short notice, thus disrupting previous breeding goals and removing value from prior breeding effort
- Market targets from industry different from those of the CWB are discovered by breeders, but cannot readily be acted upon because of an inability to register new types that do not conform to approved grades

(B) Industry / System level infrastructure constraints

- Canadian loss of retiring plant breeder positions in public programs over time
- Inability to attract sufficient students into plant breeding as a career, or to provide career length funded positions for highly qualified staff
- Lack of pilot testing facilities available to cereal breeders for testing advanced lines at affordable cost
- Inadequate investment for product development, and relative lack of regional centres for bio-fermentation, bio-processing, bio-products, or specialty food product development, which could pull new products through the value chain
- Danger of over-expectation by bio-visionaries
- Consistent lack of financial support of breeding from non-farmer end users such as the feed industry and the bread wheat and food industry

(C) CDC Infrastructure constraints

- Lack of a dedicated CDC laboratory with leading edge equipment and fully funded long-term highly qualified technical staff for (a) conducting doubled

haploidy and (b) molecular marker research and routine assays, to service the needs of the CDC wheat, oat and barley breeding programs
- Need for succession planning for CDC breeders in oats and barley, including replacement of the barley position just lost. Oat plus barley breeding at CDC requires more than one breeder
- Expanded technical support for wheat breeding at CDC is desirable
- Decision is required re the future of winter wheat breeding at CDC, as breeding resources are limited, and Dr. Fowler plans to retire in two years time
- Off station testing by CDC works well through collaborations with other institutions and seed partners, but could benefit from a more consistent approach

"Step change targets' – CDC (with GrainTek commentary)

No specific suggestions were received by GrainTek either from individual CDC breeders or in the position paper. GrainTek interpretation of this is that CDC breeders have already determined for the present conditions what these are, and have generally succeeded in already locating partners and funding to support those new leading edge research concepts as they come forward. Thus, the list of CDC current breeding projects gives the best view of the CDC program vision of where future 'step-change' gains can best be made.

The CDC cereal breeding programs all appear to be very well integrated with industry and market needs, and are jointly funded by industry in most cases. CDC breeders have a stellar record of foreseeing the future trait and market needs for the cereal grains they breed, to design varieties with specialty market driven traits that are needed as market needs change. A`large part of this success can be attributed to the continuing dialogue that each CDC breeder has with the potential industry users of the targeted breeding type. CDC breeders have also been extremely successful in obtaining suitable funds for innovative projects (some of which are step-change traits, and some of which are yield stabilizing / protection traits), built on their continuing, long-term, overall support from SADF. The constraints CDC identifies are real, and their ability to make gains in the future is now mainly infrastructure limited. CDC breeders, like other breeders throughout W. Canadian, have excellent access to funds to support innovative breeding goals / projects, but very limited access to funds for use in maintaining and developing their breeding infrastructure needs at a competitive level.

II. AAFC

A summarized assessment of AAFC priorities and overall strategy in cereal breeding was not received, but information about some of the high priority projects was received in separate submissions prepared on behalf of AAFC by Dr. Stephen Fox (LRC) for AAFC wheat breeding programs, Dr. Mario Therrien for AAFC barley breeding programs, and by Dr. Jennifer Mitchell-Fetch (CRC) for AAFC oat breeding. Detailed information from these was listed in the earlier tables. This section is used to report significant commentary made in those three submissions, and in other communiqués received by GrainTek directly from other AAFC cereal breeders.

(A) 6 row malt barley breeding (AAFC, Brandon documentation)

Infrastructure needs

1. The management, funding and strategic approach to long-term breeding goals in AAFC still requires further improvement, in a way which will build one fully integrated system capturing all public / private linkages in cereal breeding for the future. Build on AAFC Brandon strength in their use of the Male Sterile Facilitated Recurrent Selection breeding technique.

2. Need access to a fulltime Functional Plant Genomics group and lab in W. Canada, which would have a mandate to support W. Canadian cereal breeding goals, for basic and applied research that supports cereal breeders. Need to have more PDF's and graduate students working / training in the AAFC breeding programs, solving their problems, associated with this approach, and to ameliorate future Highly Qualified Staff needs.

3. Despite excellent existing linkages nationally and internationally, need to establish closer ties with US Universities, and SAB Miller (one of the two main customers for this type of malt barley), and expand funding from Anheuser Busch.

Priority areas for expanded or new breeding work, and breeding constraints

1. Best step change would be a good level of resistance to FHB, with a 50% reduction in DON levels.

2. IP issues that restricted germplasm exchange have occurred, but there is a fulltime office at AAFC to help breeders in such cases. Recurring problems occur with seed exchanges to some countries in Asia, S. America and Africa, due to their failure to recognize and/or respect international agreements that are in place.

(B) Forage barley (AAFC, Brandon documentation)

Infrastructure needs

1. Better links needed with the forage and cattle industries, for objectives and funding, including creation of partnerships with the Canadian Cattleman's Association and with the AAF / AAFC program(s) in Lacombe.

Priority areas for expanded or new breeding work, and breeding constraints

1. Best step change would be a 30% increase in biomass. AAFC current work targets domestic forage use for traditional animal consumption, as well as high biomass production for the cellulosic based ethanol industry which will dominate in the future. More breeding resources are needed to achieve the 30% increase, but a new forage barley (FB012) to be released in 2008 will equal open-pollinated corn in biomass, averaging 5.5 T/ha DMB. Other lines have a biomass potential of 6-7 T/ha DMB.

(C) 2 row hulless food barley (AAFC, Brandon documentation)

Infrastructure needs

1. Access to a food research lab to develop the necessary technologies for detailed breeding activities, integrated with industry interests in specific barley based food products.

2. Expansion of breeding goals and achievements for hulless barley food products requires new linkages to the domestic and US food industry, for developing market based goals, and for partnering and funding.

Priority areas for expanded or new breeding work, and breeding constraints

1. A significant step change would be for the food industry to adopt barley to replace wheat as the primary cereal food supplier, and breeders to achieve novel barley varieties that have superior nutritional value and equivalent processing characteristics as wheat (including gluten strength etc). It could take 20 years to do this, to recreate the high status for barley based food (that the Romans granted to their elite warriors…way back…Graintek comment). This objective responds to a societal demand for healthier food, including healthier cereals. The genetic means and technological methods to tackle this already exist in the Triticeae, for application in barley, but considerably more breeding resources are needed to support this poorly developed ‘barley for human food‘ breeding area.

AAFC Spring wheat breeding programs – Summary report

Although no specific summary report about step changes, or breeding constraints for AAFC wheat breeding was submitted, the following summarizes a number of issues that arose from the breeding program descriptions and from discussions

Strengths of AAFC wheat programs:

1. It was felt that linkage to the markets and with the industry and through the Canadian Wheat Board and CGC and CIGI was at an excellent level for determining the quality and other requirements needed in new wheat varieties. This linkage was further strengthened through the continued dialogue with producers, through the checkoff funding and review system via WGRF, for which producers themselves pay.

2. A major strength in AAFC was seen as the access for breeders to a very large number of scientists in AAFC, who carry out basic research on cereal crops, and who also develop and provide tools and services for use by AAFC wheat breeders. For person years the estimate was 8.6 team leaders / professionals (involving 25 scientists), 77 PY of technical help (involving 125 staff), 2 PDF's, 30 summer students and 6 graduate students, all focused on wheat breeding projects or programs. This cadre provides additional strengths for molecular marker assisted selection, doubled haploidy methods for elite materials, quality and pathology testing, provision of FHB screening nurseries, suitable environments for screening for midge resistance, and reliable multi-location yield and agronomics trialling.

3. Collaborations with other breeders, nationally and internationally, were described as Very good, which resulted in AAFC breeders often being asked for access to genetic populations they have developed, for international collaborative research of both basic and applied nature. AAFC has a well deserved and very high reputation for the nature and quality of the outputs that it achieves on both fronts, and many of its recent achievements in wheat have been leading edge international standard, by any measure. (This last statement is from GrainTek, concurring with the more modest AAFC self-evaluation of this aspect).

4. As in the other crops, AAFC wheat breeders emphasize that the value of a new variety is in its total performance for market needs, not just in its yield or any other specific trait. Whilst new traits of value can always be identified, and breeders can usually find genetic variation and ways to get those traits expressed in a suitable variety, this can only be done when the longterm infrastructure of a program is healthy, so the new trait can be added to the objectives within the existing germplasm base. AAFC has large pools of well adapted germplasm that it is continuously developing.

The following (editorialized) comments from one successful AAFC cereal breeder should be noted, as they singularly apply to the current bio-energy from cereals review. They describe the chances of any new variety actually being supported for registration:

‘Quality deficiencies in markets where quality is of high value are not compensated by pathological or yield gains’.
‘Significant gains in pathological disease resistance can compensate for deficiencies in yield potential, depending on the importance of the disease’.
‘High yield very rarely compensates for susceptibility to important diseases’.
‘KVD trumps everything, but is not a large breeding hurdle for CWRS and durum wheats’.

From many years of genetic R & D, AAFC now has access to a vast array of primary genetic materials for its use, and to well developed adapted genetic populations in all its current wheat classes. This source of wide genetic variation is the key to past breeding successes, and will continue to be the key in the future.

AAFC Infrastructure challenges / desired improvements (GrainTek notes)

1. Some breeders in AAFC seem to lack conviction that there is a well developed strategy from government that is establishing the long-term security for market oriented, variety oriented breeding programs. Is AAFC in wheat breeding for the long-term? Related to this concern one suggestion made was that the AAFC breeding programs should all be set up in an organization separate from government, in close association with industry and the users of the varieties, instead of the breeding programs being ‘government driven’. Such an approach would encourage much greater collective use of all public resources for crop breeding in W. Canada, which present institutional limitations tend to deny.

Not in this review but in other venues, GrainTek has also heard that there may be a perceived conflict of interest for AAFC breeding programs, when the same government applies the registration standards and regulatory mechanisms for approval of its own varieties.

2. Being within a branch of government, AAFC breeders are generally limited to targeting breeding objectives which fit current regulatory requirements, usually constrained to the grade standards and market types set by the CGC and the Canadian Wheat Board. Although Contract registration is available for other types of wheat, there is little incentive for an AAFC breeder to target such a type, especially when total resources are limiting.

3. There is a need for ‘deep science’ Centres of Excellence to support cereal breeding in (a) Pathology, (b) Molecular genetics and plant physiology, and (c) Doubled haploidy / breeding methods, which have a focus on the needs of breeders, to expand genomic and physiological understanding, the development of usable genetics, screening methods, and basic breeding support services. The potential for having these in Canada is large, but they do not exist at this time. As a result, most of the in-house breeding program work that would otherwise be done in these Centres of Excellence is short term funded and project based, and does not lead to capacity building.

4. Top to bottom, from field / race surveys to resistance gene ID and delivery in breeding programs, and even in Coop registration testing, the level of pathology R & D to support cereal breeding in W. Canada is far less than is needed. The best pathologists spend far too much of their time in servicing routine requirements of the registration process, tasks for which they get little credit, and which could be done by others at lower cost and with improved timeliness, if an investment was made.

5. To obtain significant cereal breeding gains in the future, the funding system must pay more attention to program level funding, and infrastructure needs. AAFC access to short-term project based funds for sound projects is less problematic, especially where there is industry interest and the MII can be used.

<u>Best step changes, and other ideas, that could be targeted (AAFC suggestions):</u>

1. In CWRS wheat the best step changes achievable would be the following
(a) Eastern prairies – Increased yield + FHB resistance + good standability
(b) Central prairies – Increased yield + midge tolerance + good standability
NB: In 2006 >50% of CWRS downgrading in some parts of SK was due to midge

2. Need for FHB resistance in all wheat classes is huge, not only in food wheats, but for feeds and for industrial uses where DDG's have concentrated DON levels.

3. Breed a better disease package into SWS wheat, especially since it may be widely used by the ethanol industry. However, most wheat breeders also feel ethanol production will switch to cellulosic sources before significant yield gains could be made specifically for the ethanol market, within 10 years. Consequently, GrainTek was left with the impression that AAFC wheat breeders do not have the specific 'grain for ethanol' market as a primary breeding goal at this time, except in the SWS class.

4. Find an affordable way to measure DON levels, and implement selection for this throughout the wheat breeding programs, to allow low DON varieties to be developed, if this is possible.

5. In the CWRS and Durum classes, continue to protect the extra value of these classes that is based on strict registration standards that maintain the quality and price premium in these bulk commodities, which is where their value lies.

6. Expand research into the nutritional properties of food wheats, to see whether over-expression of desired nutritional traits can be achieved (i.e. Zinc metabolism; High lutein; Gluten-free wheat? Specialty starch types? Others?)

7. Winter wheat yields can increase significantly in the wetter parts of W. Canada, but only if the KVD constraint is removed. Current varieties probably out-yield other grains, but recent trials to compare modern spring and winter wheat and triticale varieties have not been carried out

III. FCDC (AAF), Lacombe

Notated concerns listed are based on GrainTek interpretations from the site visit discussions between AAF, GrainTek and Alan Hall, ACIDF. It should be noted that all barley work at Lacombe is part of a joint agreement between AAFC and AAF for integrated barley crop development, of which the breeding program is only a part.

(A) Infrastructure concerns

1. Budgetary cutbacks have caused loss of backbone capabilities for ongoing breeding programs, for many aspects of the barley, winter wheat, triticale and barley programs, although infrastructure for land, growth rooms and buildings was good to very good. The total of line budget plus soft funds fill-in still results in a shortfall to support technical help for field trials, lab work and other areas. Capacity cuts now result in insufficient new crosses being made each year, because of inability to screen larger numbers of populations, in all programs. This issue was also noted in the recent External Scientific Review, 2006, at Lacombe. Long-term commitment to infrastructure funding is required for breeding programs to function properly, because of the long-term nature of the work, and the essential requirement for continuity of highly qualified staff. (An example of an unsatisfactory outcome is the training of a new Post-doc in a three year Fusarium resistance project at Lacombe, who had to be let go when the funding stopped).

2. Balanced investment is needed for supporting each approved breeding program, to maintain program breadth and integrity to produce varieties that have broad adaptability, including tolerance or resistance to diseases and other stresses, and market suitability. FCDC discussions mainly focused on the need for a ‘critical mass of capacity’ to achieve effective breeding progress. Reviewers of the FCDC program (2 reviews in 2006) have identified the need for funds expansion if all current goals are maintained, or the need to consider reduction in program scope to gain more effective use of available funds.

3. The need at FCDC to link the breeding with molecular and biotechnology approaches was identified in the mid 1990’s, but funds to establish full capability (lab, modern equipment, highly trained staff) at FCDC, Lacombe have never materialized, leaving the programs disadvantaged. Use of collaborations to compensate has been dependent on variable access to soft funds, and has suffered from soft fund discontinuity. At the time of this review GrainTek was advised that there was no capability for biotech work for food crops conducted at Lacombe, as the only existing staff has been transferred to work on non-food applications.

4. Attempts by IFASA to provide better links between projects, programs and funding sources have not yet improved the ability to solve infrastructure funding issues at FCDC. The need for multiple approvals for almost everything has slowed, not accelerated, the funding process. Diversified funding has also resulted in the need for fragmented and diversified reporting requirements about research progress, rather than a single unified reporting line. Ability of FCDC to set breeding priorities is made complex due to diversified reporting streams and expectations from different funding sources and from AAF management.

5. Seed industry support for promoting and expanding triticale production and utilization as a bio-energy source, even using existing varieties, is very limited.

6. Testing capacity for yellow rust and net blotch is limited, even in the B and C Coop registration trials.

7. Breeding programs should have the flexibility to reassign funds within their approved budgets as they see fit, to gain efficiencies within their mandate. If funders could agree on the front end of projects about what the outcomes should be, then the breeders should be given the budgetary flexibility to achieve those goals in the manner they need, to achieve the targets and deliverables within the timelines agreed.

8. Registration KVD requirements have not allowed registration of any of the recent advanced AAF winter wheat lines. Non-approval of some lines has also been due to insufficient completion of formal testing, partly explained by insufficient Coop pathological or quality testing capacity, or by intervention of other crop priorities in the Coop testing system.

(B) Specific FCDC / AAF breeding project areas that lack adequate infrastructure funding, including lab equipment and dedicated staffing

1. Malting barley breeding
2. Winter wheat breeding
3. Pathology support for the breeding programs, professional and technical
4. Crop physiology expertise
5. Molecular research capacity (e.g. marker applications, discovery, etc) to support the breeding

(C) Priority areas for further work at FCDC / AAF, Lacombe (from discussions with GrainTek / ACIDF)

1. FCDC / AAF Lacombe priority is for feed grains, in two areas, which is a recommendation also supported by the most recent review of the FCDC barley program, and in its 2006 full program scientific review.

    a) Feed for cattle
    b) Feed for hogs, including hulless barley
    c) Barley and triticale should be the primary focus to meet these goals

2. Genetics of digestible energy (based on new methodologies, and leading edge excellence in this area for feed grain development)

3. High energy triticale is the best bet for further breeding investment for biomass (grain, forage and silage), but requires long-term investment in making new primaries, to broaden the germplasm base. Existing linkages with CIMMYT, ICARDA and Oregon State University can all be exploited for this (and also for barley improvement).

4. Continue leading edge work re barley scald, but additional technical support for all pathology is needed. Focus on use of marker assisted selection (MAS) in this area

5. Expand scope for use of NIRS technologies to support selection in breeding programs

6. Need for a better DON testing method in triticale and other grains, in relation to selection for improved Fusarium tolerance. The level of DON testing now ongoing in breeding programs is very low to zero, mainly because of the cost of the test

7. There is a new threat to cereal production in W. Canada from stripe (= yellow) rust, due both to global warming and the development of new races with higher temperature tolerance. The resistance trait should be incorporated in new varieties.

8. Stripe rust resistance in winter wheat

9. New projects have just been approved on breeding for N Use Efficiency (with Dr. Alan Good, University of Alberta), and to expand prior work on Water Use Efficiency.

10. Discussions highlighted the importance of developing a broader germplasm base to support the barley breeding program, locally and nationally.

(D) Other notes by GrainTek, re discussion with FCDC / AAF, Lacombe

1. The winter wheat program was described as mainly germplasm development, particularly in relation to parent building for the triticale program. It was indicated that materials developed are freely available to other programs, but that few requests for FCDC germplasm were received by other Canadian winter wheat programs. Newer materials have a lower protein content, but hard white lines with improved baking quality are also in place.

2. FCDC places a high level of confidence in the future potential of triticale (spring and winter) for contributing in diverse ways to the future of W. Canadian agriculture, for bio-energy use as feed, forage and industrially. It has received significant project based funding to achieve several specific outcomes, including the new Triticale Biorefinery Project with LRC / AAFC, Lethbridge. However, an overall strategic plan for future triticale breeding at FCDC, including the widening of the genetic base was not available for review. It was noted that some recent triticale varieties released by FCDC have improved starch content.

3. Step Change Identification: Reticence to identify 'step change' breeding goals was evident as in other organizations, but priorities within FCDC programs are evident by the types of special breeding projects currently in place (see lists). FCDC has been under strong direction from AAF to focus more on individual breeding projects, rather than on a longer term breeding approach or support. Two significant suggestions did emerge, as follows:

(a) To plan for (non-Select) winter wheat to increase in acreage significantly in W. Canada because of its high yields, early maturity and partial escape from FHB effects and ideal suitability in grain quality for the ethanol industry. However improved levels of winter-hardiness are necessary to achieve this, which may require application of molecular breeding approaches once the cold hardiness physiology is better understood.

(b) Design and breed a perennial triticale for grain and / or forage use in W. Canada, based on creating new primary triticales from Tetraploid PC rye. This very loing-term work is partially underway with the International Triticale Association Consortium, but requires genomic research and marker technology applied, to gain understanding of gene expression and gene regulatory mechanisms in this new species. FCDC has just made 100 new primary triticale crosses, but this work would require significant expansion to achieve this goal.

4. National and international collaborations of FCDC, Lacombe programs with other institutions / breeders / researchers are extensive and effective. FCDC felt that there was good germplasm exchange and access with CIMMYT and Australian programs.

5. FCDC exchanges germplasm freely with other institutions, following normative ethical standards and protocols for such activity. Hindrances to germplasm exchange due to IP constraints have thus far been rare and insignificant for these FCDC breeding programs.

6. For review purposes GrainTek had access to the 2005-2006 Work Plan of the Alberta/Canada Barley Development Agreement, but not to the 2006-2007 Work Plan. The latter should be requested by ACIDF / AARI as soon as available, for use in further developing the Bio-energy from Cereal Grains Initiative.

IV. University of Alberta

The University of Alberta program is limited to breeding spring wheat in the CWRS and CPS (CWGP) classes. Program and project summaries are shown in the Inventory tables. This section includes notes derived from the questionnaire response of Dr. Dean Spaner.

1. The importance of FHB resistance in high yielding wheats for ethanol use is noted as a requirement for breeding, because of residual DON effects in by-product DDG's.

2. In the CPS class this program is targeting lower protein content, which was described as a trait of 'medium ease' for breeding, with expectation of delivery in a new variety in 5-10 years.

3. The existence of a $10m plant genomics lab at the University of Alberta, with deep professional and other genetic research capability across campus, was described as a strength that should be recognized in relationship to W. Canadian application of molecular technologies and research in plant breeding. The limiting factor for doing this was described as shortage of funds to staff the facility with highly trained plant molecular genetics personnel, with prospects for continuity of employment.

4. As of March 2007 the personnel base for breeding was listed as 1 team leader (Spaner), 2-3 technical staff, 1 PDF, 2-4 summer students, and 4-12 graduate students. In-kind University contribution is estimated at $375,000 per year, soft grants have averaged around $100,000 - 250,000 per year, plus student scholarships of around $100,000 – 200,000 per year.

5. Linkages with industry in relation to setting breeding goals were described as Very good, and the continuity of input and linkages for updating goals was described as 'About right'. Research linkages were established as needed to meet the breeding goals, and especially involve AAFC Research Stations, FCDC / AAF, Lacombe and CDC Saskatoon. New linkages with ECORC and AAFC, Laval are also planned.

V. University of Manitoba

A full report describing the University of Manitoba winter and spring wheat research and breeding programs was received and is viewable as Appendix XI. Breeding details from this have been listed in the appropriate tables in this report. Directions in this program of Dr. Brule-Babel (mainly but not solely focused on disease improvement in winter wheat) are well established, and seem unlikely to change significantly in the near future. Yield improvement goals in winter wheat of 5% for the near term, and 15% for the longer term are targeted.

Primary goals:
1. Disease resistant, semi-dwarf, high yielding, cold hardy, hard red winter wheat cultivar for the moister regions of the E. prairies. Disease work includes leaf and stem rust, tan spot, and Septoria tritici. Work has also started on FHB resistance in winter wheat

2. Special emphasis on germplasm development for leaf spot resistant wheat (tan spot and Septoria tritici), including genetic mapping approaches

3. Coordinator for the major FHB permanent screening nursery for wheat at Carman, Manitoba, with >13,000 plots per year.

4. New project in 2006, to breed a high yielding, disease resistant winter wheat suitable for the bioethanol industry, for moist regions of the E. Prairie. 5% yield increases are expected in the short-term, and 15% in the long-term. Project is funded by a NSERC / Husky Energy CRD grant.

<u>VI From the questionnaire: Relative potential for 15 W. Canadian cereal types to provide a significant contribution to (a) the Bio-energy requirements, and (b) the Feed requirements of W. Canada in the future</u>

27 breeders were canvassed by the GrainTek questionnaire, which included a question addressing the above topic. Respondents (only 4 out of 29 contacted) were asked to rank the 15 cereal crops for both potential uses, but very few comments were received explaining reasons for rankings or differences for the two uses.

Respondents rankings of crops for the two uses varied considerably, except for the notable 'highest' and 'lowest' groupings that were evident.

<u>Results:</u>
Rank values out of 15 (1 Highest, 15 Lowest) are shown as Mean followed by Range for
(a) Bio-energy. and
(b) Feed energy

		Bio-energy:		Feed energy:	
	Crop	Mean	Range	Mean	Range
Highest rankings:	Winter wheat	5	3-6	4	1-7
	Hulled barley	5	1-8	5	1-7
	CWGP wheat	6	4-10	6	4-8
	Winter triticale	6	1-12	7	2-12
	CPS wheat	7	5-9	6	3-9
	Hulless barley	8	7-10	4	1-7
Intermediate rankings:	Corn	8	2-15	9	2-15
	Hulled oat	8	2-13	10	6-13
	SWS wheat	8	5-12	11	9-14
	Spring triticale	9 !?	2-15	8 !?	3-9
	Hulless oat	9	7-10	9	3-12
Lowest rankings:	Fall rye	11	7-15	13	11-15
	CWES wheat	12	10-14	10	8-12
	CWRS wheat	13	11-14	11	7-14
	Spring rye	14	10-15	14	10-14

GrainTek commentary: Whilst many cereal grains are interchangeable for feed and other uses, factors that would influence the rankings above would include:

- Soft white wheat – softness causes milling problems during feed formulation.
- Winter wheat and triticale – identified as having high bio-energy potential.
- Hulled barley – hulled grains are less suitable for ethanol processing, because of high fiber level.
- Fall and spring rye – limited yield and acreage potential, plus anti-nutritionals in the grain.

- CWES and CWRS wheat – insufficient yield potential, and feed problems due to gluten in many cases. CWES class effectively discontinued.
- Spring triticale was very surprisingly discounted by respondents, and this may reflect both an absence of acreage and/or up to date information, as triticale has high potential for both energy markets.
- Hulless oat – New lines of CDC, designed for Feed oat, including low acid detergent hull high groat fat (LLH-HOG) oat for ruminants and high oil groat oat for non-ruminants, may offer high potential in both applications, but would need to gain significant acreage and adoption as a new bio-energy source for W. Canada. CDC SO-I (OT3017) was just registered as the first oat of this type, with the feed value of barley for ruminants (personal communication, Dr. Brian Rossnagel)
- Hulless barley – respondents identified the high value of this grain type for feed, but new unpublished data also suggest some level of yield competitiveness for the ethanol market (from unpublished interim results, SAF/Husky project).
- Corn has a local advantage in some regions, mainly S. Manitoba, although FHB susceptibility is still a factor in that province.

VII GrainTek independent findings / concerns / views

The following are independent views of GrainTek, based on Dr. Briggs past 35 years of experience in cereal breeding / research in W. Canada, grouped by category of opportunity. Some of these issues were also flagged by other breeders.

(a) Blue-sky (future oriented) opportunities and visions (not in priority order)

1.Vision: Within 25 years, at least 30-50% of W. Canadian cereal production is in winter types under minimum tillage systems, taking advantage of superior yield potential, better winter survival due to genetics and warming climate, and drought and disease escape through earlier maturity, also providing soil improvement features. This requires significant genetic improvement in winter types, especially for disease resistance in winter wheat, and for winter hardiness, and will not be likely if KVD for wheat remains in place. A new agronomy and rotation would also be needed to accommodate this major change.

2. Vision: Sustainable genetic resistance is in place for all 2007 Priority 1 cereal diseases, and current and emerging insect pests.

3. Vision: Within 10 years at least some Canadian manufactured wheat based products are produced from varieties that are bred for special nutritive properties that cause them to be in demand by consumers, and these products are also exported. (No such breeding goals were found during this review process).

(b) Addressing regulatory issues

1. Vision: Within 2 years, KVD is no longer a significant limiting factor for genetic yield improvement in Canadian wheat classes, as it will have been replaced by a system that either accurately determines variety being delivered (coupled with statutory declaration), or a system based on the actual quality functionality of the delivered sample.

2. Vision: Within 1 year the exclusively Canadian and scientifically arbitrary system of declaring Plants with Novel Traits (PNT's) and the burdensome regulatory requirements that are associated with registering PNT's, are abandoned in favor of a system that is solely based on scientifically based considerations of food and environmental safety, coupled with market considerations about new varieties that are GMO, as defined in those markets that apply GMO considerations as a criterion for market acceptability..

3. Recommendation: In crops for which registration is still required, and as the regulatory agency responsible for the registration process, the Government of Canada should create a separate technical capacity for the Coop testing system, including the creation of an independent testing agency responsible for obtaining the necessary agronomic, quality and pathological data. Existing public cereal breeders and researchers could continue to be partners in this data collection process, but should not have to be responsible for the system itself, to the detriment of time spent on basic research and breeding. With limited

PY's for breeding related research, AAFC and other government staff should not have to carry this entire burden of regulatory work for the Government of Canada.

This approach would also eliminate any perceptions of conflict of interest in the registration process for AAFC varieties. Resources are even now insufficient for the present Coop testing system to function efficiently, or to allow testing of a larger number of potential varieties at the B test or at the Coop level.

(c)Addressing infrastructure gaps in the cereal breeding system

1. Vision: In 10 years time Canada would be recognized for its pre-eminent position as a leader in cereals research (Triticeae) for (a) molecular genetics and physiology, (b) cereal pathology, and (c) doubled haploidy and breeding methodology, all directed towards the breeding of its major cereal crops. This could be achieved by establishing Centres of Excellence in these areas at W. Canada's agricultural Universities in joint research ventures with all existing public programs, both levels of government, industry and growers. Such Centres of Excellence would deliver a balance of (a) knowledge discovery about the Triticeae (at an international level), (b) development of genetic and other tools that can be transferred for use into ongoing public and private Canadian breeding programs, and (c) at least some level of service function that can be accessed by individual breeding programs, especially for use of high technology assays that would not be possible in individual breeding program labs. These Centres of Excellence would also serve as the main training venue and source for career track highly qualified technologists and future professional breeders needed to maintain cereal breeding in Canada at a competitive level.

2. Recommendation: Invest heavily in boosting cereal plant pathology and entomological research and breeding capacity in W. Canada, including at least all of the following components

- New field task force (and budgets) to monitor cereal crops throughout W. Canada for new diseases, races and insects, with dedicated laboratory staffing and resources to determine annual race changes etc. This information is vital for breeders to ensure that they can find and identify suitable new resistances, as threats from different pests and diseases change over time. This work has to continue forever, and requires long-term resource allocation. Real time information collection by this task force during the crop season will also be of high value to producers, in their determinations as to whether economic thresholds have been reached to merit chemical or other control measures.
- Expand disease testing (phenotyping) capacity for all W. Canadian cereal breeders, so that larger numbers can be tested in the breeding programs, as well as in the B tests and in the Coops. With larger numbers of diseases becoming significant, and a different profile of diseases to be expected with climate change, more testing capacity will be needed across the board. For the breeders this is a numbers game to a large extent, and adding a single disease requirement means larger populations must be screened. Some programs have limited access to

disease phenotyping, which limits their probability of success to register a variety, or causes some priority 1 diseases to be deliberately ignored.

- Support novel disease breeding approaches that can lead to achievement of durable (longer-term) resistances, using molecular marker technologies and other novel approaches to staying ahead of race change. Most programs have limited laboratory or highly qualified staff capacity to do this to the extent that is desirable, or on a routine basis, so centrally resourced labs for carrying out some of this work are desirable.

(d) Specific genetic investments to raise long-term cereal competitiveness

1. Vision: All W. Canadian barley varieties are low phytate in 15 years time, and benefits accrue to producers due to potentially lowered P input requirements, and use of manure with less P loading and environmental risk.

2. Vision: Achieve success within 5 years with FHB resistance and at least 50% DON reduction in most cereal varieties widely grown in W. Canada.

3. Recommendation: The single triticale breeding program in W. Canada has been very limited in its funding scope thus far. Given the successes seen with triticale as a major feed, forage and food crop in other countries, there should be a substantial increase in the core breeding resource for the Alberta program, including funds sufficient to access molecular breeding support that could be expanded in several W. Canadian university labs. Canadian triticale varieties recently released are in many cases higher yielding than the best varieties in other cereal energy grain crop classes, although further work is needed to quantify these comparisons more accurately.

4. Recommendation: Conduct a thorough multi-year, multi-location study to compare the grain yield of spring and winter cereal grains, especially focusing within the various 40 mile radii of sites where it is known that bio-ethanol plants will be built. (As another source of information are comparative crop yield maps available for these locations from crop insurance files?).The data bases comparing spring and winter cereal crops head to head for yield and for ethanol production in W. Canada are very scarce, and are not all based on the most modern varieties of all of the cereal crops. This comparative productivity project is urgent, and the results should then drive the crop choice where any breeding effort for ethanol production should be set, if any. Even if the grains for ethanol push declines in the future, new high biomass varieties of triticale and other cereals will still have value in the system for feed and forage.

SECTION 5 DISEASE AND INSECT RESISTANCE AS A CONSTRAINT

The role of genetic resistance to diseases and insects as an essential continuing constraint to release of future cereal varieties in W. Canada

Commentary by GrainTek

W. Canada is no exception to the estimate that plant breeders worldwide likely spend more than 80% of their breeding effort ensuring protection from diseases and insects that, without genetic resistance in place, would cause debilitating yield losses or complete crop failure. Without this disease resistance in place, and insect resistance in some instances, costly use of pesticides would be required, with negative effects both environmentally and economically for producers. Additionally, significant improvements in genetic yield potential sometimes achieved by breeders cannot be expressed in a stable, sustainable manner unless control of potential disease and other pest outbreaks is ensured. The most effective and economical way to achieve protection has always been through breeding resistances into varieties, and this will always remain a core objective, often surpassing in importance the high yield objective in many instances. The parallel essential requirement to ensure longevity of the genetic resistances used, is to ensure that a range of resistances are deployed in the full crop rotation, in different varieties in any particular crop, and by use of a wide range of host resistance found in the genetic diversity amongst crop types grown in sustainable rotations.

Without exception, all cereal breeders consulted emphasized very strongly the importance of maintaining high standards of disease resistance in all classes of cereals, because of the danger of catastrophic crop loss in the event of epidemic from new virulent races if they should develop. They all support an expansion of investment in this strategy for protecting yield levels thus far achieved.

Priority 1 Wheat and Triticale Diseases:

In the case of W. Canadian cereal crop breeding, pathologists have identified Priority 1 diseases, that will always be significant threats to crop production, through their potential negative affects on yield, grade and market value.

Table 9 lists these Priority 1 diseases (and others), and the minimum resistance standards that have been recommended by the breeders and pathologists for registering new wheat and triticale varieties. These standards tend to be higher in the CWRS and durum wheat classes, reflecting a longer history of breeding in these classes, and the higher priority set for them because of their historically large acreages in W. Canada. Breeders spend proportionately more effort on disease resistance in these classes because of the very high economic losses that would occur in the case of disease epidemic, as in the 1930’s, or as now potentially threatened by the Ug99 stem rust race that has emerged in Africa, and that is spreading towards Europe, or from the emerging yellow rust infections nor starting to be found widely across the Canadian prairies..

Although most of the Priority 1 diseases have some potential to cross attack susceptible varieties in all wheat and triticale classes, it should be noted that different minimum resistance standards for registration are in place by class, even though breeders always seek the best possible level of resistance, higher than the minimum. This is a reflection of the level of resistance that has been capturable to date in registered varieties, that varies by wheat / triticale class, even though higher resistance levels may be available in research level germplasm (See Appendix IX). As with other traits, the higher the bar is set for the expression level of disease resistance traits, the harder it is for the breeder to improve yield or the many other traits that are needed in a new variety. This is because of limitations to population sizes that can be screened for all traits, and because of frequent negative inter-trait genetic associations that can occur, especially with yield potential.

Despite the constraints mentioned above, W. Canadian wheat and triticale breeders have been extremely successful at registering varieties that significantly exceed the minimum standards needed (Table 10). However, special note should be taken of the following information in Table 10.

1. About the rusts:

Stripe rust has very recently emerged as a new disease threat throughout W. Canada in cereals, although its occurrence was previously mainly limited to irrigated, soft white wheat production in Alberta, and to limited acreage in S. British Columbia. AC Andrew was specifically selected for stripe rust resistance, but this was not the case for other varieties with a Good rating in the other classes, which fortunately nevertheless brought in some resistances along with their diverse genetic pedigrees. Stripe rust testing will now be added as a future breeding requirement for all classes of wheat and triticale in W. Canada, as it is believed that there has been a change to a new race better adapted to warming W. Prairie conditions, and which can infect at higher temperatures than before.

Although stripe rust resistance is rated by breeders / pathologists as a trait that is relatively easy to breed (Appendix IX), along with the other rusts, the rusts all have the ability to produce new virulent races at a very high rate, especially in response to single gene resistances that are deployed by breeders. It is the ease of selection for and incorporation of new resistance genes that is relatively easy, not the search for new resistance genes as old ones fail. (GrainTek did not have time to learn from the pathologists / breeders which of the varieties that are rated Good for stripe rust are protected by only a single gene).

The Fair reaction of AC Andrew for leaf rust resistance should be noted, as it may soon occupy large areas of production for the ethanol industry, much of this outside of its originally intended area of adaptation. It may join a longer list of other wheat varieties (including some CWRS varieties) which are grown on large acreages for their high yield, but that do not necessarily have good levels of resistance to one or more rusts, or other diseases. Rusts would have the capacity to move across the prairies very quickly if there was a significant inoculum source (usually derived from the US, Mexico or from the E. Prairies if an epidemic started there), significant acreage of susceptible varieties in place to allow secondary local or distant spread, and correct environmental conditions for the pathogen.

The industry will need to closely monitor the potential for rust race evolution on high yielding wheat varieties grown intensively in short rotations within 40 mile radii around ethanol plants, if new varieties with less resistance than the best CWRS varieties are registered and grown / contracted. Some estimates place the potential for this kind of acreage as high as 30+% of all spring wheat acreage in the Prairies. Disease evolution within these islands of intense wheat production, using new varieties not previously widely grown, may have potential to negatively change the future disease ratings of currently popular CWRS varieties, if significant race changes should occur. It is also possible, of course, that this scenario might not play out at all.

The new stem rust race Ug99 from Africa has knocked out some resistance genes used worldwide, and is moving towards Europe. It might in time be a threat to Canadian wheat production, but research to deal with that threat is already underway. This is another disease which has been absent for many years, but for which continual monitoring and breeding is still required.
(See http://www.westerngrains.com/n_researchMag/rm_0602a.html)

2. About Fusarium Head Blight (FHB):

This debilitating worldwide cereal disease is already causing significant problems for all cereal crop classes in W. Canada, eliminating some cereal crops from the rotation in some regions (eg. Manitoba). It is very high priority in all cereal classes. Note that all the wheat and triticale classes have low minimum standards of resistance, which reflects the worldwide difficulty thus far in finding high levels of resistance, both for the yield reducing symptoms on the plant, and for the DON levels in the grain, or in the byproducts.

A high research investment level into W. Canadian projects to find good resistance and control methods is evident from this review, but will have to be sustained. FHB will continue to be a major problem for all cereal grains in W. Canada in the foreseeable future, although phyto-sanitary measures to slow its introduction into Alberta are in place. Earlier suggestions that winter types (wheat, triticale) can escape the effects of this disease have not so far been confirmed (but GrainTek lacked time to conduct a current review of the most recent W. Canadian research findings for FHB).

Table 9 Minimum registration standards for disease reaction, W. Canadian wheat and triticale classes
Source PGDC website, April 18, 2007, including February 2007 PGDC standards for CWGP

Ratings vary from best to worst by the codes R, MR, I, MS, and S (Susceptible)
A minimum standard for stripe rust is so far not set in SWS wheat (indicated by ?)

Disease name and CWRS/CWAD (Priority 1-3)	**CWRS**	**CWAD**	**CPS + CWGP (S)**	**CWES**	**SWS**	**CWRW + CWGP (W)**	**Triticale (S + W)**
Stripe rust (1)	?	?	?	?	MR	?	?
Leaf rust (1)	MR	MR	I (1)	I (1)	- (1)	I (1)	MR
Stem rust (1)	I	MR	I (1)	MR (1)	- (1)	I (1)	MR
Common bunt (1)	I	MR	I (1)	I (1)	- (1)	MR (1)	I
FHB (1)	MS	MS	MS (1)	MS(1)	- (1)	- (3)	MS
Leaf spots (1)	MS	I	MS (1)	MS (1)	- (1)	- (2, 3)	- (2, 3)
Loose smut (1)	MR	MS	MS (1)	MR (1)	- (1)	- (2)	- (2)
Blackpoint (2)	-	-	- (2)	- (3)	MS (3)	- (3)	- (2)
Common root rot (2)	-	-	- (2)	- (2)	- (2)	- (3)	- (2)
Powdery mildew (3)	-	-	- (3)	- (3)	I (3)	- (3)	- (3)
Ergot (3)	-	-	- (3)	- (3)	- (3)	- (3)	- (3)
Take-all (3)	-	-	- (3)	- (3)	- (2)	- (3)	- (3)
BYD virus (2)	-	-	- (2)	- (3)	- (3)	- (3)	- (2)
Wheat streak MV (2)	-	-	- (2)	- (2)	- (2)	- (2)	- (2)
Bacterial blight (3)	-	-	- (3)	- (3)	- (3)	- (3)	- (3)

Table 10 Best disease reaction of registered varieties for W. Canadian wheat and triticale classes, 2007, for Priority 1 diseases – named varieties
Source ACOAC, SVPG and MCVET Variety description publications, 2007

Ratings vary from best to worst by the codes Very Good, Good, Fair, Poor, Very Poor
MR = Moderately resistant, MS = Moderately susceptible, and I = Intermediate
na = information not available

Priority 1 diseases	**Wheat class**	**Minimum standard**	**Best reaction**	**Names of varieties with best reaction in W. Canada**
Stripe rust	CWRS	na	Good	AC Intrepid, Lillian,
	CWHW	na	Good	Snowbird
	CWAD	na	Good	AC Navigator, Strongfield
	CPS	na	Good	5701PR
	CWES	na	Good	AC Corinne, Glenlea, CDC Rama, Burnside
	SWS	na	Good	AC Andrew
	CWRW	na	na	na
	Triticale	na	na	na
Leaf rust	CWRS	MR	Very Good	CDC Alsask, AC Cora, Lillian, McKenzie, 5600HR, 5602HR
	CWHW	MR	Good	Kanata
	CWAD	MR	Very Good	All varieties
	CPS	I	Very Good	5701PR
	CWES	I	Good	All except Glenlea
	SWS	na	Fair	AC Andrew
	CWRW	I	Very Good	McClintock
	Triticale	MR	Very Good	All varieties
Stem rust	CWRS	I	Good	Nearly all varieties
(but not Ug99)	CWHW	I	Good	Snowbird
	CWAD	MR	Very good	All varieties
	CPS	I	Good	All varieties
	CWES	MR	Good	All varieties
	SWS	na	Good	AC Andrew
	CWRW	I	VG	CDC Falcon, McClintock, CDC Raptor
	Triticale	MR	Very Good	All varieties
Common bunt	CWRS	I	Very good	AC Cadillac, McKenzie, Peace, Prodigy
	CWAD	MR	Very good	All varieties except Strongfield
	CPS	I	Very good	All varieties except 5701PR
	CWES	I	Good	CDC Rama
	SWS	na	Fair	AC Andrew, AC Nanda

	CWRW	MR	Good	AC Bellatrix
	Triticale	I	Very good	All varieties
FHB	CWRS	MS	Good	5602HR
	CWAD	MS	Very poor	All varieties
	CPS	MS	Very poor	All varieties
	CWES	MS	Fair	CDC Rama
	SWS	MS	na	na
	CWRW	MS	Very poor	All varieties
	Triticale	MS	Fair+	Pronghorn, AC Certa, AC Ultima
Leaf spots	CWRS	MS	Fair	AC Elsa, Infinity, Journey, Kane, Lovitt, CDC Osler,
	CWAD	I	Fair	AC Avonlea, Napoleon, Strongfield
	CPS	MS	Fair	AC Crystal, AC Taber, 5701PR
	CWES	MS	Poor	All varieties
	SWS	na	na	na
	CWRW	na	na	na
	Triticale	na	na	na
Loose smut	CWRS	MR	Very good	AC Cadillac, AC Domain
	CWAD	MS	Poor	All varieties are Poor to Very poor
	CPS	MS	Good	Snowwhite476
	CWES	MR	Very good	All varieties
	SWS	na	Good	Bhishaj
	CWRW	na	na	na
	Triticale	na	Good	All varieties

Priority 1 Barley and Oat Diseases

A listing of Priority 1 diseases is presented in Table 11. Similar general observations apply to disease breeding in barley and oat as in wheat and triticale, especially the need to continue resistance breeding forever, in order to protect gains made in other traits, including yield.

A listing of the W. Canadian varieties with the best disease reactions is presented in Appendix IX, which indicates a high performance level of breeders delivering resistance into new varieties in a continuously effective manner. The best reactions to FHB in barley varieties appear to be somewhat better than those available in wheat, triticale or oat.

Ability to make progress in scald resistance in hulless barleys, and particularly in malt barleys, has been frustrating for breeders, even though several resistance genes are already well characterized. Manny, from FCDC (AAF) is a notable exception, with its Very good level of scald resistance. Barley will be the first cereal crop worldwide in which a molecular marker based project to breed a variety with three different pyramided scald resistance genes will be carried out, involving several different Canadian public breeding organizations.

Table 11 Required priority disease evaluations agreed by PGDC in 2007 for registration of new barley and oat varieties

Source: PGDC Website, April 19, 2007

	2row and 6 row barley Hulled and hulless	Oat Hulled and hulless
Barley yellow dwarf	+	
Common root rot	+	
Net blotch 102b	+	
Net blotch 858b	+	
Net blotch 857c	+	
Scald 692e	+	
Scald 1493c	+	
Septoria	+	
Spot blotch	+	
Smut: Ustilago nuda	+	
Smut: Ustilago hordei	+	
Smut: Ustilago nigra	+	
Stem rust	+	+
Fusarium head blight	+	+
Oat smut		+
Oat crown rust		+

Table 12 Best disease reaction of registered varieties for W. Canadian barley and oat classes, 2007, for Priority 1 diseases – named varieties

Source ACOAC, SVPG and MCVET Variety description publications, 2007

Ratings vary from best to worst by the codes Very Good, Good, Fair, Poor, Very Poor
na = information not available

Priority 1 diseases	**Crop type**	**Best reaction**	**Names of varieties with best reaction in W. Canada**
Net blotch	Malt barley	Good	Calder, CDC Tisdale, CDC Battleford
Net blotch	Feed and food barley, hulled	Very good	CDC Trey
Net blotch	Hulless barley	Very good	CDC McGwire
Spot blotch	Malt barley	Very good	Lacy, CDC Battleford
Spot blotch	Feed and food barley, hulled	Good	AC Rosser
Spot blotch	Hulless barley	Fair	CDC McGwire, AC Bacon
Scald	Malt barley	Poor	All varieties
Scald	Feed and food barley, hulled	Very good	Manny
Scald	Hulless barley	Fair	CDC McGwire, CDC Gainer, CA Bacon, Peregrine
Loose smut	Malt barley	Very good	AC Metcalfe, Calder, AC Bountiful
Loose smut	Feed and food barley, hulled	Very good	CDC Coalition, CDC Helgason, Ponoka
Loose smut	Hulless barley	Fair	HB 805
Other smuts	Malt barley	Very good	Calder
Other smuts	Feed and food barley, hulled	Very good	Ponoka, CDC Trey, Manny
Other smuts	Hulless barley	Good	CDC McGwire, Falcon, Tyto, CDC Freedom, HB 805
Root rot	Malt barley	Good	>50% of varieties
Root rot	Feed and food barley, hulled	Good	>33% of varieties
Root rot	Hulless barley	Good	CDC McGwire, Peregrine
Stem rust	Malt barley	Good	>65% of varieties
Stem rust	Feed and food barley, hulled	Good	> 60% of varieties

Table 12 cont.			
Priority 1 diseases	**Crop type**	**Best reaction**	**Names of varieties with best reaction in W. Canada**
Stem rust	Hulless barley	Good	CDC McGwire, CDC Freedom, AC Bacon, Peregrine
Fusarium head blight	Malt barley	Good	Harrington, Calder
Fusarium head blight	Feed and food barley, hulled	Good	Xena, CDC Cowboy
Fusarium head blight	Hulless barley	Good	CDC McGwire, AC Bacon. CDC Freedom
Stem rust	Oat, hulled	Fair	60%, rest are Very poor
Stem rust	Oat hulless	Fair	All except GEHL (Poor)
Leaf rust	Oat, hulled	Very good	HiFi, Leggett,
Leaf rust	Oat hulless	na	na
Fusarium head blight	Oat, hulled	na	na (Likely poor)
Fusarium head blight	Oat hulless	na	na (Likely poor)
Oat smut	Oat, hulled	Very good	60% of varieties
Oat smut	Oat hulless	Very good	All except AC Assiniboia (Fair)
Oat crown rust	Oat, hulled	Very good	Leggett
Oat crown rust	Oat hulless	Very good	AC Assiniboia
BYDV (virus)	Oat, hulled	Good	>50% of varieties
BYDV (virus)	Oat hulless	Good	GEHL, Lee Williams

Breeding for insect resistance

Climate warming is expected to increase the activity and range of cereal damaging insects in W. Canada, of which the two significant ones at this time are wheat stem sawfly and wheat midge. No others are especially flagged as threatening at this time, as far as GrainTek has been able to determine. W. Canadian wheat breeders have been very successful in breeding resistant varieties of both named insects, including use of molecular markers as selection assists in some cases.

Wheat midge is mainly restricted to attacking wheat, but can also attack barley, but rarely at significant levels. There is concern that this relatively newly serious insect in W. Canada may increase significantly unless resistant varieties are extensively deployed. Midge damage was a very significant contributor to wheat downgrading in the 2006 crop season (DePauw – personal communication). The wheat stem sawfly is able to attack wheat, rye, triticale and some barley varieties, and the main approach to breeding resistance is to select for solid stem types, with considerable success. Sawfly damage has been increasing in new areas where it has not been a problem in the past.

Routine breeding for resistance in areas of W. Canada where these insects can be prevalent will be required, as well as the use of prairie-wide trap nurseries and monitoring systems. There will also be a need to support / fund lab facilities and highly qualified entomology staff, that are needed to indicate to breeders where the problem exists, to carry out selection for resistance, and to evaluate the effectiveness of resistance genes as they are deployed in new varieties..

SECTION 6 GRAINTEK SUMMARY OF RECOMMENDATIONS

GrainTek commentary

Section 6 of this report summarizes the most important suggestions received and recommendations made during this review, for potential new investment into public cereal breeding, to gain improved genetics cereal genetics and competitiveness for W. Canada. The listing also includes several suggestions independently forwarded from GrainTek. All items are presented only in tabular form, as details about each are presented in other parts of this report.

GrainTek recommends that the setting of priorities for potential new investment in cereal breeding reflect the views of the widest array of inputs from industry (cereal users) and breeders, based on strategic development of business plans for breeding objectives with inclusion of estimates of expected benefits. It is understood that ACIDF and AARI will seek to develop such an industry wide consultative process, that will also use as input suggestions made in this phase of the competitiveness initiative.

As seen from these lists, the largest number of opportunities was seen by most programs in the area of a strongly stated need to boost infrastructure and core breeding capabilities (17 items), then by specific (mostly project level) investment proposals (9), followed in frequency by ‘Blue sky’ future oriented suggestions / visions (5), and regulatory (but pivotally important) changes needed (4).

Because of the extent of these recommendations, they are presented as lists in tabular, form, to which GrainTek has added its own semi-quantitative ‘best estimates’ of:

- Potential Impact on long-term cereal competitiveness
  (M Moderate, H High, VH Very high); BE = relevant to Bio-energy
- Recommended Date for implementing new investment
  (Now; Later)
- Extent of all Mentions for the listed investment, from all programs reviewed
  (Single; Freq. Frequent; VFreq.Very frequent)

Recommendations are also organized in separate tables according to their nature, as follows, but are not listed in priority order:

I ‘Blue sky’ visions of future W. Canadian cereal breeding opportunities
II Addressing regulatory issues
III Fixing breeding infrastructure gaps and deficiencies
IV Specific genetic investments to raise long-term cereal competitiveness

(I) 'Blue sky' visions of future W. Canadian cereal breeding opportunities

Item	Brief description (Blue sky items)	Impact	Date	Mentions
1	Perennial triticale for feed and forage, including cellulosic bio-energy in the future	VH BE	Later	Single
2	Winter wheat and winter triticale will occupy up to 30%+ of W. Canadian cereal acreage in the future	VH BE	Now	VFreq.
3	In 10 years Canada is recognized for its Collaborative Centre of Excellence in Triticeae Research (Functional genomics, plant physiology, pathology and breeding methods), for gene discovery, personnel training and the basic and applied servicing of cereal breeding programs	VH BE	Now	VFreq.
4	Nearly all barley varieties grown in W. Canada are low phytate within 15 years	H ?	Later?	Freq.
5	Barley varieties with over-expressed food and nutritional functionality, for domestic and US markets	H	Later	Freq.
6	Wheat varieties with improved novel nutritional properties, vertically integrated into Canadian made cereal products for domestic and US markets	H	Later	Freq.

(II) Addressing regulatory issues

Item	Brief description (Regulatory items)	Impact	Date	Mentions
7	Replace KVD system in wheat with a system based on variety ID plus statutory declaration, or one based on sample functionality	VH BE	Now	VFreq.
8	Replace current scientifically invalid definition of PNT's with one based solely on food, health and environmental safety	VH BE	Now	VFreq.
9	Federal Government to fully and separately fund the resources necessary to collect the data for the Coop registration system, and to transfer the responsibility for it from the public cereal researchers and breeders to a newly constituted Federal office. The public programs could still conduct the trials under the terms of the PGDC committees, but on a cost recovery basis, but would not bear the management burden for the Coop testing system, freeing them for full-time innovative research. Another alternative would be to contract out the entire process, charging entries full cost recovery, or for Government to cover that	VH BE	Now	Freq.

	full cost, since the system is required by government			
10	Ensure that the registration system leaves more flexibility for the successful breeding, approval and commercial use of cereals that do not fit into the grade standards defined by CGC and the CWB	H	Later?	Freq.

(III) Fixing breeding infrastructure gaps and deficiencies

Item	Brief description (Infrastructure gaps)	Impact	Date	Mentions
11	Reverse the little to no investment in cereal breeding by the major users of cereal grains in W. Canada, including the milling and food industry, and the feed and livestock industry	VH BE	Now	VFreq.
12	Shortage of investment in training of new breeders and highly qualified technologists to support future cereal research and breeding programs, coupled with a shortage of long-term funded, career track, opportunities for such personnel in public breeding programs	VH BE	Now	VFreq.
13	Funding agencies need to find ways to strengthen support of core infrastructure needs in breeding programs, and to avoid the past discontinuities associated with short-term funding for ‘trait-based’ breeding projects. Most public programs are suffering some shortfalls in required facilities, permanent technical support, or equipment maintenance/ modernization, which limits the ability to add new traits to the programs	VH BE	Now	VFreq.
14	Substantially increase investment level in all aspects of pathology disease monitoring and support for breeders. (Ideally this should be linked to development of the proposed TECC Chair in Cereal Pathology, but is urgently needed even if there is no such new Chair – GrainTek)	VH BE	Now or sooner	VFreq.
15	Amalgamate all four W. Canadian winter wheat breeding programs into one pooled program, sharing resources and capabilities, with major leadership provided from the fulltime program at LRC/ AAFC. Total breeding effort to date with winter wheat has been limited and major potential yield gains are forecast for winter wheat, for feed and industrial use, if there is significant investment made now. New funds should be directed to	VH BE	Now	VFreq.

	program core needs in pathology, winter hardiness and regional adaptation, as different types are needed in different parts of the prairies. The E. Prairies require good FHB resistance combined with rust resistance and good standability. (NB The suggestion to form a single winter wheat breeding consortium is from GrainTek, not the breeders, and has not been discussed with them, but the need to better share resources is agreed by all)			
16	Make a major investment in SWS breeding at LRC/ AAFC, which is now hiring a new breeder. Program size has been very small to date and most wheat breeders feel that major yield gains can be made in this class, especially as adaptation is sought for dryland areas where it may be widely grown to support the ethanol industry	VH BE	Now	VFreq.
17	Rebuild full infrastructure support for the barley feed and forage breeding programs at CRDC / AAF, Lacombe	VH	Now	Freq.
18	Rebuild full infrastructure support for the triticale feed and forage breeding programs at CRDC / AAF, Lacombe, and expand the core program significantly. This to include linkages with Functional Genomics Centers, and pre-breeding with rye and wheat to make new primary triticales, to expand the germplasm base. ‘Breeding of high energy triticale is the best investment towards increasing biomass, for grain, forage, feed and bio-ethanol’	VH	Now	Freq.
19	Replace recently lost barley breeding position at CDC. Coupled with this, reinstate full activity level in hulless feed barley breeding, cut back in 2006 due to reduced WGRF check-off funding	VH BE	Now	Freq.
20	Establish a new multi-location, University based, multi-institute W. Canadian Triticeae Excellence Centre for Cereals(TECC), with the following structure and objectives targeted towards all cereal grain crop improvement. Each TECC Chair would also have technical and other infrastructure support 1. Chair in Functional Genomics (U of AB, initial focus on triticale, plus focus on genetic tools for cereal breeding and gene selection) 2. Chair in Cereal Physiology (U of SK, focus on stress tolerance and winter and cold hardiness) 3. Chair in Cereal Pathology (U of MB +	VH BE	Now	Freq.

	CDC/AAFC, primary focus on FHB and rusts) Functions of the TECC would be: (a) Genomic, genetic, phenotypic and physiological discovery in cereals (b) ID of genes, marker systems and other selection tools for breeder use in their programs, including transformation techniques and doubled haploidy (c) Prioritise and address cereal breeding needs on a continuing basis, for agronomic performance, disease / insect resistance, and quality aspects (c) Up to 25% of resources to be used for conducting routine phenotyping assays that require specialty equipment / personnel unavailable in individual breeding programs TECC would develop seamless research linkages with all other cereal research labs and programs in W. Canada, and offer a standing forum for the strategic planning of future integrated cereal breeding development for W. Canada. Goals would also include more sharing of breeder access to resources / facilities found throughout all public cereal breeding programs			
21	Lack of regional centers for product development, (such as bio-fermentation, bio-processing, bio-product development, specialty food product development) to pull improved genetics through the food chain. This also includes the need for more pilot scale testing facilities for use by cereal breeders	VH	Later?	Freq.
22	Gain new brewing and malting industry resources as partners to fully support Malt barley breeding at FCDC, Lacombe. Otherwise, reposition the existing very limited funding for the valuable genetic work in these crops at CRDC / AAF (particularly for disease resistance and adaptation phenotyping) to support core malt breeding programs that are fully funded at other public breeding institutions	VH	Now	Freq.
23	Establish an annual (or standing) W. Canadian forum for coordinating all W. Canada cereal research funding and cereal breeding resource sharing throughout the region, with greater scope than is presently done by WGRF and ABC managed check-off funds, or the Alberta Funding	H BE	Now	Freq.

	Consortium.			
24	Insufficient technical support for CDC wheat breeding	H BE	Now	Single
25	AAFC forage barley program could benefit from better links with the AAF/AAFC Lacombe program, and with the cattle industry, for funding and direction. It targets forage and cellulosic ethanol	M BE	Now	Single
26	Collaborative research links and connections to market requirements were not viewed as limiting, but most programs identified areas where they could individually benefit from better linkages of one kind or another. (Individual programs should solve their own needs on this – GrainTek)	M	Now	VFreq.
27	Move AAFC cereal breeding programs out of government, to be arm's length from Federal Regulatory oversight, perhaps in a new joint Public / Private W. Canadian Cereal Breeding Institute	M	Later	Single

(IV) Specific genetic investments to raise long-term cereal competitiveness

Item	Brief description (Specific genetic investments)	Impact	Date	Mentions
28	Gain FHB resistance and 50% reduction in DON levels in barley	VH BE	Now	VFreq.
29	Breed a better disease package into SWS wheat for feed and bio-energy use. What was a small breeding program needs to receive large new investment, especially to achieve adaptation to non-traditional areas for the SWS type, including rainfed production for feed or bio-ethanol	VH BE	Now	VFreq.
30	Breed a high yielding, FHB resistant, CWRS wheat for the E. prairies, with good standability	VH	Now	VFreq.
31	Breed a high yielding, midge resistant, CWRS wheat for the Central prairies, with good standability	VH	Now	VFreq.
32	Gain better winter-hardiness in W. wheat and W. triticale, to take advantage of much higher yield levels compared to spring types, and other potential advantages for grain and forage production	VH BE	Now	VFreq.
33	Invest in genetic research and methodology development for phenotyping of digestible energy in feed, building on recent innovations with NIRS technology at FCDC / AAF, Lacombe	VH BE	Now	Freq.
34	Sustainable genetic resistances are required for all	VH BE	Now	Freq.

	Priority 1 cereal diseases, which can be achieved by using new gene marker systems that allow gene pyramiding and other novel molecular based approaches. These methods depend on access to (a) molecular assay methods and specialist labs for large numbers of samples on a routine basis, and (b) expanded phenotyping capacity at all levels, as also described in infrastructure needs			
35	LLH-HOG (= Low acid detergent lignin hull, high groat oil) oat becomes established as a significant alternative whole oat cereal grain crop with the feed value of barley for ruminants (especially dairy), for national and international markets. Potential 1m acres in W. Canada. (CDC program: 1st released variety is CDC SO-1 / FarmPure Seeds, involving SuperOats Canada)	VH	Now	Single
36	Expand phenotyping capacity for net blotch resistance in barley, and stripe rust in cereals	VH BE	Now	Freq.
37	Gain a 30% increase in biomass in forage barley, to provide competitiveness with open-pollinated corn, for cellulosic bio-energy and forage use	H BE	Later?	Single
38	Complete a multi-year, multi-location study at locations proximate to new and planned ethanol plants, to compare new varieties of winter and spring cereals for their grain productivity and for potential ethanol production. This should also include evaluation of high yielding hulless barley such as McGwire	VH BE	Now	Freq.

SECTION 7   ACKNOWLEDGEMENTS AND DISCLAIMERS

Acknowledgements

Many breeders and research managers contributed to discussions and provided materials for review during this project process, but particular thanks are due to the following:

Members of the ACIDF / AARI review team
Ms Dorothy Murrell, Research Manager, CDC
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Dr. Brian Fowler, University of Saskatchewan
Dr. Mike Dolinski, Private consultant (entomology), Alberta
Individual breeders of the public cereal breeding programs of Western Canada
Dr. Rob Graf, LRC, AAFC
Dr. Stephen Fox, CRC, AAFC
Dr. Mario Therrien, BRC. AAFC
Dr. Jennifer Mitchell-Fetch, CRC, AAFC
Dr. Ron DePauw, SPARC, AAFC

Disclaimer

GrainTek has made every effort to ensure that the source confidentiality of any sensitive comments or materials has been respected. GrainTek has also made every effort to ensure that information provided or reviewed during this project is correctly represented, but some errors and omissions may have occurred because of the extent of the materials and programs surveyed. In cases of errors or omissions in the report GrainTek accepts editorial responsibility and apologizes for any instances of informational misrepresentation. In case of disagreement concerning breeding activities, or in summary tables, the originating breeders or documentation should be consulted to clarify any apparent errors or contradictions. GrainTek would appreciate being advised of any such instances, so that corrections can be made to the report.

SECTION 8

Appendices (See separately indexed file)

SECTION 8

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Appendix X University of Manitoba Wheat Research Program, Dr. A. L. Brûlé-Babel, April 2007 71 - 73

Appendix XI University of Saskatchewan Winter Wheat Breeding Report (Dr. Brian Fowler program. Note that this program is no longer within the current CDC mandate, because of withdrawal of SADF funds several years ago) 74 - 75

Appendix I. Sources of information used

Annual reports, Field Crops Development Centre, AAF, Lacombe
Annual report for 2006-2007, CDC, University of Saskatchewan – Dorothy Murrell
Discussion Paper for ACIDF on Constraints Facing Plant Breeding in Western Canada: Crop Development Centre - Bruce Coulman, Dorothy Murrell, Curtis Pozniak, Brian Rossnagel, April 11, 2007
Summary report on AAFC Wheat Breeding – Dr. Steven Fox, AAFC, Lethbridge
Summary report on AAFC Barley Breeding – Dr. Mario Therrien, AAFC, Brandon
Summary report on AAFC Oat Breeding – Dr. Jennifer Mitchell-Fetch, AAFC, Winnipeg
GrainTek + Alan Hall visit with Dr. Helm's breeding group, AAF, Lacombe, March 15, 2007
GrainTek visit with Dr. Jeff Stewart, breeders, and members of the Triticale Bio-refinery Initiative, Lethbridge Research Centre, AAFC, Lethbridge, March 30, 2007
Attendee, discussions and interviews with breeders, February 19-22, 2007, PGDC meetings, Saskatoon
Attendee, AIA Annual meeting, Banff, March, 2007, 'Bio-energy – A Realistic Opportunity for Agriculture?, Annual AIA Conference, March 28-29, 2007
Attendee, 'Creating the Next Generation of Biological Feedstuffs', AARI / Industry meeting, Leduc, April 10, 2007
AAFC Science and Innovation Strategy Documentation at http://www.agr.gc.ca/index_e.php?s1=sci
European Technology Platform 'Plants for the Future' documentation: Stakeholders proposal for a strategic agenda 2025, including draft action plan 2010. 102pp + related documentation, from the web (e.g. Plants for the future – The way there)
Provincial, national, international and industry web pages
Personal contacts with individual breeders, to the extent possible (approx. 30% response)
Cereal breeder responses to the GrainTek competitiveness questionnaire (less than 15% response)

Appendix II Activity time log for the project

Available on request: Total 23.0 days actual to report completion

Appendix III Discussion Paper for ACIDF on Constraints Facing Plant Breeding in Western Canada: Crop Development Centre

Bruce Coulman, Dorothy Murrell, Curtis Pozniak, Brian Rossnagel

April 11, 2007

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1. Industry

1.1 KVD
While KVD provides a level of risk amelioration to grain handlers and sellers and helps brand CWRS bulk shipments, it places a limit on the germplasm which can be utilized in breeding programs and in some cases halts the release of varieties which may be completely fit for purpose in all respects.

1.2 "Novelty"
The PNT definition and the regulations around novel feeds and foods, coupled with slow response to need for change in CFIA, are proving to be a huge barrier to innovation in Canada. Examples include safflower with specific molecular characterization which can provide a replacement to synthetic insulin production, innovative plant products from entrepreneurial startups in Saskatchewan which are finding markets in the US and not in Canada due to regulatory impediment, and new feedstuffs for monogastric livestock which provide cost savings and environmental benefit, again available in the US and not in Canada.

1.3 Gradual Eroding of Human Resources
There are simply too few people attempting to do too much stuff. Positions are not being filled, and funding is uncertain. Plant breeding is not apparently appealing at the grad student level leading to a reduced cadre of new brains available. We need more scientists in the breeding programs, not fewer.

1.4 CWB Influence on Breeding Goals
Wheat breeders can respond only to the CWB's direction in setting breeding goals, even though they hear other advice from industry. There are many examples of these goals being switched in short time frames and with short notice, or of the CWB completely pulling out of certain classes.

1.5 Technical constraints in pilot facilities
There is a lack of pilot facilities for testing new products at realistic pricing levels.

1.6 Technical constraints in innovative product development
There is less than adequate resourcing for innovative product development, and often resources are short term. We could see great use in setting up regional centres for bio-fermentation, bio-processing, bio-products, specialty food product development, which could pull products through the value chain.

1.7 Bio-visionaries

We must be careful not to promote over-expectation.

1.8 Support from End Users
There is a consistent lack of financial support of breeding from non-farmer end users such as the feed industry and the bread wheat industry.

2. Crop Development Centre

2.1 R&D
The CDC needs to set up some basic scientific facilities including such things as a DH lab and a marker lab, both of which require technically sophisticated staff on a year round basis, therefore requiring secured operations funding.

2.2 Off Station Testing
The CDC works well on a collaborative basis with other breeding institutes and seed partners to coordinate off site trialing; however, we would like to set up a more consistent approach.

2.3 New Breeding Positions
We currently see a need for succession planning around two breeders who may retire within the next two years, and in addition, we would see merit in separating our huge barley and oat program into two separate programs. In addition, there is merit in consideration of adding breeder resources to our wheat development group.

2.4 Winter Wheat
We must make a decision in 2007 whether the CDC winter wheat program will continue or be shelved. Resources are limited, and the Principal Investigator, Dr. Brian Fowler, plans to retire in two years.

Appendix IV Annual Report, Crop Development Centre, University of Saskatchewan, April 1, 2006 to March 31, 2007 Compiled by Dorothy Murrell, Managing Director, Crop Development Centre

Annual Report (Cereal breeding portion only)

Crop Development Centre
University of Saskatchewan
April 1, 2006 to March 31, 2007
Compiled by

Dorothy Murrell, MSc., PAg.
Managing Director, Crop Development Centre

March, 2007
Contributors:

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Executive Summary

The 2006 growing season was generally very good. Moisture conditions were generally favourable throughout the season with the exception of too much moisture in the northeastern region of Saskatchewan. Temperatures were good. Crop development was on time to early but wet conditions during September delayed some crop harvest.

The Crop Development Centre continued its breeding, research & development work, gaining recommendation of 12 new crop varieties and making headway in exciting and cutting edge research. Its breeders participated in teaching, extension and scientific outreach activities in Saskatchewan, Canada, the United States and as far away as Turkey and Syria.

Notable staff changes were the hiring of Dr. Curt McCartney as Cereal and Flax Pathologist and Ms. Dorothy Murrell as Managing Director.

Accomplishments and Progress:

The past year has been another productive one for the scientists in the Crop Development Centre and the details of all SAFRR funded programs are provided in the following pages. Some of the highlights of the past year's work include:

- **Plant Breeding - 12 new crop varieties recommended for registration in February 2007:**
    - CDC 1400-8 pea
    - CDC 1410-15 pea
    - CDC 1434-20 pea
    - CDC 1519-10 black bean
    - CDC 1190M-13 navy bean
    - 1073M-38 pinto bean
    - 3110 extra small red lentil
    - 3114 small red lentil
    - 2471 medium green lentil
    - 1308M-7 small red lentil
    - OT3018 milling oat
    - HB388 two row hulless feed barley (Second low phytate feed barley)

- **Research Highlights**

In addition to plant breeding, CDC scientists are involved in a very large number of research projects that contribute to the agricultural economy of Saskatchewan and western Canada. These are described in detail in this report. A few examples include:

- Improvement of quality attributes in red lentils
- Frost tolerance in Phaseolus vulgaris
- Douple haploidy techniques in peas, chickpeas and lentils

- Development of low phytate peas
- Characterization and molecular mapping of drought tolerance in chickpea
- Improvement in ascochyta resistance in chickpea
- Enhanced straw fibre in flax.
- Gene movement in spring wheat
- Progress in spring wheat organic cultivar development
- Progress in canario development
- Genomics tools for crop improvement using wheat and rye as the base crop
- Genetic mapping for low grain cadmium concentration in durum
- Wheat varieties for ethanol production
- Examination of low phytate barley for malting and brewing

- **Scientific Publication and Technology Transfer**
  - 43 extension presentations and field days
  - 71 conference presentations / posters
  - 44 refereed manuscripts
  - 3 international activities
  - 23 graduate students supervised

Administration:

A. Facilities and Infrastructure:

The Crop Science Field Laboratory is up and running, and into its second year of operation.
The Crop Development Centre is planning the next addition to the Field Lab in the form of a Grains Innovation Laboratory. Funding of $5 million for this project was announced in a joint communiqué by the provincial and federal Ministers of Agriculture on February 12, 2007.
A Haygrove Tunnel System was built at the Field Lab site in 2006 for lower cost production and increased reliability of production of F1 plants.
There remain a number of infrastructure opportunities for the CDC:

- Irrigation system for a field crop disease nursery to allow for screening of breeding material and pulse pathology research. Estimated cost is $200,000. Budget has been set aside. A parcel of existing Plant Sciences/CDC land along Preston Avenue has been designated as the site for the new disease nursery and installation should occur during 2007.

- Expanded shop facilities for equipment maintenance and repair ($400,000). This expenditure has not yet been budgeted.

B. Research Funding:

The Crop Development Centre depends heavily on financial support received from a wide variety of sources:

- SAF provides an annual operating grant of $1,000,000 to the CDC. In addition, in 2005-06, approximately $1,200,000 in funding from other sources was used to support the operation of the Centre.
- Total research funding held by CDC scientists in 2006-07 totals approximately $8 million.
- New agreements in 2006-07 include:

HuclADFHulled Wheat Varieties with End-Use Traits
HuclADFFHB Resistance in Spring & Durum Wheat
McCartneyADFLeaf Spotting Resistance in Spring & Durum Wheat
McCartneyADFNovel Oat Crown Rust Resistance
PozniakNSERC/Unv ABGenomics in Durum Wheat
RossnagelFarmPure SeedsOat Breeding Research
RowlandSeCanDev. Of Industrial Oil Flax Cultivars
Ta'ranADFOff-season Eval of Chickpeas (Phase II)
Ta'ranADFMolecular Improvement of Kabuli Chickpeas
VandenbergADFAsexual Propagation for Large Seeded Pulses
WarkentinWalker SeedsMarrowfat Pea Development

C. Personnel

One of the scientist – technician positions allocated to the CDC was recently filled by Dr, Curt McCartney. Dr. McCartney completed his PhD in 2002 at the University of Manitoba, with a thesis entitled “Inheritance and chromosomal location of race-specific resistance to *Mycosphaerella graminicola* in wheat”. From 2002 until 2006 Dr. McCartney filled two post-doctoral positions at the University of Manitoba, studying the genetics of resistance to fusarium head blight (FHB) and leaf rust in spring wheat, and undertaking genetic mapping of agronomic and quality traits in spring wheat. Dr. McCartney also managed the University of Manitoba’s high erucic acid rapeseed breeding program for six months.

Dr. Holm, Director of the CDC, retired from the position in June, 2006. The directorship remained vacant until January 1, 2007, when Ms. Dorothy Murrell took up the position. Ms. Murrell joins the CDC from a business management role with Svalöf Weibull Seed Ltd, a plant breeding and licensing company with its head office in Sweden.

D. Commercialization:

Royalties earned on CDC varieties totalled approximately $740,000 in 2006-07. Thirty-five percent of these funds are used to support the central operating costs of the Centre and the remaining 65% is allocated back to the breeding program that generated the revenue. For the first time the CDC has received substantial royalty income from an international marketing program, that of CDC pea varieties into the United States.

During 2006-07, the following marketing agreements were finalized:

Barley HB379 Farm Pure – contract pending final decision by CFIA re: novel feed status

Barley CDC Coalition Canterra – signed

Barley CDC Mindon SeCan – contract pending

Oat CDC ProFi Farm Pure – signed

Oat CDC SO-I Farm Pure – signed

Summary

The CDC enjoyed a successful and productive year in 2006-07 and looks forward to further success in 2007-08. The strategic financial support provided by Saskatchewan Agriculture and Food to the CDC is fundamental to the CDC's output. The CDC is a well known brand throughout Canada's agricultural value chain, from seed growers and farmers, to agricultural distribution and grain handling companies, to end users, and its breeders and scientists are known world wide for their productivity, competence and sound science.

The CDC looks forward to continued support from SAF as we work together to enhance Saskatchewan's and Canada's agriculture industry.

Respectfully submitted,

Dorothy Murrell

Managing Director

Spring Wheat and Other Crops

Principal Investigator: **Pierre Hucl**

Objectives:

Development of high yielding and well adapted cultivars of bread and soft white wheat, and new well adapted cutlivars of niche cereals and canaryseed.

Sub-objectives:

1. CWRS Wheat
2. CWHW Wheat
3. Spelt
4. Puffing Wheat
5. Canaryseed

Results:

CWRS Wheat:

Lines in Years 1 and 2 of Variety Registration Tests

BW852 and BW854, both 2nd year entries in the 2006 WBWC, were advanced for quality evaluation and passed KVD criteria. BW852 yielded 14% higher than AC Barrie in 2005 and 18% higher in 2006. **BW377** was a second year entry in the 2006 CBWC test. BW377 yielded 1% less than the mean of the checks in that test and will likely be dropped.

Of the first year entries in the 2006 WBWC, all were advanced for quality testing and passed the KVD step. Three CDC entries (**BW882, BW884 and BW885CL)** were dropped due to quality deficiencies. Three lines will be advanced: **BW880** and **BW881** yielded 19% higher than of AC Barrie while **BW883** yielded 24% higher. BW883 carries midge resistance from the winter wheat cultivar Seneca.

Of the 1st year CDC entries in the 2006 CBWC, two were dropped on disease reaction (**BW399** and **BW400**) while a third (**BW398**) was dropped on quality. A fourth line (**BW397**) received a "serious" flag on quality so its future prospects are tenuous at this point.

In the Parkland Test, **PT574CL** (2nd year entry) will likely be dropped on the basis of disease reaction. **PT575 CL,** a first year entry was advanced for quality evaluation and received the most positive endorsement (6 support: 6 do not object) of the nine 1st year entries.

Three CWHW lines (**HW607, 608** and **609**) were 1st year entries in the 2006 Hard White Wheat Registration Test. All three lines were advanced for quality evaluation but have not been voted on at the time of report preparation.

No CWES lines were entered in Registration Tests in 2006 and none will be entered in 2007.

Lines selected from the WBW 'B' Test for advancement

The CDC spring wheat breeding program coordinates the Western Bread Wheat 'B' Test. This is one of two cooperative tests that is used to identify breeding lines for entry into bread wheat Registration Tests. In 2007 the WBWB consisted of 56 entries and was planted at seven sites across western Canada. The CDC, AAFC-SPARC and U of A contributed entries to the test. Of the 52 experimental lines, 22 were from the CDC. Of the 22 lines, six were retained for proposed entry in either the 2007 WBWC or Parkland C tests. The most promising lines were significantly earlier than the check cultivars. One of the lines (entry 47) is a product of a backcrossing scheme to increase the sprouting tolerance of CDC Teal. This was successful as demonstrated by the Falling Number value obtained from a nursery that was subjected to > 100 mm of rainfall post-maturity.

CWRS and CWHW Lines entering Variety Registration trials in 2007:

We anticipate about twelve CDC spring wheat lines being advanced as first year entries in 2007 Registration Tests. Of the 12, three will likely be hard white lines. No CWES lines are being advanced for Registration Testing in 2007.

Between 22 and 26 new CDC lines will be entered in 2007 pre-Registration ('B'-level) Tests.

Spring Spelt and other Alternative Wheats Project (ADF):

99SPELT9-Z was supported for Registration in February 2006.

The Spring Spelt Private Coop Test was coordinated by this Program in 2006. A third year entry (03SPELT4) performed well (Table 1). The line 99SPELT9Z also performed well relative to CDC Nexon. The line 04SPELT48 (entry 4) represents a significant improvement in maturity and straw reduction.

Outputs

Other Alternative Wheat Types:

Puffing wheat:

The most advanced selections from our puffing wheat breeding effort were grown at three sites in 2006. We have been able to develop lines that are large seeded with increased yield relative to our first semi-dwarf line (99PUFF1). Examples of this are entries 7, 11 and 13. Interspecific lines (eg 05PUFF7) that have a more rice-shaped grain have long kernels (20 Seed Length) but lower test weights. The long, narrow kernels have less packing ability hence the reduced grain density. We have met our objective of identifying adapted lines for this potential niche market.

CWHW Wheat Germplasm Improvement Project (ADF)

As part of our hard white wheat development program funded by WGRF and ADF we identified one line out of a 16 entry test that appears promising and will be advanced for further testing (CWHWB Test) in 2007. The number of lines tested in 2006 was limited in scope due to the very high leaf rust culling rate in 2004.

As part of our ADF project initiated in March, 2005 we completed two backcross equivalents (87.5% HWS wheat parentage) of molecular markers tightly linked to two major QTL's for FHB resistance to hard white wheat from red-grained donor parents. These populations were advanced one generation during the summer of 2006. Subsets of this material will have been advanced a further one or two generations during the winter of 2006/2007. The most advanced material will be lined out in 2007 and the plan is to phenotype some of this material for FHB reaction in 2008.

As part of that project we have now developed two non-destructive procedures to distinguish red pericarp wheat from white pericarp wheat. The first procedure, the pricking method, can distinguish red from white wheat by pricking individual imbibed grains with a needle and placing a droplet of 5% sodium hydroxide (NaOH) on the wound. This method does not limit germination any more than the water control and has a higher final germination percentage than soaking the grain in NaOH.

Our 2006 results indicated that the pricking method is stable over environments and genotypes. Any damage that a grain does incur from the pricking method is most likely due to the NaOH rather than the physical penetration damage caused by the needle. No differences were detected for germination velocity among the pricking method, the NaOH soak method, and the untreated water control, however for emergence velocity the NaOH soak emerged the fastest while the pricking method and the untreated water control emerged slower and were not different from one another. No differences in final emergence percentages were detected among the pricking method, NaOH soak, and untreated water control.

Our second procedure to distinguish red wheat from white wheat made use of a Satake ScanMaster II color sorter machine. Samples with small initial volumes (<1 kg), segregating in ratios of 1 white grain: 63 red grains can be separated into white and red grain after several passes, although the greatest returns are found in the initial color sorts. There were high correlations between the percentage of white grain after color sorting with the percentage of white grain prior to color sorting and the L* value after color sorting. No correlation between percentage of white grain before color sorting and the presence of piebald seed was detected. With the color sorter, material that has been color sorted once, grown out in the field and then color sorted again is nearly 100% white grained.

Canaryseed Development project (ADF):

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The glabrous canaryseed (Canario) line **C99037** was Supported for Registration in February, 2006. Five replicated trials were conducted in 2006. The most advanced trial was conducted as a mandated Registration Test. The results for some of the more promising lines are presented in Table 4.

Table 4. Performance of advanced canaryseed lines in 2006 registration test

TYPE	**ENTRY**		**NAME**	**gy**	**dse**	**dpm**	**ht**	**twt**	**kwt**	**gy**
GB	1	CDC Maria		**100.0**	0.0	0.0	0.0	0.0	0.00	100.0
GY	2	C99005	Maria x CY184	**108.7**	-2.1	-1.7	-2.5	-0.3	0.20	108.4
GB	3	C99037	Maria x CY184	**107.5**	-0.1	-0.1	2.3	-0.1	0.13	106.3
GB	4	CDC Togo	Cantate x Maria	**102.4**	-0.7	0.4	-5.4	-1.1	0.73	107.9
GB	**5**	**C00038**	**Maria x 46**	**108.8**	**0.0**	**0.8**	**-4.4**	**-1.7**	**0.07**	**115.8**
GY	7	C03087	Cantate*2/Maria//CY186	**105.5**	-0.2	1.9	-1.3	-1.1	0.61	111.2
GY	9	C04035	Maria/CY184//CY186	**111.0**	1.0	0.7	5.8	-0.9	0.54	116.5
GB	15	C05004	Cantate*5/Maria	**114.4**	-3.7	-2.2	-5.4	-1.7	0.01	123.2
GY	26	C05028	C99005//Cantate*4/Maria	**108.0**	-2.9	2.5	-6.5	-1.1	**0.80**	108.7
GY	30	C05041	C99005//Cantate*4/Maria	**105.4**	-0.6	0.1	**-9.8**	-0.1	0.48	**110.2**
GY	33	C05046	C99005//Cantate*4/Maria	105.6	-3.3	0.7	-6.7	-0.2	**0.83**	107.5
SY#	**5**			4	5	**5**	**5**			**5**

C00038 is our next promising GB (glabrous hull – brown seeded) line. Breeder seed production was initiated in 2006 and will require further multiplication in 2007 and 2008 prior to cultivar release.
Approximately 240 glabrous lines were be evaluated in unreplicated yield trials at Kernen in 2006. Half of those lines were harvested and 12 were retained for further testing. Approximately 6,000 lines were grown in F3 or F4 hills in 2006. Half of the hills were selected and F4 and F5 progeny of those lines will be grown in hills in 2007.
Four new crosses were made in 2006.

Undergraduate theses supervised:

Two projects were supervised in 2006. Both provided interesting results.
Eric Nielsen– Agriculture 494.6: Selection for enhanced seed dormancy in spring wheat under low temperature incubation
Peter Sawatzky – Agriculture 492.3: Pre harvest sprouting resistance in an interspecific wheat cross

Listing of collaborations:

Quality- related projects
Dr. ESM Abdel-Aal. AAFC, Guelph
Breeding-related in Canada:

Dr. A. Brule-Babel, U. of Manitoba
Dr. D. Spaner, U. of Alberta
Drs. S. Fox, G. Humphreys and D. Brown, AAFC Winnipeg
Drs. R. DePauw and J. Clarke, AAFC Swift Current
Dr. D. Salmon, FCDC, Lacombe
Mr. M. Etienne, Hyland Seeds
Dr. D. Potts, Ms. Kathy Hanson, Saskatchewan Wheat Pool
Mr. W. May, IHARF
Mr. E. Johnson, AAFC Scott
Semican, Que.
Mr. K. MaCallum, Syngenta, Rosebank, MB
Overseas:
Dr. L. Talbert, Montana State Univ., Bozeman
Dr. T. Nakamura, MAFF, Japan

Sources of funding:

P. Hucl and C. Perron. Development of hulled wheat varieties with improved agronomic and end-use traits. (SADF). 2007-2012

P. Hucl, C. Pozniak, C. McCartney and D. Somers. Enhancing fusarium head blight resistance in spring and durum wheat using novel approaches. (SADF). 2007-2009

P. Hucl and M. Matus-Cadiz. Development of Food Grade canary seed. (SADF). 2005-2007

P. Hucl and M. Matus-Cadiz. Hard White wheat improvement (SADF). 2005-2009

P. Hucl. Mitigating out-crossing in spring wheat breeder seed development. (CSGA), 2005-2007

P. Hucl. Breeding and quality evaluation of improved Alternative wheats. (SADF). 2002-2006

P. Hucl and M. Matus-Cadiz. Gene flow in spring wheat at the commercial scale. (SADF). 2002-2006

R.Chibbar, P. Hucl and M. Baga. Understanding amylose synthesis to develop high amylose wheat. (SADF). 2003-2006

P. Hucl. Spring wheat for Organic Production. (SADF). 2004-2009

P. Hucl and M. Matus-Cadiz. Identifying pigments darkening colour in hard white wheat. (SADF). 2004-2007

P.Hucl. WGRF wheat check-off. 2005-2010

P.Hucl. SWP spring wheat joint development Agreement 1995 ongoing.

P. Hucl. BASF. CLEARFIELD spring wheat development Phase 2. 2003 ongoing.

Outreach activity:

Presentations:

June 26&27 2006 Canadian Wheat Improvement Network Saskatoon, SK, CDC Spring Wheat disease resistance breeding update

January 10, 2007. Canaryseed research update (CAC), Saskatoon

Dept. of PLSC - Field Experiments Committee, Member

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Dept. of PLSC - Grain Quality Committee, Member
Dept. of PLSC - Variety Committee, Member
Dept. of PLSC - Graduate Student Committee, Chair
Coordinator Western Bread Wheat 'B' Test
Member, PRRCG
Member, SIA
Member, SACGC
Member, WGRF Technical Advisory Committee on Wheat
Member, Soils and Crops Organizing Committee
Advisor, Canaryseed Association of Canada
Member, SPG – R&D Committee
Member, IOC of the 10th International Wheat Genetics Symposium
Member, LOC of the 2007 North American Wheat Workers Meeting
Public property:

El-Sayed M. Abdel-Aal, Christopher Young, Iwona Rabalski, Pierre Hucl, and Judith Fregeau-Reid. 2007. Identification and Quantification of Seed Carotenoids in Selected Wheat Species. J. Agric. Food Chem. 55: 787 -794

M.A. Matus-Cádiz, C.J. Pozniak, G.R. Hughes, and P. Hucl. A Simplified Multiplex PCR Method to Screen for the Major QTL Carrying Fusarium Head Blight Resistance in Sumai-3. Canadian Journal of Plant Science 86: 711-716.

S. Ganeshan, S. V. Chodaparambil, M. Båga., D. B. Fowler, P. Hucl, B. G. Rossnagel and R. N. Chibbar. 2006. In vitro regeneration of cereals based on multiple shoot induction from mature embryos in response to thidiazuron. Plant Cell, Tissue and Organ Culture. 85: 63-73.

H.H. McDuffie, K. Nakagawa, P. Pahwa, J. Shindo, M. Hashimoto, N. Nakada, S. Ghosh, S.P. Kirychuk and P. Hucl. 2006. Tumor necrosis factor alpha and pulmonary function in Saskatchewan grain handlers. J. Occup. Environ. Med. 48: 505-512.

P. Hucl. Breeding and quality evaluation of improved Alternative wheats. **Final Report** to SADF. September 2006.

P. Hucl and M. Matus-Cadiz. Gene flow in spring wheat at the commercial scale. **Final Report** to SADF. December 2006.

Commercializable Property:
CDC Imagine (2005 launch by SWP and AU and BASF) grown on 600,000 ac in 2006.
CDC Go to be marketed by Individual Pedigreed Seed Growers (Public Release) (2007 launch)
CDC Osler to be marketed by Individual Pedigreed Seed Growers (Public Release) (2007 launch)
CDC Togo canaryseed to be marketed by Canterra Seeds (2006 launch)
CDC Alsask CWRS wheat to be marketed by Saskatchewan Wheat Pool (2008 launch)
Winfield hrs spring wheat to be marketed by Hyland Seeds in Ontario (2006 launch)
Hobson hrs spring wheat to be marketed by Hyland Seeds in Ontario (2008 launch?)

Research Projects

Spring Wheat Cultivars For Organic Production Project (SADF)

Three replicated crop competition field experiments were conducted at Saskatoon in 2006 using protocols used in 2004 and 2005 and previously developed and validated by the CDC spring wheat program in earlier research studies. The largest experiment was designed to measure the competitive ability of spring wheat (common wheat and durum wheat) cultivars currently described in the Saskatchewan Varieties of Grain Crops pamphlet along with some older varieties such as Red Fife and Marquis.

The second and third experiments were designed to evaluate and select elite breeding lines form the CDC spring wheat breeding program. Wheat grain yield reductions among wheat cultivars ranged from 33 to 58%. In 2006, the most competitive wheat cultivars were Red Fife, Lovitt, CDC Rama, Infinity and CDC Merlin. However, with the exception of CDC Rama and Infinity, the most competitive lines ranked amongst the lowest for yield (43, 31, and 44) under non-weedy conditions. In 2006, cultivars which provided an over-all higher level of competitive ability with reasonable yield potential were Infinity, CDC Rama, AC Morse (durum wheat), CDC Teal and CDC Go.

Averaged over the three years of testing, the cultivars Lovitt, CDC Go and CDC Bounty appear to offer the best balance of yield potential and competitive ability for CWRS wheat. CDC Rama and CDC Walrus appear promising for the CWES class. Of the six CPS cultivars, AC Vista was the best compromise for the yield potential- competitive ability combination. Napoleon fulfilled the same role in the CWAD market class. The soft white spring wheat cultivar AC Andrew was consistently the highest yielder under both weedy and non-weedy conditions

In the second and third experiments we tested elite bread wheat breeding experimental lines from the CDC breeding program for competitive ability. Thirty four experimental lines that appeared to be more competitive than the check cultivars in trials conducted in 2004 and/or 2005 were retested in 2006. The remaining entries were lines that were part of the CDC multi-location testing program in 2006.

Gene-Movement in Spring Wheat at the Commercial Scale Project (ADF)

This past year (2006) was the final year of this five-year project. The following is a summary or our findings. Good pollination overlap between the cultivar AC Cadillac and Purendo-38 (blue aleurone pollen source) along with strong and prevailing winds from the south were factors that likely contributed to the lone out crossing event detected in 2002. Good pollination overlap between the recipient fields and Purendo-38 along with prevailing winds appears to be associated with all nine out crossing events in 2003, indicating that gene flow rates should not be based on experiments oriented in only one direction from the pollinator. In particular, strong and prevailing winds from the SSE (22 km h^{-1} ±8) were associated with the out crossing event detected in recipient field HR5500 at 2.75 km to the NW of the pollen source.

Pollination periods in 2002 were generally hotter and less humid relative to pollination periods in 2003, indicating that the higher gene flow rates observed in 2003 were likely promoted by cooler and more humid conditions. De Vries (1972) reported that the highest concentration of pollen dispersal appeared to be released at a temperature of 16-20°C and relative humidity of 70-75%. Wheat pollen grains have been reported to be viable for 15 to 20–min, or up to 30 min under optimal conditions (de Vries, 1971). In the present study, the weather conditions in 2003 fall within the optimum range reported by de Vries (1972).

Pollen dispersal during flowering varies with pollinator field size (de Vries, 1974). Gene flow studies in wheat have generally used small pollinator plots (≤0.25 ha) and, thus, likely have limited application in estimating the amount of gene flow taking place between neighboring commercial fields. Matus-Cádiz et al. (2004) reported trace intraspecific pollen-mediated gene flow (0.01%) at 300 m using a 50 x 50 m (0.25 ha) blue-grained pollinator block. The latter study used the largest pollinator field tested to date; however, its small size relative to using commercial scale pollinator fields (20 to 100 ha) may explain, in part, why gene flow was not detected beyond 300 m even though sampling occurred up to 2.76 km from the 0.25 ha pollinator source.

The current project is likely the first large scale commercial study on gene flow in wheat. We detected long distance pollen-mediated gene flow at trace levels (≤0.01%) beyond 300 m which remained constant up to 2.75 km from the pollinator. Trace rates of 0.01% can be considered worst-case scenarios if compared with gene flow rates that are averaged across samples within years. In 2002 one-hybrid seed was confirmed out of three million seeds (gene flow = [1/3000000] x 100 =0.00003%; 300 times lower than 0.01%) while nine hybrid seeds were confirmed out of 10 million seeds in 2003 (gene flow = [9/10000000] x 100 =0.00009%; 100 times lower than 0.01%).

The three year post-harvest surveys failed to detect volunteer blue aleurone volunteer wheat in the 76 recipient fields initially sampled in either the 2002 or 2003 experiments. A single putative out-crossed blue aleurone volunteer was detected in the 2003 donor field. Thus, the probability of a gene-flow event ending up as a volunteer in another crop, wheat or otherwise, was very low. For the wheat fields sampled over the three years post-harvest, an estimated 4.2 million seeds were examined in total. Of those 4.2 million seeds 28 were blue aleurone and were traced to the single putative volunteer plant.

In conclusion, our results suggest that gene flow will be a minor contributor to product admixture (≤0.01%), but a tolerance level of 0% transgenic wheat in non-transgenic wheat grain, as currently demanded by some groups of producers and consumers, is unrealistic. Tolerance levels, likely ranging from one to 5%, will have to be established based on the impurities arising from various trans-gene contributors such as breeder and certified seed purity, gene flow from neighboring fields, occurrence of gene introgression from related or weedy interspecific hybrids, crop volunteers, on-farm admixture, and mechanical admixture during grain handling at or beyond the primary elevator.

Future studies on gene flow in Saskatchewan-grown wheat might focus on wheat growing regions were wheat is the dominant crop in the crop rotation. In the current project we sampled a region where wheat represented 5 to 38 % of the fields surveyed in the post-harvest portion of study. In regions with a higher frequency of wheat in the crop rotation, gene flow and subsequent introgressed volunteer levels may very well be higher.

Identification of Pigments Darkening Grain Colour in Hard White Wheat Using Non-Targeted and Targeted Methods ADF Project

Based on the metabolome data, we concluded that the metabolites responsible for bran pigmentation in ND690 (darkening white wheat) and RL4137 (3 gene red seeded wheat) were 3',4',5-trihydroxy-3,7-dimethoxyflavone ($C_{17}H_{14}O_7$, mass 330.0742), its glycosylated form (mass 492.1267; ($C_{23}H_{24}O_{12}$), and the acetylated form of 492.1267 (mass 534.137; $C_{25}H_{26}O_{13}$). These metabolites were observed in the bran samples, but not in the whole seed samples, suggesting that these metabolites occur within the wheat bran. Further work will be required to validate the identity of these related metabolites.

The next objective this project was to extract, isolate and identify the compound(s) responsible for the reddish dark pigments in the seed coat of wheat. To this end, we extracted the dark pigments from the bran of up to five different spring wheat varieties: RL4137, Glenlea, Red Bobs, W98616, ranging in color from dark red to white respectively, and also from the darkly colored but genetically white wheat variety ND690. First, because the dark coloration might be due to phenolic compounds, we measured the free and bound phenolics present in the wheat bran. Second, after basic digestion of wheat bran and extraction by solvents, we spectrophotometerically determined the absorption spectra of the above wheat varieties.

Our data suggests that the darker coat color in the ND690 bran may be due to the higher phenolic content and also to a more complex mixture of phenolic and acidic compounds. These compound(s) may be responsible for the reddish color, increasing with the number of ‘R’ genes. However, we were not able to conclusively verify the specific pigments that darken the grain of certain white wheat cultivars. A number of analytical columns and high performance liquid chromatography methods were performed so as to separate the acidic and phenolic compounds within the extracts. We did develop a novel method by way of which, albeit laboriously, the dark pigment in the bran extracts from all five wheat varieties may be isolated in the future.

Ph.D. project (Rajender Singh) Supervisor (R.N. Chibbar)

This project is based on material developed and phenotyped by Matus-Cadiz and Hucl. The following is extracted from an oral presentation abstract (2006 AACC annual meeting):

A mapping population of one hundred and fifty one doubled haploid (DH) lines from a cross between two spring wheat cultivars ND690 (non-dormant) and W98616 (dormant) was developed for molecular mapping of PHS resistance loci. Initially, 20 dormant and 20 non dormant lines were used for molecular mapping with SSR (simple sequence repeat) and AFLP (amplified fragment length polymorphism) markers. A total of 613 markers (307 SSR markers and 306 AFLP) markers have been mapped on different chromosomes. Five chromosomal regions on the chromosomes 1A, 3B, 4A, 5B and 6B were found to be associated with PHS resistance. A major QTL was detected on the long arm of chromosome 4A in this mapping population.

Durum and High Yielding Spring Wheat Breeding and Genetics

Program Manager: C. Pozniak

Overall Program Objectives

- **Durum Wheat**: To develop conventional strength durum wheat varieties 5% higher yielding than AC Avonlea, with similar maturity, protein content, but stronger gluten. A second objective is to develop durum wheat varieties with extra-strong gluten properties with higher protein concentration than Commander. Improved resistance to the orange blossom wheat midge, wheat stem sawfly, leaf spotting diseases (especially tan spot) and improved resistance to Fusarium head blight are major breeding objectives for both the conventional and extra-strong gluten types. All cultivars developed will possess reduced cadmium content (<100 pbb) and high yellow pigment concentration (similar to AC Navigator).

- **High-yielding CPS Wheat:** The CDC High yielding wheat focuses on CPS-red (90%) and CPS-white types (10%). The major objectives of the high yielding wheat program are to develop varieties with high grain potential, appropriate maturity, acceptable end-use quality, and improved disease and pest resistance. Efforts to develop high yielding CPS-red wheats to service the ethanol and feed industry are ongoing. Kernel distinguishability will be maintained as long as KVD is mandated by the Canadian Grain Commission.

Activities and Results

A. Conventional and Extra-Strong Gluten Durum Wheat

Co-op Testing

Seven CDC lines were evaluated in the Co-op Test, six first year lines and one third year line. Two of the six first year lines, DT550 and DT552 will be advanced to second year of testing in 2007. DT550 is an extra-strong gluten type. The remaining first year lines were dropped because of short falls in milling quality. DT540 was evaluated as a third year line. Over three years of testing, DT540 has shown yield potential equivalent to AC Avonlea, has excellent test weight and seed size and represents a significant improvement in lodging resistance over AC Avonlea and Strongfield. DT540 has low grain cadmium concentration and protein concentration similar to AC Avonlea and Strongfield. DT540 also has good yellow pigment concentration and has significantly stronger gluten than AC Avonlea as assessed using the gluten index and Alveograph. Breeder seed was developed in 2006. However, DT540 has consistently been lower yielding than Strongfield (4% lower) over all three years of testing and is one-two days later maturing. As such, we will not be pursuing support of registration for this line.

Durum Wheat Germplasm Evaluations

As stated in previous years, a critical component of any breeding program is to evaluate international durum wheat germplasm as potential sources for useful traits. In 2006, over 350 advanced breeding lines from CIMMYT and ICARDA were evaluated in unreplicated/replicated yield trials. The majority of these lines were found to be significantly lower yielding than Strongfield (high yielding durum wheat check). Since the durum program at AAFC-SPARC evaluates similar lines, we will be combining our databases to improve estimates of phenotypic worth. One or two of the best lines will be used in our 2007 crossing program.

Specialty Durum Wheat breeding

In collaboration with Dr. Pierre Hucl, efforts to breed durum wheats with special quality properties are ongoing. These include waxy durum wheat evaluation, high amylose durum and durum wheats with novel rheological properties associated with enhanced baking quality. Approximately 10 F2 populations grown in 2006 with the objective of producing specialty durum cultivars. A similar breeding methodology as described above is being utilized.

B. High Yielding Wheat

Co-op Tests

Four CPS-white seeded lines designated as HW603, HW604, HW605, and HW606 were evaluated in the 2005 Hard White Wheat Test. HW603 was a second year line whereas the remaining lines were first year entries. All four lines have excellent yield potential, yielding on average 125% of the average of the bread wheat checks (AC Vista data was lost because of seed vigour problems) with similar maturity. The four lines have consistently shown protein concentration approx 1.5-2% lower than the bread wheat checks, and maybe useful ethanol feedstock lines. The highest yielding of these lines maybe submitted to the General Purpose Class Co-operative test in 2007 (pending CFIA approval of regulations for that co-op). All four lines were noted to have good resistance to the wheat rusts and common bunt, but poor FHB tolerance.

Expected Outcomes

Expected outcomes of the CDC durum/ High Yielding wheat breeding program include increased economic returns to producers and the province by providing:

- lowering costs of production by improving disease resistance;
- Incorporation of novel sources of Fusarium resistance into durum wheat;
- improved food quality (low grain cadmium concentration);
- access to higher return durum markets (extra-strong durum; specialty durums);
- higher yielding durum, CPS-red and CPS-white seeded cultivars;
- Eventual development of CPS varieties tailored for feed and biofuel sectors. This is becoming more of a reality given the recent development of the General Purpose Class, which does not have a quality requirement at this time. Although disease guidelines have yet to be developed for this class, early signals are that FHB tolerance will be a requirement. This coupled with a KVD requirement (can not have any CWRS kernel types) will limit rapid progress;

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- Integration of genomics and molecular assisted breeding to improve breeding efficiency and to better understand the physiological processes associated with key crop traits;
- Training of highly qualified personnel at the technical and professional levels;
- Assist in technology transfer to the Saskatchewan and Canadian Wheat Industry.

Outputs

Durum Wheat/High Yielding Wheat Outputs

Outputs for 2006 include the following:

- Materials for further development: Two first year lines advanced to the 2007 Durum Wheat Co-op Test. One second year CPS-white seeded line (HW603) and three first year lines (HW604, HW605, HW606) in the 2006 Hard White Wheat Co-op will be advanced to the second year of co-op testing in 2007.
- Conducted Durum SAC Trials at Saskatoon
- Two scientific manuscripts published in 2006

CJ. Pozniak, R.E. Knox, F.R. Clarke, and J.M. Clarke. 2007. Mapping of QTL and Association of a Phytoene Synthase Gene with Variation in Endosperm Color in Durum Wheat. Theor. Appl. Genet. 114 (3), 525-537.

M.A. Matus-Cádiz, C.J. Pozniak, G.R. Hughes, and P. Hucl, 2006. A Simplified Multiplex PCR Method to Screen for the Major QTL Carrying Fusarium Head Blight Resistance in Sumai-3. Canadian Journal of Plant Science, 86: 711-716

- Two additional Manuscript communicated for Peer Review

D.J. Somers, T. Banks, R. DePauw, S. Fox, J.M. Clarke, C.J. Pozniak, and C. McCartney. Genome-wide linkage disequilibrium analysis in bread wheat and durum wheat. Communicated, Genome.

T.S. Grewal, B.G. Rossnagel, C.J. Pozniak, and G.J. Scoles. Mapping quantitative trait loci associated with barley net blotch resistance. Communicated

- Posters and Presentations

C. Pozniak and B. Rossnagel. 2007. Crop Development Centre Variety Update Seminar. Annual Meeting of the Saskatchewan Seed Growers Association, Saskatoon, Saskatchewan. January 9th-10th.

S. Reimer, D. Somers, F. Clarke, R. Knox, J. Clarke, and C. Pozniak. 2007. Association mapping for Endosperm Color in Durum Wheat. Proceedings of the Plant and Animal Genome Conference XIV. January 13-17, 2007, San Diego, CA, USA.

Y. Suprayogi, F. Clarke, R. Knox, J. Clarke, and C. Pozniak. 2007. Mapping Quantitative Trait Loci for Grain Protein Concentration in Canadian Durum Wheat. Proceedings of the Plant and Animal Genome Conference XIV. January 13-17, 2007, San Diego, CA, USA.

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F.R. Clarke, R.E. Knox, J.M. Clarke, and C.J. Pozniak. 2006. Quantitative Trait Loci for Agronomic, Pest Resistance and End-Use Quality Traits in a Durum Wheat Doubled Haploid Population. Proceedings of the EUCARPIA meeting on "Cereal Science and Technology for Feeding Ten Billion People: Genomics Era and Beyond". November 13 - 17, 2006: Lleida, Spain.

N. Harris, K. St. Onge, M. Bryman, D. Silver, C. Pozniak, and Greg Taylor. 2006. Transcriptome comparison of high and low Cd accumulating, near isogenic lines of durum wheat. Proceedings of the Annual Meeting of American Society of Plant Biologists. August 5-9 2006, Boston, MA, USA.

T. S. Grewal, C. Pozniak, B. G. Rossnagel and G. J. Scoles. 2006. QTL mapping of Net Blotch Resistance Using DArT. Proceedings of the Third International Workshop on Barley Leaf Blights. July 23-27 2006, Edmonton, AB, Canada.

C. Pozniak, Y. Suprayogi, R. Knox, F. Clarke, and J. Clarke, 2006. A Phytoene Synthase Gene Maps to a QTL for Yellow Pigment in Durum Wheat. Proceedings of the Plant and Animal Genome Conference XIV. January 14-18, 2006, San Diego, CA.

S. Reimer and C. Pozniak, 2006. Identification of Zeta-carotene Desaturase Genes from Durum Wheat. Proceedings of the Soils and Crops Workshop, University of Saskatchewan, March 2nd and 3rd, 2006, Saskatoon, Saskatchewan.

Y. Suprayogi, C. Pozniak, R. Knox, F. Clarke and J. Clarke, 2006. Identification of QTL for Grain Protein Concentration in Durum Wheat. Proceedings of the Soils and Crops Workshop, University of Saskatchewan, March 2nd and 3rd, 2006, Saskatoon, Saskatchewan.

J. Clarke, C. Pozniak, J. Thomas, M. Fernandez, and R. Knox. 2006. Breeding for Disease Resistance in Durum. Annual Meeting of the Canadian Wheat Improvement Network, Saskatoon, Saskatchewan. June 27th-28th.

- Teaching:
  - Plant Science 411.3. Plan Breeding (undergraduate course) Winter Term 2006/2007
  - Plant Science 816.3 Quantitative Genetics (graduate course) Winter Term 2005/2006
  - Three graduate Students Supervised; three undergraduate research projects
    - Sherisse Reimer (M.Sc).
    - Bandla Rao (M.Sc).
    - Yogi Suprayogi (Ph.D.)
    - Heather Englot (Starch Analysis of Wheat Varieties for Ethanol) (undergraduate student)
    - Megan Lynch (Viscosity Measurements of Cereal Grains for Ethanol) (undergraduate student)
    - Jenny Callow (Photoperiod response in a diverse set of durum wheat cultivars) (undergraduate student)
- Graduate Student Supervisory committee for 4 M.Sc/2 Ph.D students
- Public Service and Outreach Activities:

Associate Editor, Canadian Journal of Plant Science, 2006-2009

Secretary, Canadian Wheat Improvement Network, 2006-2009

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Secretary, Committee to review the utility of the single composite sample utilized by the Wheat, Rye and Triticale Quality Evaluation Team of the PRCWT for predicting cultivar grain quality characteristics of wheat entering the marketplace, 2006

Member, North American Wheat Workers Workshop Organizing Committee, 2006

C. Pozniak. Update on Clearfield Durum Wheat Breeding. BASF, December 12th, 2006

C. Pozniak. Genetics of Yellow Pigment Accumulation in Durum Wheat. Australian Grain Technologies, March 6th, 2006.

C. Pozniak. Update on CPS Wheat Breeding at the Crop Development Centre. Warburtons. May 16th, 2006.

C. Pozniak and P. Hucl. Identification of Potential Traits for Value Addition in Durum Wheat. BASF, June 20th, 2006.

C. Pozniak. Varieties for Ethanol Production. Scott Field Day, July 2006.

Durum and High Yielding Wheat Research Projects

Project: Use of Genomics Tools for Crop Improvement in Temperate Climates

Funding source: Genome Canada

Term: 2006-2010.

Principal Investigators: D.B. Fowler, R. Chibbar, C. Pozniak

Summary

The goals of this project, which commenced in 2006, are to identify and characterize the major genetic components of low-temperature (LT) adaptation of wheat and rye to develop strategies for their improvement using conventional plant breeding and biotechnological methods. This will be accomplished by utilizing the latest in genomics technology to determine the underlying genetic factors involved in the expression of LT adaptation at the whole plant and molecular level so that the LT tolerance can be manipulated to enhance crop adaptation. A major objective of this project will be to apply the biological knowledge and genomic resources developed to the crop improvement programs at the Crop Development Centre. As part of this research, crosses are being made to transfer LT tolerance into adapted spring wheat genotypes. The mapping, isolation, and characterization of the LT adaptation genes from the hardy winter wheat cultivar Norstar has allowed us to begin incorporating critical genes (*Fr2-A2* region) to enhance the LT survival of spring wheat genotypes. To date we have completed crossing *Saskhardy-8*, a spring wheat isogenic line of Norstar to BW252 (AC Superb), a popular high yielding spring wheat variety grown in Western Canada. We are currently in the process of making additional backcrosses/topcrosses to adapted spring wheat varieties (AC Superb, CDC Go, CDC Alsask, HW603). We have completed haplotyped all of the spring wheat lines across *Fr2-A2* and have identified the necessary markers to introgress that locus into the spring wheat cultivars. We have also identified a series of approx. 80 polymorphic markers distributed evenly throughout the genome (including markers for the major rust resistance genes in CDC Go and CDC Alsask) for marker assisted “background selection” for rapid reconstitution of the spring wheat recurrent parents. The first backcross has been completed and marker selection on greater than 300 BC_1F_1 plants is nearing completion to identify suitable plants (i.e. those that contain *Fr2-A2*) for further backcrossing. The next round of crossing has begun. Background selection for the recurrent parent is also being completed. The second backcross should be complete by the end of March, 2007.

In addition to haplotyping in spring wheat genotypes, we have completed haplotyping *Fr2-A2* in 48 winter wheat cultivars with varying levels of LT tolerance (range -17.1ºC to -24.7 ºC). We have determined allele sizes for approx. 20 SSR markers spanning the *Fr2-A2* region. Chinese Spring deletion lines were used to confirm that only alleles from 5A were being scored in instances where multiple loci were amplified. The number of alleles per marker ranged from 2-13 with an average polymorphic information content (PIC) value of 0.58 (range 0.16-0.82). Across the Fr2-A2 region (approx 25-30 cM region based on the wheat consensus map), we have identified numerous haplotypes, suggesting large variation exists at *Fr2-A2*. The majority of winter wheat cultivars developed at the Crop Development Centre have the identical haplotype to Norstar, despite some lines having less LT tolerance than Norstar. This suggests that factors other than *Fr2-A2* maybe involved in LT tolerance. In contrast, cultivars developed by Agriculture and Agri-Food Canada possess *Fr2-A2* haplotypes similar to Redwin and Winalta, varieties with poor LT tolerance. The AAFC lines were also noted to have poor LT tolerance relative to lines carrying the Norstar haplotype. Alabaskaja, one of the most cold tolerant varieties in our haplotyping experiment (-24.7°C) had a unique haplotype not shared by any of the other winter wheat cultivars. This haplotype information will be used in later experiments to select winter wheats with the best levels of LT tolerance possible, by selecting genotypes with the appropriate haplotype. More detailed analysis of the region using association mapping techniques has identified two discrete regions within *Fr2-A2* that explain large portions of phenotypic variation for LT50. One notable association was at SSR marker *gwm186*, which is linked to a *Cbf*-like gene cluster based on the hexaploid wheat consensus map, and had the highest polymorphic information content (PIC) value (0.82). The second region was localized approximately 3 cM distal near *gwm639*. However, only two molecular markers were noted to separate the two regions, but both were noted to have PIC values near the average for the *Fr2-A2* region (0.51 and 0.64). These results do suggest that sufficient molecular variation exists, despite no association with phenotypic variation in LT50. We are targeting more markers in this region to get a more accurate genotype of *Fr2-A2*. This will help better understand the molecular variation in this region prior to conducted marker assisted selection experiments in winter wheat.

Project: Integrating functional genomics and genetic mapping to clone genes responsible for low grain cadmium concentration in durum wheat

Funding Source: NSERC Strategic Grant Program

Co-Investigators: C. Pozniak/G. Taylor

Duration: 2006-2009

Summary: Cadmium (Cd) is a ubiquitous soil contaminant that is readily absorbed by roots and transported in plants. Consequently, Cd transfer through the food chain is a major risk pathway for human exposure. In North America Cd accumulates in grain crops grown in prairie soils with naturally elevated Cd availability. Among cereals, durum wheat has a genetic propensity to accumulate Cd in grain to levels exceeding proposed international trade standards. Genetic analysis has shown that the low grain-Cd trait is highly heritable and maps to a single quantitative trait loci (QTL) on chromosome 5BL that accounts for ~80% of phenotypic variation. Differences in root-

to-shoot Cd translocation are most closely associated with Cd concentrations in grain, but the mechanism that limits Cd translocation to the shoots has not been identified. To identify genes that are potentially involved in regulating Cd accumulation in durum grain, we compared gene expression in roots of pairs of durum wheat near-isogenic lines (NILs), high and low for Cd accumulation in grain, using a wheat microarray. Out of ~10,000 probes that produced repeatable hybridization across replicate slides, 37 were differentially expressed between the high and low Cd accumulating NILs. 15 were more highly expressed (1.17 to 2.05-fold greater) in the high Cd isolines, while 22 were more highly expressed (1.12 to 1.52-fold greater) in the low Cd isolines. Our results demonstrate the potential of microarray-based transcriptome profiling to identify variation in gene expression that may underlie the low Cd QTL. This approach can identify both positional candidates (genes that map to the low Cd QTL) and functional candidates (genes that provide mechanistic explanations for this trait but do not map to the QTL). This allows for the possibility that the QTL may regulate a conserved Cd sequestration mechanism present elsewhere in the genome that is not being detected through QTL analysis. The candidate genes identified by these experiments are currently the focus of genetic mapping and functional analysis studies.

Project: Genetics and Genomics of Yellow Pigment Content, an Important Quality Trait in Durum Wheat

Funding Agency: Western Grains Research Foundation Endowment Fund

Principal Investigators: C. Pozniak, R. Knox, J. Clarke, N. Ames.

Term: 2004-2007

Summary: One of the primary quality traits targeted by durum wheat (*Triticum turgidum* L. var *durum*) breeding programs is the bright yellow color of semolina and pasta products as this trait becomes increasingly important in global markets. The degree of yellowness is influenced by several factors, including the presence of carotenoid pigments, semolina extraction rate, processing conditions, and oxidative degradation by lipoxygenases. Locating genes controlling color expression in durum grain would facilitate breeding efforts to select genotypes with elevated color by directly selecting for desirable alleles at critical loci. We hypothesized that variation in the genes coding for phytoene synthase (*Psy*), a critical enzyme in carotenoid biosynthesis, may partially explain the phenotypic variation in endosperm color observed among durum cultivars. Using rice sequence information, primers were designed to PCR clone and sequence the *Psy* genes from Kofa (high color) and W9262-260D3 (medium color) durum cultivars. Sequencing confirmed the presence of four *Psy* genes in each parent, corresponding to a two member gene family designated as *Psy1-1*, *Psy1-2* and *Psy2-1* and *Psy2-2*. A genetic map was constructed using 155 F_1-derived doubled haploid (DH) lines from the cross W9262-260D3/Kofa with 194 simple sequence repeat (SSR) and DArT® markers. Using *Psy1-1* and *Psy2-1* allele-specific markers and chromosome mapping, the *Psy1* and *Psy2* genes were located to the group 7 and 5 chromosomes respectively. Four quantitative trait loci (QTL) underlying phenotypic variation in endosperm color were identified on chromosomes 2A, 4B, 6B, and 7B. The *Psy1-1* locus co-segregated with the 7B QTL, demonstrating an association of this gene with phenotypic variation for endosperm color. This work is the first report research on the mapping of *Psy* genes and supports the role of *Psy1-1* in elevated levels of endosperm color in durum wheat. S. Reimer, a graduate student in the durum program, has begun sequencing this gene from a diverse set of 93 durum lines with a wide range in yellow pigment concentration (4.2 –

13.5 mg/kg) to identify and develop markers for the most useful alleles of *Psy1-1* for marker assisted breeding.

Project: A Novel Approach to Identifying Quantitative Trait Loci in Cereal Crops.

Funding Agency: NSERC Discovery (2005-2010)

Principle Investigators: C. Pozniak, with collaborations from D. Somers, J. Clarke

Summary: The development of new approaches to facilitate QTL identification, and the isolation and functional characterization of genes underlying quantitative traits is an important component of our overall research program. For this proposal, we are using available germplasm, and the molecular and end-use quality data we have collected over years of extensive field evaluation as a tool to assess the potential of association mapping (AM) in wheat. AM not only allows for a greater assessment of allelic variation, but allows mapping in breeding materials and germplasm pools. The latter point is important, as my primary responsibility at the Crop Development Centre is durum wheat breeding. However, to implement association mapping techniques, the extent of linkage disequilibrium (LD) in the wheat genome was first determined using microsatellite markers distributed across the genome (Collaboration with Dr. D. Somers, AAFC-CRC). The allele database consisted of 189 bread wheat accessions genotyped at 370 loci and 93 durum wheat accessions genotyped at 245 loci. A significance level of $p<0.001$ was set for all comparisons. The bread and durum wheat collection showed 47.9 and 14.0 % of all locus pairs were in LD respectively. LD was more prevalent between loci on the same chromosome compared to loci on independent chromosomes and was highest between adjacent loci. Only a small fraction (0.9% bread wheat and 3.2% durum wheat) of the locus pairs in LD showed R2 values >0.2. The LD between adjacent locus pairs extended (R2>0.2) approximately 2 – 3 cM on average, but some regions of the bread and durum wheat genome showed high levels of LD (R2=0.7 and 1.0 respectively) extending 41.2 and 25.5 cM respectively. The wheat collections were clustered by similarity into subpopulations using unlinked microsatellite data. Analysis within subpopulations showed 14 to 16 fold fewer locus pairs were in LD, higher R2 values for those pairs in LD and LD extended further along the chromosome. The data suggest LD mapping wheat can be performed with SSRs to a resolution of <5 cM. Using this information, we have performed association genetic tests for yellow pigment content and identified significant marker-trait associations (<5cM gaps) on the group 2 chromosomes, 4B, 5B, 6B, and the group 7 chromosomes. The majority of marker-trait associations identified are in agreement with QTL we have identified in bi-parental mapping populations, and will now be evaluated as selection tools for yellow pigment concentration. Our results suggest that AM is a viable alternative approach to QTL mapping. However, precision of endosperm color estimates were high, and maybe the reason for effective detection of marker-trait associations using association mapping. Further studies are needed to validate association mapping for those traits were precise estimates of phenotypic value are more difficult to obtain.

Project: QTL mapping and physiological study of high grain protein concentration in Canadian durum wheat.

Y. Suprayogi and C.J. Pozniak

Funding Agency: NSERC, Discovery (as above)

Summary: Durum wheat varieties with high grain protein concentration (GPC) produce pasta products with greater cooking firmness and increased tolerance to overcooking. However, the large environmental effect on expression of GPC and the negative correlation between GPC and grain yield have slowed development of durum wheat varieties with elevated GPC. Identification of molecular markers associated with high GPC would aid durum wheat breeders to select for this important trait earlier. "Strongfield" is adapted to the durum production area of the southern Canadian prairies combines high yield with high GPC. The objective of this study is to identify molecular markers associated with quantitative trait loci (QTL) for elevated GPC in durum wheat, and in particular the durum variety Strongfield. A preliminary genetic map was constructed by screening polymorphic SSR markers on a set of 95 double haploid lines derived from the cross Strongfield X DT695. Single marker regression was performed on least square (LS) means of GPC collected at Swift Current and Regina in 2002; Swift Current, Regina and Saskatoon in 2003, and Saskatoon and Swift Current 2005. To date, we have identified five regions associated with variation for GPC on chromosome 1B, 2A, 5A, 6B and 7A. The QTL for GPC flanked by *Xgwm448* and *Xgwm558* on chromosome 2AS and the QTL localized near *cfa2040* on chromosome 7A were the most notable and could be useful for selection of GPC in earlier generations. No QTL for high GPC could be detected on chromosome 6BS, the location of a high GPC gene isolated previously from durum wheat, suggesting that Strongfield contains novel QTL for high GPC not previously reported in the literature.
Grain protein concentration is influenced by several factors including nitrogen (N) uptake, assimilation, and remobilization to the grain during grain filling. To better understand the basis for elevated GPC, total plant nitrogen content for 25 durum cultivars varying in GPC were determined at anthesis, milk stage, and physiological maturity, and portioned into total vegetative N and seed N. Similar to "Langdon", the semi-dwarf varieties "Commander" and "WB881" possessed lower total plant N at physiological maturity. "LDN-DIC6B" had both higher plant N uptake post milk-stage and higher N remobilization when compared to Langdon. "Strongfield" durum wheat had the highest uptake of N throughout the grain fill period. In these experiments, lower-GPC genotypes tended to have higher N remobilization but lower N uptake during grain fill.

Project: Breeding for Fusarium Head Blight Resistance in Wheat.

C. Pozniak   Funding Source: ADF (2004-2007)

Fusarium head blight (FHB) is a devastating disease of wheat, durum and barley. In this research we set out to a) test the possibility of using deoxynivalenol (DON), a *Fusarium graminearum* produced mycotoxins, as a selection tool in tissue culture to allow selection of FHB tolerance *in vitro* and b) to identify and incorporate novel sources of resistance into durum wheat, which at present is lacking effective resistance genes. Prior to conducting selection experiments, a workable microspore culture system was first developed. From these studies, it was found that for both spring and durum wheat, microspores extracted at the mid-late uninucleate stage were the most embryonic, and an induction temperature (temperature stress to induce microspores into embryonic development) of 33ºC was optimal. It was noted that durum wheat AC Avonlea was more recalcitrant than spring wheats CDC Teal and AC Barrie, with lower numbers of embryonic microspores obtained. For selection experiments, inclusion of DON at any

concentration from 0-1000 mg L-1 in NPB99 media significantly reduced the number of embryonic microspores and derived embyroids in both resistant and susceptible types. No statistical differences were detected between resistant and susceptible varieties, suggesting that embryonic microspores are not suitable for *in vitro* selection. Similar results were obtained for *in vitro* selection experiments using microspore-derived plantlets with one exception. Maringa, which is reported to have Type III (resistance to DON) FHB resistance, had a higher LD50 for DON than any of the other cultivars tested. However, at the concentration required to effectively differentiate that variety from the others, a 50-60% reduction in plantlet survival was observed, and results were highly variable. Given this, it is doubtful that this assay could be used for routine screening. A coleoptile assay was also tested where germinated seedlings were plated on MS media with concentrations of DON ranging from 0 mg L-1 to 20 mg L-1. No significant differences were observed between varieties with increasing concentrations of DON, suggesting that this assay is not suitable for FHB selection. In this project, heritable resistance to FHB in four *Tritium dicoccoides* “TG” accessions in both greenhouse and field trials was confirmed. The best line TG3475 had resistance significantly better than DT735, a durum breeding line with better FHB resistance than AC Morse and Strongfield. This line is recommended as a useful source of resistance for durum wheat. Selections from the cross TG3475/2*DT735 have been made for further backcrossing of resistance into an adapted durum wheat background. In controlled environment studies, it was found that the ferulic acid content was significantly higher in TG accessions and DT735 when compared to AC Avonlea and Strongfield, and confirms other reports that ferulic acid differences maybe the cause of elevated resistance. However, this needs to be confirmed with further study. Durum lines containing an introgressed resistance gene *(Fhb1)* from spring wheat were also evaluated as a source of resistance. Six durum lines containing *Fhb1* were found to have improved resistance, but there yield performance was well below current check varieties. However, these lines could be used as parents for further backcrossing to combine *Fhb1* with suitable agronomic performance.

Project: Wheat Varieties for Ethanol Production.

Co-investigators: C. Pozniak and S. Phelps

Funding Source: Husky Oil, SAF (2006)

This project was designed to collect agronomic performance data and “ethanol quality” data (starch concentration, protein concentration, and sample viscosity) of the highest yielding wheat varieties available in different wheat classes. Three triticale and one hulless barley were also included. Data from replicated yield trials grown at eight locations across Western Canada indicated that Hoffman, a hard red wheat from Eastern Canada yielded similar to Bhishaj, the top yielding soft white wheat variety in the trials (See table below for yield data summaries). AC Ultima was the highest yielding triticale, yielding similar to AC Andrew. We are currently conducting starch and viscosity analyses on these varieties. Similar trials will be grown in 2007 to collect further data to allow variety recommendations to producers.

Other Sources of Funding:

C. Pozniak. Breeding of Improved Durum Wheat/High Yielding Wheat Cultivars. $2,014,050. WGRF Wheat Research and Development Check-Off Fund. 2005-2015.

C. Pozniak. BASF Funded Breeding Project: 2003-2011. Amount: Confidential

New Funding Obtained/Applied For in 2006:

C. Pozniak. Genomic applications to durum wheat: Grant for Capillary Electrophoresis Upgrade Purchase. $15,210. Canada Foundation for Innovation (peer reviewed). 2007. (Obtained)

G. Taylor and C. Pozniak. Integrating functional genomics and genetic mapping to clone genes responsible for low grain cadmium concentration in durum wheat. $388,705. NSERC (peer reviewed). 2007-2010. (Obtained)

C. McCartney, C. Pozniak, P. Hucl. Combining Effective Resistance to the Leaf Spotting Complex in Spring and Durum Wheat. $170,500. Saskatchewan Agriculture Development Fund. 2007-2011. (Obtained)

C. Pozniak, P. Hucl, and C. McCartney. Enhancing Fusarium Head Blight Resistance Using Novel Approaches. $260,567. Saskatchewan Agriculture Development Fund. 2007-2010. (Obtained)

C. Pozniak and S. Phelps. Evaluation of Wheat and Triticale Varieties for Ethanol Production. $15,000. Husky Oil. 2006. (Obtained)

C. Pozniak and P. Hucl. Equipment for Genetic Analysis of Breeding Populations. $100,000. BASF 2006. (Obtained)

Listing of Collaborators:

Dr. John Clarke, Durum Wheat Breeder, AAFC-SPARC;

Dr K Kumar, Durum Wheat Breeder, CIMMYT,

Dr. Ron Knox, Biotechnologist, AAFC-SPARC;

Dr. Fran Clarke, Quantitative Geneticist, AAFC-SPARC;

Dr. Daryl Somers, Molecular Geneticist, AAFC-CRC.

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Dr. Daryl Klindworth, Plant Genetics, USDA-ARS, Fargo, North Dakota;
Dr. Patrick Hayes, Barley Breeder, Oregon State University
Dr. Greg Taylor, Plant Physiologist, University of Alberta
Dr. Dean Spaner, Wheat Breeder, University of Alberta
Dr. Ron DePauw, Spring Wheat Breeder, AAFC-SPARC;
Dr. Doug Brown, Spring Wheat Breeder, AAFC-CRC;
Dr. Gavin Humphreys, Wheat Breeder, AAFC-CRC;
Dr. Nancy Ames, Durum Wheat Quality, AAFC-CRC;
Dr. Jim Dexter, Durum Wheat Quality, GRL, Canadian Grain Commission;
Dr. Ravi Chibbar, Molecular Biologist in Grain Quality, U of S;
Dr. Brian Fowler, Winter Wheat Breeder, Dept. Plant Sciences;

Barley and Oat Breeding and Genetics

Program Manager: Brian Rossnagel

Objectives

General Barley and Oat Breeding Objectives

Improve agronomic traits including disease resistance, appropriate maturity, resistance to lodging and shattering, enhanced yield potential, improved stress tolerance.

Improved quality traits to enhance levels of desirable quality parameters, reduce levels of undesirable quality factors and modify chemical composition to foster development of new uses for barley and oat and their components.

Breeding Objectives Specific to Barley

In July 2005 the 2 row malting barley breeding program of the Department of Plant Sciences was added to and integrated into the CDC barley and oat project. Breeding objectives and deliverables have been modified accordingly, with the major changes being a de-emphasis on the hulless feed type and amalgamation of 2R hulled malting and feed activities**.**

Develop new, improved, hulled and hulless two row malting, feed and food barley cultivars to maximize and diversify barley productivity in Saskatchewan and western Canada, and to maximize the marketability and value of Saskatchewan and western Canadian barley in domestic and export markets.

Traits for prime consideration are: high grain yield potential, acceptable maturity, acceptable straw strength and adequate resistance to important barley diseases and shattering. These agronomic parameters must be combined with superior grain quality (high test weight and grain plumpness, low hull content, bright colour, peeling and sprouting resistance and malting quality) for maximum marketability. Additional requirements for hulless barley include: maximizing threshability, minimizing embryo damage, manipulating viscosity and β-glucan (lower for feed and malting, higher for human food markets), lowering phytate levels, and developing specialty starch food and industrial types.

Assist in technology transfer regarding barley management and cultivar commercialization to the Saskatchewan and Canadian barley industry.

Introduce and evaluate novel barley germplasm for suitability for use in developing cultivars adapted to Saskatchewan conditions.

Sub-objectives

1) Hulled 2R malting barley
2) Hulled 2R feed barley for non-ruminants
3) Hulled 2R feed barley for ruminants including slow rate dry matter disappearance barley
4) Hulless feed barley for non-ruminants including low phytate hulless barley
5) Hulless food barley including waxy hulless food barley and high amylose hulless food barley
6) Hulless malting barley

Breeding Objectives Specific to Oats

Develop improved milling and feed oat cultivars for Saskatchewan to maximize value and marketability in export and domestic markets.

Prime trait targets will be: high grain yield potential, appropriate maturity, acceptable straw strength, adequate levels of disease resistance and superior grain quality for maximum marketability. Quality objectives include: maximum test weight, plumpness, whiteness (brightness), grain size and milling yield and minimum hull, hull aid detergent lignin and groat breakage and combining low lignin hull with high groat fat. Internal chemical quality factors such as protein, fat and β-glucan content are maintained at optimal levels.

Introduce and evaluate novel oat germplasm for suitability for use in developing cultivars adapted to Saskatchewan conditions.

Assist in technology transfer regarding oat management and cultivar commercialization to the Saskatchewan and Canadian oat industry.

Sub-objectives

1) Milling oat including high beta glucan food oat
2) Feed oat including low acid detergent hull high groat fat (LLH-HOG) oat for ruminants and high oil groat oat for non-ruminants

Barley & Oat Program Expected Outcomes

Lower cost of production by provision of barley and oat varieties which produce more product with the same or lower inputs.

Increased probability of successful premium product production (sustainability) via lower production risk due to biotic and abiotic stresses.

Increased domestic and international marketability and value of resulting products.

Increased possibility for post-harvest value added processing.

Training high quality personnel at the technical and professional levels.

Production of improved and unique germplasm with high value for germplasm exchange - the lifeblood of any breeding program.

Innovation in breeding technology and germplasm development.

Results: Highlights 2006/07

Double smut resistant hulless barley for organic producers

Two fully smut resistant hulless barley selections rapidly developed using blind MMAS (molecular marker assisted selection) were entered in the 2006 HBCoop and will be retained for final year Coop testing in 2007 with anticipated release of one of these in spring 2008. While important for all hulless barely producers, this is of special significance to organic producers since without this resistance or the use of chemical seed treatment organic hulless barley production is simply not possible. This will be especially significant as the demand for organically grown hulless food barley moves forward.

OT3018 milling oat proposed for support for registration.

CDC selection OT3018 milling and feed oat will be presented to the 2007 PRCOB for support for registration. This selection has been the number one yielder in the 2005 and 2006 WCoop oat trials (23 SYs across the Prairies) and the 2005 and 2006 Quaker Uniform Oat Nursery (16 SYs across Canada and the USA). That yield potential (10% > CDC Dancer and 5% > Morgan) is combined with excellent straw strength, very good grain quality and milling yield and average to above average disease resistance.

TR06389 and TR06390 2 row hulled feed barley selections to final year 2007 2RCoop trials**.**

These CDC selections ranked first and third in yield across 16 western Canadian sites in the 2006 2RCoop trials. This high yield potential is combined with good straw strength, very good grain quality and good disease resistance. In particular TR06389 demonstrates improved FHB tolerance. Both lines will be retained for a final year of Coop testing in 2007 with the best one being submitted for support for registration in 2008.

TR05104 2 row malting barley to final year Collaborative Malting trials.

TR05104 completed final year 2RCoop testing and first year Collaborative Malting trials in 2006. Over the 2005 and 2006 test years it averaged 12% higher yield than the malt check AC Metcalfe and has quality attributes similar to Harrington, AC Metcalfe and CDC Kendall. It is anticipated that it will be accepted for second year Collaborative Malting trials in 2007. Pending results from those trials it would be presented for support for registration in 2008.

HB379 2 row hulless low phytate feed barley supported for registration in February 2006. Another first for the CDC barley and oat program, as this is the first known low phytate barley to be released in Canada and probably the world. This new type of barley will deliver benefit both to the hog feeder and to the environment by reducing the amount of phosphate added to diets and improving mineral nutrition as well as delivering swine effluent with less P pollution potential. *Unfortunately CFIA Feeds Division has declared HB379 as a novel feed, delaying the registration and release of this value-added variety and creating significant resource cost to the CDC project in our ongoing efforts to reverse the CFIA's scientifically unsound decision. If these efforts are not successful we will be forced to abandon the registration of HB379 in Canada.*

TR04378 to be registered as CDC Mindon. TR04378 2 row hulled feed barley supported for registration in February 2006. The first variety to be released from the CDC's collaborative FHB screening efforts with AAFC, Brandon. TR04378 is a strong strawed variety with good yield and excellent grain quality, but its main feature is a unique combination of FHB and spot blotch tolerance for eastern Prairie producers. Since the main reason for the release of this variety is its improved FHB tolerance it will be a joint release between the CDC and the AAFC FHB group (another first for the CDC). Seed marketing will be handled by SeCan.

CDC SO-I (OT3017) LLH-HOG feed oat registered. Another first for the CDC program in that this LLH (low acid detergent lignin hull) – HOG (high oil groat) variety is the first variety selected to combine a more digestible hull (LLH) with the higher energy of increased groat fat (HOG) to provide a whole oat grain with the feed value of barley for ruminants. This variety is the result of a seven year collaboration with Super Oats Canada of Regina and will be marketed by that company. The release of CDC SO-I has generated significant interest in the domestic and international feeding industry. Pedigreed seed production of CDC SO-I will be undertaken by FarmPure Seeds, Regina, SK. Commercial production of CDC SO-I will be handled in a closed loop system by Super Oats Canada to protect the integrity of the quality of this new development.

CDC ProFi (OT3006) specialty milling oat supported for registration in February 2006**.** This variety will be registered by March 2007 and is being exclusively released to FarmPure Seeds of Regina for a specialty new FarmPure oat processing and marketing project. The variety's combination of excellent milling yield and increased groat protein and beta glucan are an excellent fit for this new venture. Seed and commercial production will be conducted by FarmPure Seeds and FarmPure Foods

New grants received and projects initiated or altered include:

- a 5 year agreement with SuperOats Canada Ltd., Regina with increased funding in support of our LLH-HOG oat R&D project
- a 5 year agreement with FarmPure Seeds Ltd., Regina in support of the CDC oat R&D project
- a 10 year agreement with PhytoGene Resources Inc., Ottawa for evaluation and development of CDC oat selections for eastern Canada
- an ongoing agreement with Plant Research NZ for evaluation and development of CDC oat selections for New Zealand.
- initiated sharing of oat and barley for annual forage R&D project with Bruce Coulman, Plant Sciences/AAFC Saskatoon and rec'd ADF funding for said project (Coulman as PI)
- one year renewal of the CDC/Agricore United food barley R&D agreement
- initiated collaborative oat and barley R&D activity with C. McCartney, CDC cereal/flax pathologist
- ongoing collaboration with J. McKinnon, A&PS re LLH-HOG evaluation with ADF funding (McKinnon as PI)
- participation in several other new separately funded programs from the SK ADF and other industry players with other collaborators as PIs.

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Expansion of CDC Barley & Oat program
The amalgamation of the University of Saskatchewan 2 row malting barley program with the CDC oat and barley program took place July 1, 2006 with the retirement of Professor B. L. Harvey from the Dept. of Plant Sciences. The amalgamation is now complete and has created a very large portfolio of activity with the full time staff complement of the specific group ballooning from 6.5 to 12 PYs. Ongoing part-time and casual help bring the total staff complement to some 16+ PYs and the number of separately funded research projects increased by four. This increased activity requires considerably more administration and comes with high industry expectations from both the barley and oat sectors.

Results as per Expected Outputs

Barley

Six final year entries

- TR05386 hulled feed dropped from further testing.
- TR05101, TR05102 and TR05104 malting selections completed 2RCoop testing. One or two of these will be advanced to 2nd & final year Collaborative malting testing in 2007 for possible release in 2008.
- TR05915 – joint malting entry with AAFC, Brandon – CDC Kendall with improved FHB tolerance – completed 2RCoop testing and will be advanced to 2nd & final year Collaborative malting testing in 2007 for possible release in 2008.
- TR05912 – joint malting entry with Sapporo/PML with improved pre-harvest sprouting tolerance – to be advanced to 2nd & final year of Collaborative malting testing in 2007 for possible release in 2008.

Nine first year entries – Feed types TR06389 and TR06390 and malting types TR06109 and TR06918 (joint entry with Sapporo/PML) advanced to final year 2007 2RCoop. Others dropped.
Fifteen entries in Eastern Prairie Barley trial
All hulled entries. Feed selection SB040216 to be advanced to 2007 2R Coop
One low phytate hulless entry in final year HBCoop
HB388 2R low phytate hulless barley – seeking support for registration in 2007.
Two 2 row hulless entry in final year HBCoop (malt quality)
HB402 to be re-entered in 2007 HBCoop and HB384 dropped from further testing
Two 2R hulless food, two 2R hulless feed and two 2R hulless double smut resistant entries in first year HBCoop
Hulless food – HB393 low ant waxy advanced to 2nd year 2007 HBCoop. HB392 – dropped.
Hulless feed – HB391 and HB395 dropped
Double smut resistant – HB390 and HB394 advanced to 2nd year 2007 HBCoop.

- complete registration and variety release for TR03373 (CDC Coalition), TR04378 and HB379 barley

CDC Coalition registered
TR04378 (CDC Mindon) registration to be completed in March 2007.
HB379 (CDC Lophy-I) registration being delayed due to CFIA declaration as novel feed. If that claim is not removed we will NOT register HB379 in Canada.

- complete PBR for CDC Cowboy, CDC Aurora Nijo and TR03373 (CDC Coalition) to be completed March 2007

- complete or end negotiations with Japanese company re specialty food barley project and initiate same

Unfortunately we still have not been able to complete this negotiation, but a joint research program has been initiated.
The arrival of Dr. Curt McCartney to the CDC staff complement during 2006 has led to beginning to integrate his expertise into the barley program.

- Applications for supplemental funding to various agencies

Extension of CDC/Agricore United special starch hulless barley R&D agreement
Multiple LOIs submitted to SK ADF – one project for full proposal – not successful
Successful collab application to BMBRI with Legge (PI) & Edney re low phytate barley for malting and brewing.
Collaborator on CFI proposal re U of S Research Feed Processing facility – successful
Collaboration on ACIDF proposal re food barley with K. Swallow (PI), AB Food Res Centre – not successful
Collaboration on ADF proposal re annual cereal forage evaluation and development project with B. Coulman – successful.
Collaboration on project re functional properties of hulless barley in pigs with P. Leterme, PSC - funded by Alberta Barley Commission – successful.

- Attend and participate in appropriate barley R&D meetings

Multiple meetings attended – PRRCG/PRCOB, NFS, CFIA, CSGA, USDA Barley CAP, WBGA, CVCRT-BWG, APF2, CFIA etc.

- Initiate new special projects re – *Hordeum spontaneum* disease resistance introgression (with Steffenson)

Project initiated with 282 2x haploids from *H. vulga*re x *H. spontaneum* cross from U of Minn planted in 2006 summer GH. 174 “vulgare like” lines were harvested and will be evaluated for disease resistance beginning in 2007.

- Initiate new special projects pending supplemental funding - scald pyramiding (with Turkington), low phytate hulless evaluation (with CWB & U of Man.)

Scald pyramiding project – after a successful LOI a proposal for funding was submitted to the Alberta ACIDF – results not available yet.

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Low phytate hulless evaluation with U of Manitoba – due to CFIA declaration that HB379 low phytate is a novel feed this project is still on hold.

Oat

- three final year and seven first year milling/feed entries in WCoop Oat trial

OT3018 –requesting support for registration. OT3019 and OT3021 dropped from further testing

3 of 7 first year WCoop entries (OT3025, OT3028 and OT3029) advanced to final year 2007 WCoop. Others dropped.

- one first year LLH-HOG entry in WCoop Oat trial

OT3026 LLH-HOG dropped from further testing after 1st year WCoop testing

- six or seven milling/feed entries in Rust Area Trial

7 entries evaluated. SA03257 and SA03195 advanced to 2007 WCoop.

Applications for supplemental funding to various agencies

Successfully negotiated new funding arrangement with SuperOats Canada Ltd. Re LLH-HOG oat R&D with increased funding level

Successfully negotiated a new general support agreement for CDC oat R&D with FarmPure Seeds, Regina.

Successfully negotiated a new general agreement for evaluation of CDC oat germplasm in New Zealand with Plant Research NZ, Lincoln, NZ..

Multiple applications submitted to SK ADF – none successful

Collaborator on CFI proposal re U of S Research Feed Processing facility - successful

Collaborator with N. Tinker et al re application to NAMA Oat committee for DaRT oat molecular mapping project – successful.

Collaborator with S. Shirtliffe re application to NAMA Oat committee for graduate student project funding – successful

Collaborator with Curt McCartney re ADF application re oat crown rust resistance – successful.

Collaboration on ADF proposal re annual cereal forage evaluation and development project with B. Coulman – successful.

- Attend and participate in appropriate oat R&D meetings

Multiple meetings attended –PRRRCG/PRCOB, NFS, CFIA, CSGA, POGA, VCCRT-OWG, APF2, CFIA etc.

Collaborations:

CDC – PLANT SCIENCES Dept. U of S

Dr. B.L. Harvey (Professor Emeritus) Dr. G.J. Scoles Dr. S. Shirtliffe
Professor Professor Associate Professor
Malting Barley Breeding Barley Biotechnology Agronomy
F.A.Holm Dr. C. McCartney Dr. R. Chibbar
Professor Assistant Professor (CDC) Professor and CRC
Weed Science Cereal Pathology Carbohydrate
Chem & Mol Biol
ASSOCIATED RESEARCHERS AT UNIVERSITY OF SASKATCHEWAN:
Department. of Animal & Poultry Science:
Dr. M. Drew, Animal Nutrition & Feed Processing
Dr. H. Classen, Poultry Nutrition
Dr. J. McKinnon, Beef Nutrition
Drs. D. Christensen (Prof. Emeritus) and A. VanKessel, Dairy Nutrition
Dr. P. Thacker, Swine Nutrition
Dr. P. Yu, Dr. S. Wright and V. Racz, Feed Innovation Institute
Department. of Applied Microbiology & Food Science:
Dr. R. Tyler, Cereal Chemist
Plant Gene Resources Centre, Agriculture and AgriFood Canada Research Centre:
Drs. Ken Richards, Axel Deidreichsen & Yong Bing Fu, Germplasm Conservation
INDIVIDUALS and AGENCIES OUTSIDE SASKATOON:
Pathology:
Drs. A. Tekauz, J. Chong, T. Fetch, J. Menzies, J. Gilbert & S. Haber, CRC-AAFC Winnipeg
Dr. B. Steffenson, R. Dill-Macky, Univ. of Minnesota
Mr. J. Tucker, AAFC, Brandon
Dr. D. Falk, U of Guelph
Dr. A. McElroy, PhytoGene Resources, Ottawa
Dr. K. Turkington, AAFC, Lacombe
Drs. K. Xi, FCDC, Lacombe
Dr. R. Martin, AAFC, Charlottetown
Dr. L. Skoglund, BARI, Fort Collins, USA
Quality:
Drs. M. Edney, M. Izydorczyk & J. Dexter, CGC-GRL, Winnipeg
Dr. N. Ames, CRC-AAFC, Winnipeg
Dr. S. Miller, AAFC, ECORC, Ottawa
Drs. Y. Li, R McCaig, CMBTC, Winnipeg

Dr. E. Armstrong, BMBRI, Winnipeg
Dr. V. Raboy, USDA-ARS, Aberdeen, Idaho

Drs. T. Vasanthan & F. Temelli, Univ. of Alberta
Dr. J. Hoover, Memorial University, NFLD
Dr. P. Wood, AAFC, Guelph
Dr. K. Swallow, Food Res Centre, Leduc, AB
Dr. P. Leterme, Prairie Swine Centre
Dr. A. Speers, Dalhousie Univ, Halifax
M. Brophy, Canadian Wheat Board Market Dev. Branch, Winnipeg
Sapporo Breweries, Japan
InfraReady Products Ltd., Saskatoon.
Cevena Bioproducts, Edmonton
Emerald Seeds, Avonlea, SK
Breeding & Biotech:
Canada:
Drs. W. Legge & M. Therrien, AAFC Brandon Res. Centre
Drs. J. Helm, P. Juskiw & J. Nyachiro, FCDC, Lacombe
Dr. A. McElroy, PhytoGene Resources, Ottawa
Drs. W. Yan, N. Tinker. S. Molnar, J. Fregeau-Reid, ECORC, AAFC, Ottawa
Dr. F. Belzile, U of Laval
Dr. Jennifer Mitchell-Fetch, CRC, AAFC, Winnipeg
Jim Dyck, Jim Anderson, T. Ferguson, Dr. J. Dean, T. Hyra, Proven Seed Ltd., Agricore United, Winnipeg
K. Hanson, SWP, Watrous, SK
Drs. H. Love, R. Jonsson, Svalof Weibull Ltd. Canada and Sweden
Farm Pure Seeds Ltd., Regina, SK
Canterra Seeds, Winnipeg
SeCan, Ottawa
Foreign:
Drs. K. Smith, D. Stuthman U. of Minnesota
Drs. R. Horsley and M. McMullen, NDSU, Fargo
Dr. D. Clark, Western Plant Breeders, Bozeman
Dr. B. Cooper, BARI, Fort Collins, USA
Dr. T. Blake, Montana State Univ., Bozeman
Dr. S. Ullrich & A. Kleinhoffs, Washington State Univ., Pullman
Dr. P. Hayes, Oregon State Univ., Corvallis
Drs. P. Bregitzer, D. Obert, USDA-ARS, Aberdeen, Idaho
Dr. H. Bockleman, USDA-ARS, Aberdeen, Idaho
Dr. H. Ohm, Purdue University
Dr. F. Kolb, University of Illinois
Dr. H. Kaeppler, University of Wisconsin
Dr. R. Barnett, University of Florida
Dr. S. Harrison, Louisiana State Univ

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Dr. J. Frankowiak, QDPI, Warwick, Aust.
Dr. J. Eglington & A. Box, Waite Inst., Adelaide, Aust.
Drs. R. Lance & C. Li, West. Aust. Department. of Ag., Perth, Aust.
Drs. W. Thomas, S. Swanston, Scottish Crop Res. Inst., UK
Dr. R. Pickering, C&FR, Lincoln, NZ
Dr. P. Zwer, SARDI, Adelaide, Australia
W. Saito, Drs. S. Takahashi and S. Ito, Sapporo Breweries, Japan
Numerous other barley and oat breeders in the EU

Funding Sources: (PI is first listed)

B.G. Rossnagel, Grant-in Aid of CDC Oat R&D, Grain Millers Inc. 2005/06.

B.G. Rossnagel and G.J. Scoles. Use of Molecular Genotyping to Identify Barley and Oat Varieties for Registration and PBR. Canadian Seed Growers Association. 2005/06.

B.G. Rossnagel, Grant-in-Aid of CDC Oat R & D, Can Oat Milling Ltd., 2005-06, on-going 1997-2006.

B.G. Rossnagel, Oat Breeding and Research, $15,500, Quaker Oats of Canada Ltd., 2005-06; on-going 1976-2006.

K. Turkington, J. Helm, B. Rossnagel and K. Xi, Screening for Scald Resistance for future Alberta Variety barley Varieties, Alberta Barley Commission and AARI, 2005-06.

W. Legge et al. including B.G. Rossnagel, funding to enhance FHB screening capabilities at AAFC, Brandon, MB. Canadian Wheat Board, 2005.

R. Chibbar, M. Baga, B.G. Rossnagel, Brewing and Malting Barley Research Institute, Increasing A-type Starch Granules in Barley to Improve Malting Quality. 2005-2006.

B.G. Rossnagel, Oat R&D enhancement agreement, FarmPure Seeds, 2006/07 – 2010/11.

B. G. Rossnagel, Joint malting barley R&D agreement, Sapporo Breweries Japan and Prairie Malt Ltd., Biggar, SK. 2005/06 - 2007/08

B.G.Rossnagel, FHB screening of CDC barley breeding selections, Sask. ADF 2006/07 - 2010/11.

B.G. Rossnagel, LLH-HOG Oat R&D, Super Oats Canada Ltd., 2005/06- 2009/10.

B.G. Rossnagel. 2-row Malting Barley Development, SeCan Association, 2005-2008.

B.G. Rossnagel and G.J. Scoles, Eastern Prairie Barley Check-off CDC Project, WGRF, 2006-2014.

B.G. Rossnagel, R&D Agreement re joint oat variety development for New Zealand. Future royalties from commercial product sales. Plant Research, NZ, 2005.

B.G. Rossnagel, R&D Agreement re joint oat variety development for eastern Canada with PhytoGene Resources Inc., Orleans, ON. Future royalties from commercial product sales. PhytoGene Resources, 2006-2016.

W. Legge et al. including B.G. Rossnagel, funding to enhance FHB screening capabilities at AAFC, Brandon, MB. Canadian Wheat Board, 2006-2008.

W. Legge et al. including B.G. Rossnagel, funding to enhance FHB screening capabilities at AAFC, Brandon, MB. Manitoba ARDI, 2006-2008.

W. Legge et al. including B.G. Rossnagel, funding to enhance FHB screening capabilities at AAFC, Brandon, MB. Alberta ACIDF, 2006-2008.

R. Chibbar, M. Baga and B. Rossnagel, Study of starch granule size distribution to improve barley grain quality. Sask. ADF, 2006/07 - 2008/09.

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*J. McKinnon, B. Rossnagel et al., Optimizing opportunities for specialty oat varieties for feedlot rations. Sask. ADF, 2006/07 - 2007/08.

*P. Yu and others including B. Rossnagel. Evaluation of nutritive values of different varieties of barley for ruminants comparisons. Sask. ADF, 2006/07 - 2008/09.

B.G. Rossnagel, G.J.Scoles & T.S. Grewal. Resistance genes and markers for net blotch resistant barley for western Canada. Sask. ADF, 2004/05 - 2007/08.

B.G. Rossnagel. 2-row Standard Quality Hulled Feed Barley Development, SeCan Association, 1999-09.

B.G. Rossnagel, G. Scoles, T. Grewal. The development and utilization of non-field screening techniques for FHB resistance in barley. Sask. ADF, 2002-06.

B.G. Rossnagel, G.J. Scoles, D.A. Christensen, J. McKinnon, V. Racz. Development of a low lignin hull, high energy oat as a superior ruminant feed for domestic and export markets, Sask. ADF, 2003-06.

B.G. Rossnagel, G.J. Scoles, D.A. Christensen, J. McKinnon, V. Racz, D. Maenz, L. Campbell, Development of a low lignin hull, high energy oat as a superior ruminant feed for domestic and export markets, Super Oats Canada Ltd., 2000-06.

B.G. Rossnagel, Improved rate of dry matter disappearance (slow DMD) in Saskatchewan barley for beef and dairy cattle, Sask. ADF, 2002/03 - 2006/07.

B.G. Rossnagel. CDC/Agricore Specialty Starch Hulless Barley Research Agreement. Agricore United, 2004-2007.

B.G. Rossnagel, G.J. Scoles and S. Shirtliffe, Preferred Milling Oat Research and Development, Quaker Oats Co. Ltd., U.S.A. and Cargill Canada Ltd., 2004-2008.

B.G. Rossnagel, R&D Agreement re Specialty starch barley with InfraReady Products Ltd., Saskatoon. 2004-2014.

R.Chibbar, B.Rossnagel, M.Baga. Development of Molecular Markers for Beta Glucan Content of Barley. Sask ADF, 2004-2007.

A. Tekauz, J. Mitchell-Fetch, N. Ames, B. McCallum, B. Rossnagel. 2004/05 - 2006/07. Identifying and incorporating resistance to FHB in Oat. WGRF.

Outreach Activities B.G. Rossnagel, March 2005.- February 2006:

Invited member of National Cereal Value Chain Round Table Barley Working Group March 2005 to date – multiple meetings

Invited member of National Cereal Value Chain Round Table Oat Working Group March 2005 to date – multiple meetings

Continued as CDC rep to SSGA Board of Directors 2005/2206

Continued membership on FII (formerly PFRC) advisory board 2005/06

CIGI Int’l malting barley course field tour at U of S July 14

SeCan group field tour August 3.

BMBI field tour Aug 2.

BARI field tour, August 8.

Sapporo Breweries Japan field tour, August 16.

Annual oat industry R&D field tour. August 1.

WGRF Barley Advisory Committee annual Barley Check-off presentation and field tour. Brandon. July 19-20.

SuperOat Canada annual R&D report. Regina SK. April, 5.

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Invited rep to International Advisory Committee USDA Barley Genomics CAP project, San Diego, Jan 12.

> 15 press and live media interviews

> 250 one-on-one producer, end-user and regulatory sector industry contacts

Public Property:

Refereed articles:

ACCEPTED:

T. Grewal, **B.G. Rossnagel**, and G.J. Scoles, 2007. Validation of molecular markers for covered smut resistance and marker-assisted introgression of loose and covered smut resistance in hulless barley. Molecular Breeding.

A. D. Beattie, G. J. Scoles and **B.G. Rossnagel**. 2007. Identification of Molecular Markers Linked to a *Pyrenophora teres* Avirulence Gene. Phytopathology.

M.J.Edney, **B.G.Rossnagel** and V.Raboy. 2007. Effect of low phytate barley on malt quality including mineral loss during fermentation. J. of the Amer Society of Brewing Chemists

Vicky Roslinsky, Peter E. Eckstein, Victor Raboy, Brian G. Rossnagel, and Graham J. Scoles, 2007. Molecular Marker Development and Linkage Analysis in Three Low Phytic Acid Barley (*Hordeum vulgare*) Mutant Lines. Molecular Breeding.

PUBLISHED:

N. Ames, C. Rhymer, B. Rossnagel, M. Therrien, D. Ryland, S. Dua and K. Ross, 2006. Utilization of Diverse Hulless Barley Properties to Maximize Food Product Quality. Cereal Foods World, 51 - 1, pp 23 – 28.

T. Grewal, B.G. Rossnagel, and G.J. Scoles, 2006. Inheritance of Resistance to Covered Smut (*Ustilago hordei* (Pers.) Lagerh.) in Barley. Canadian Journal Plant Science, 86:829-837.

P.A. Thacker and **B.G. Rossnagel**, 2006. Performance and Carcass Traits of Finishing Pigs Fed Low Phosphorus Containing Diets Based on Normal Hulled or Hulless Barley or a Low-Phytate Hulless Barley With and Without Phytase. Journal of Animal and Veterinary Advances, 5(5):401-407.

P. Thacker, **B. Rossnagel** and V. Raboy, 2006. The Effects of Phytase Supplementation on Nutrient Digestibility, Plasma Parameters, Performance and Carcass Traits of Pigs Fed Diets Based on Low-Phytate Barley without Organic Phosphorous. Canadian Journal Animal Science, 86:245-254.

Invited presentations:

B.G.Rossnagel. 2006. Malting barley R&D in Canada. CIGI Int'l Malting Barley Course, Winnipeg, July 12.

M. Baga, **B.G. Rossnagel** & R. Chibbar, 2006. Molecular Characterization of the Genetic Basis for Starch Granule Size Distribution in Barley. ASBC annual conference, La Quinta, CA, June 19.

B. Rossnagel, 2006. Invited member WECG/PRRCG panel "Fuelling innovation – How to Build a Canadian Agricultural Research Strategy to Remain Competitive in a Global Environment. Banff, AB, February 22.

G.R. Zalinko, J.J. McKinnon, V.J. Racz, B.G. Rossnagel and D.A. Christensen, 2006. Feeding Low Lignin Hull, High Energy Oats to Beef Cattle. Western Beef Development Centre field day, June 22.

B. Rossnagel, T. Zatorski, G. Arganosa, G. Scoles and S. Shirtliffe, 2006. CDC Oat R&D Update. POGA annual conference, Yorkton, SK, Dec 2006.

C. Pozniak and B. Rossnagel. 2007. Annual presentation to SSGA annual mtg re new CDC varieties, Jan, 2007.

Conference presentations

G.R. Zalinko, J.J. McKinnon, V.J. Racz, B.G. Rossnage**l** and D.A. Christensen, 2006. Nutritional Evaluation of a Low-Lignin Hull, High-Oil Groat Oat Grain for Feedlot Cattle. Canadian Society of Animal Science annual conference, Halifax, August.

B. Rossnagel, P.Eckstein, 2006. Pure lining of Breeder Seed for molecular variety identification in oat. North American Oat Workers Conference, Fargo, ND, July.

R. Chibbar, M. Baga, S. Ganeshan, J. Li, R. Singh, E. Asare, J. Drinkwater**,** B. Rossnagel, P.Hucl. 2006. Genomic strategies to improve starch and non-starch carbohydrates in cereal grains. 1st Int'l Forum on Cereal Science, AACC Int'l Symposium, Wuxi, Cnia, October.

T. Grewal**,** B.Rossnagel, C.Pozniak, G. Scoles. 2006. Genetics of resistance to net blotch in barley, molecular marker development and validation. 3rd International Workshop on Barley Leaf Blights, Edmonton. July.

T.S.Grewal**,** B.G.Rossnagel and G.J.Scoles. 2006. Mapping of QTL associated with barley net blotch resistance. Sask Div Can Phytopath Soc, Saskatoon, December.

Conference posters:

M. Edney, B.G. Rossnagel and V. Raboy, 2006. Effect of Low Phytate Barley on Malt Quality Including Mineral Loss During Fermentation. ASBC, La Quinta, CA, June 20.

P.Eckstein, T. Fetch, D. Hay, T. Zatorski, B.Rossnagel, G.Scoles. 2006. Molecular markers for the oat stem rust resistance gene Pg16. North American Oat Workers Conference, Fargo, ND, July.

J. Gao, T. Vasanthan, R. Hoover, B. Rossnagel. 2006. Reactivity of native and acid treated normal, waxy and high amylose corn and barley starches towards phosphorylation and cationization. World Grains Summit: Foods and Beverages. San Francisco, CA, September.

N. Ames, C. Rhymer, B. Rossnagel. 2006. Genotype and environment effects on oat beta glucan and total dietary fibre. North American Oat Workers Conference, Fargo, ND, July.

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J.Li, M. Baga, B. Rossnagel, W. Legge, R. Chibbar. 2007. Identification of QTL for beta glucan concentration in barley. Plant & Animal Genome IV, San Diego, CA, January.

A.D. Beattie, P. E. Eckstein[1], T. Zatorski, G.J. Scoles**,** B.G. Rossnagel. 2007. An Oat (*Avena sativa* L.) cDNA Library Representing Early Seed Development. Plant & Animal Genome IV, San Diego, CA, January.

T. Grewal, B.Rossnagel, C.Pozniak, G. Scoles. 2006. QTL mapping of net blotch resistance using DaRT. 3rd International Workshop on Barley Leaf Blights, Edmonton. July.

Commercializable property:

TR03378 2R feed barley supported for registration Feb 2006 – registration as CDC Mindon to be completed by March 2007. Seed production and distribution to be handled by SeCan.

OT3006 specialty milling oat supported for registration February 2006 – registration as CDC ProFi to be completed by March 2007. To be handled in closed loop specialty production and marketing system by FarmPure Seeds.

CDC SO-I (OT3017) LLH-HOG specialty feed oat supported for registration February 2006 and registered July 2007. To be handled in closed loop specialty production and marketing system by Super Oats Canada.

HB379 2 row low phytate hulless feed barley supported for registration February 2006. Registration being delayed by CFIA. Marketing rights awarded to FarmPure Seeds.

Cereal and Flax Pathology

Principal Investigator: Curt McCartney

Overall Objective

The overall objective of the cereal and flax pathology program is to advance knowledge of the genetics of host-pathogen interactions and apply this information in the development of cereal and flax cultivars for Saskatchewan and western Canada.

Activities and Results

My appointment to the CDC as the Cereal and Flax Pathologist began in the summer of 2006. A significant portion of the 2006 growing season was spent visiting the existing field disease nurseries operated by the CDC cereal and flax breeding programs and establishing a dialogue with the CDC breeders regarding their pathology interests and requirements. Through these consultations, the following areas of activity were established to meet the overall objective of my research program.

1. Evaluation of disease resistance in breeding lines:

Wheat: Field disease nurseries were previously established to evaluate the leaf and stem rust, common bunt, and leaf spot resistance of breeding lines developed by the CDC wheat breeding programs. The leaf and stem rust nursery was conducted on irrigated land and was inoculated with a epidemic mixture of leaf and stem rust isolates provided by Dr. Brent McCallum and Dr. Tom Fetch (AAFC – Winnipeg). Susceptible spreader rows were artificially inoculated, which produced urediniospores that ultimately infected the breeding lines. Over 9,600 wheat lines were evaluated for leaf and stem rust resistance in 2006. The common bunt nursery was inoculated with a mixture of *Tilletia tritici* races T-1, T-6, T-13, T-19 and *T. laevis* races L-1 and L-16 in an approximate ratio of 1:1:1:1:2:2. The seed of the test entries were coated with the spore mixture and seeded early in the season to promote bunt infection. Over 1,000 wheat lines were evaluated for common bunt resistance in 2006. The leaf spot nursery utilizes natural inoculum and was located at the Goodale Research Farm, where leaf spots are endemic. Forty-five wheat lines were evaluated in 2006, but this number is expected to increase in the future. Greenhouse tests were used to evaluate loose smut and fusarium head blight (FHB) resistance. For loose smut, test entries are artificially inoculated with a mixture of races at anthesis. Infected seed are planted in the greenhouse and observed for percentage of smutted plants. One hundred fifty-seven wheat lines were evaluated for loose smut resistance in 2006. For FHB, greenhouse inoculations were conducted using a point inoculation technique and observing spread of the fungus in the wheat spike 21 days post inoculation. Field FHB evaluation was conducted through collaboration with Dr. Anita Brûlé-Babel (U of Manitoba).

Oat: Managed by the CDC oat breeding program. Crown rust resistance will be evaluated in a modest number of breeding lines as part of a SAF Agriculture Development Fund grant outlined in Activity #3.

Barley: Managed by the CDC barley breeding program.

Flax: The CDC flax breeding program has established a flax wilt nursery on the research plots off Preston Avenue. The inoculum resides in the soil and is maintained by routine planting of susceptible flax lines. Test entries are planted into the soil along with resistant and susceptible flax lines and rated for disease reaction following emergence. The CDC cereal and flax pathology program will work in coordination with the flax breeding program on the evaluation of flax wilt resistance during the 2007 field season.

2. Leaf spot resistance in wheat:

A comprehensive program was initiated to combine resistance to tan spot, stagonospora nodorum blotch, and septoria tritici blotch resistance into elite spring and durum wheat germplasm. This program builds upon germplasm with leaf spot resistance developed and identified by Dr. Geoff Hughes. The CDC cereal and flax pathology program has successively adapted protocols for the evaluation of stagonospora nodorum blotch resistance. *Stagonospora nodorum* is inoculated onto V8 media seven days prior to inoculation. A conidia/water suspension is made at 3.75 conidia per ml and inoculated onto seedlings at the 3rd leaf stage using an airbrush inoculator. Inoculated seedlings are incubated in a humidity chamber for 48 hours and transferred to a greenhouse bench. Seedlings are rated on a 1-5 scale 9 days post inoculation. Dr. McCartney's experience with tan spot and septoria tritici blotch will facilitate the establishment of the necessary experimental protocols in the coming year. Preliminary data has identified a putative race structure in the Saskatchewan *Stagonospora nodorum* population. To date, 55 spring, durum, and spelt wheat lines have been inoculated with eight *Stagonospora nodorum* isolates. Completion of this preliminary study will occur in March 2007 and will see these wheat lines evaluated with 17 *S. nodorum* isolates isolated from spring, durum and spelt wheat lines. These data will form the basis of a smaller differential set that will survey the variation in virulence in the *S. nodorum* population. A differential set is also being established for septoria tritici blotch. Characterized septoria tritici resistance sources have been acquired from Plant Gene Resources of Canada and Dr. Anita Brûlé-Babel (U of Manitoba). Together, these data will also identify the most effective leaf spot resistance sources. Tan spot, stagonospora nodorum blotch, and septoria tritici blotch resistance will be transferred into elite spring and durum wheat germplasm through a backcrossing strategy. The mapping of *Snb1* has been initiated. Leaf tissue was collected from two mapping populations. Stagonospora nodorum blotch reaction and marker data will be collected on these populations in the coming year.

3. Crown rust resistance in oat:

The CDC cereal and flax pathology program is in the process of establishing the resources for the evaluation of oat crown rust resistance. Inoculation equipment has been ordered and is expected to arrive shortly. Mapping populations, new crown rust resistance sources, crown rust differential oat lines, and *Puccinia coronata* cultures have/are being made available through collaboration with Dr. James Chong (AAFC – Winnipeg). Once the oat crown rust program is fully operating, experiments will be initiated to characterize and map new seedling and adult plant crown rust resistance genes and transfer these genes into elite oat germplasm for utilization in oat breeding. Experimental protocols are well established for evaluating crown rust reaction.

New Funding Applied For and Obtained

Principle Investigator

McCartney C.A., Rossnagel B., Scoles G., Chong J., and Zatorski T. Characterization and Deployment of Novel Oat Crown Rust Resistance for Saskatchewan and Western Canada. SAF Agriculture Development Fund. 5 years.

McCartney C.A., Hucl P., Pozniak C., Brûlé-Babel A., and Gilbert J. Combining Effective Resistance Genes to the Saskatchewan Leaf Spotting Complex in Spring and Durum Wheat. SAF Agriculture Development Fund. 4 years. Awarded.

McCartney C.A. Genetic Characterization of the *Triticum-Stagonospora nodorum* Pathosystem. NSERC Discovery Grant. 5 years. Competition Results Pending.

Co-Investigator

Hucl P., Pozniak C., McCartney C.A., and Somers D. Enhancing Fusarium Head Blight (FHB) Resistance in Spring and Durum Wheat using Novel Approaches. SAF Agriculture Development Fund. 3 years. Awarded.

Rossnagel B., Eckstein P., Turkington K., Zantinge J., Legge B., McCartney C.A., and Scoles G. Incorporation of Multiple Scald (*Ryncosporium secalis*) Resistance into Malting Barley Using Molecular Marker-Assisted Selection (MMAS). Alberta Agricultural Funding Consortium. 4 years. Competition Results Pending.

Existing Funding

Principle Investigator

McCartney C.A. (formerly Hughes G.), Hucl P., and Pozniak C. Disease Resistance Screening for Spring Wheat Breeding Programs at the University of Saskatchewan. SAF Agriculture Development Fund. 2004-2008. $246,900 Total Support. 5 years. Awarded in 2004.

Co-Investigator

CDC Wheat Breeding Program. Wheat Breeding for Western Canada. Western Grains Research Foundation. 10 years. Awarded in 2005.

Outreach Activity

McCartney C.A. 2007. Fusarium Head Blight Resistance in Spring Wheat. Department of Plant Sciences Seminar Series, University of Saskatchewan, Saskatoon, SK, 9 Jan 2007.

McCartney C.A., McCallum B., Fetch T., Turkington K., Gaudet D., Xi K., and Pearse P. 2006. Wheat Stripe Rust in Western Canada. Saskatchewan Advisory Council on Crop Protection Annual Meeting, Saskatoon, SK, 5 Dec 2006.

McCartney, C.A. 2006. Resistance to the Wheat Leaf Spotting Complex. Canadian Phytopathological Society – Saskatchewan Regional Meeting, Saskatoon, SK, 4 Dec 2006.

Public Property
None to date. Research results will be published in peer-reviewed journals.
Commercializable Property
Wheat, barley, oat, and flax cultivars are expected outcomes of my program's contributions to the CDC cereal and flax breeding programs.
Collaborations
Brûlé-Babel A. – wheat leaf spots.
Chong J. – oat crown rust.
Eckstein P. – oat crown rust, barley scald.
Fernandez M. – wheat leaf spots.
Fowler B. – wheat breeding.
Gilbert J. – wheat leaf spots.
Hucl P. – wheat leaf spots, wheat FHB, wheat breeding.
Legge B. – barley scald.
Pozniak C. – wheat leaf spots, wheat FHB, wheat breeding.
Rossnagel B. – oat crown rust, oat breeding, barley scald, barley breeding.
Rowland G. – flax wilt, flax breeding.
Scoles G. – oat crown rust, barley scald.
Somers D. – wheat fusarium head blight (FHB).
Turkington K. – barley scald.
Zantinge J. – barley scald.
Zatorski T. – oat crown rust.

Appendix V Statistics Canada estimates for on-farm productivity of winter wheat compared to CWRS wheat, Prairie Provinces, 1999-2004 (From Statistics Canada website, forwarded by Dr. B. Fowler)

Statistics Canada (Web source)							
Est. Winter wheat yield (bu/a)	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**6 Yr.mean**
Manitoba	59.4	60.9	51.3	50.3	56.7	62.4	56.8
Saskatchewan	41.2	46.2	30.5	29.2	35.3	38.6	36.8
Alberta	51.0	34.0	33.3	44.0	48.2	44.6	42.5
Est. CWRS yield (bu/a)	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**6 Yr.mean**
Manitoba	36.2	39.7	31.3	35.5	42.4	38.6	37.3
Saskatchewan	34.5	31.8	24.8	20.4	26.5	29.7	28.0
Alberta	39.2	35.6	32.0	25.6	36.5	43.1	33.7
Est. WW yield as % of CWRS	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**6 Yr.mean**
Manitoba	164	153	164	142	134	162	151
Saskatchewan	119	145	123	143	133	130	135
Alberta	130	96	104	172	132	103	121

Appendix VI Questionnaire sent by GrainTek to individual breeders

Note: Draft versions of this questionnaire were reviewed by the steering committee, prior to agreement on this version. It is presented here in compressed form.

Improving the Competitiveness of W. Canadian Cereal Grain Crops

An initiative by ACIDF and AARI

February, 2007

****

Questionnaire for Public Sector Cereal Grain Crop Breeders

Please complete the questionnaire for every cereal grain crop class for which you are a designated breeder or developer of germ-plasm. Thank you for your assistance in this review process. You can insert your responses into the text of this message, use Save, and email back to me as an attachment, to Keith Briggs P.Ag. (Email graintek@shaw.ca Ph/Fax (780) 434-4472 (c/o GrainTek, 10903-35 Av., Edmonton AB T6J 2V2)

There are 18 questions in the survey, which may take 40 - 50 minutes to complete, plus research time to assemble information about budgetary aspects of your program(s).

We would like to receive all responses no later than March 9, for review and use in follow-up meetings scheduled for late March, 2007.

****
Your Name: Affiliation:

PLEASE COMPLETE A SEPARATE QUESTIONNAIRE FOR EACH CROP CLASS FOR WHICH YOU HAVE A PROGRAM. THANK YOU.

Crop kind and class:

Q1 List the most important breeding objectives for production and market aspects of this crop, also indicating your priority for each objective as Very high, High, Medium, Low, or Very low

(a) Production related objectives
(b) Market / grain use oriented objectives

Q2

a What would be the best achievable genetic step change goal for this crop class, whether accomplished by your group or others?

Q2b If this is a quantitatively measurable step change, indicate the quantitative improvement to be gained

__________% increase.

Q2c Why is this step change target important to the industry? Write comments here:

Q3 What genetic or other constraints have prevented the achievement of the step change named in Question 2, and what would be needed to achieve this change?

Q4 Indicate in the table below the kinds of markets for which you are breeding this crop class, indicating the priority which you place on each broad target market type.

Indicate priority in all appropriate boxes as one of: Very high, High, Medium, Low, Very low, or Zero), and whether this market is Domestic only, Mainly domestic, Equally domestic and export, Mainly export, or Export only

Q4 Table

PRIORITY LEVEL	Domestic market only	Mainly domestic market	Equally domestic + export market	Mainly export market	Export market only
Biofuel					
Feed					
Food					
Other Industrial					

Q5 List any other future breeding objectives for this crop class which could further improve its national and international competitiveness. For each item listed here, also indicate the market where you believe this improved competitiveness could be captured, and what new resources if any would be needed to deliver the breeding gain in a new variety

Q6 What % yield increase over the highest yielding varieties in this crop class do you believe can be achieved through genetic improvement in the next 5 and 10 years with the current or an increased breeding resource base?

Q6 Table

	% Yield increase possible with current breeding resources	% Yield increase possible with expanded breeding resources
In 5 years		
In 10 years		

Q7 Interest is growing in W. Canada in developing a cereal grain energy feedstock to competitively serve the needs of evolving ethanol / bio-energy markets

Rank the 15 grain crops shown below evaluated by your view of the competitive potential of each to provide a significant proportion of the requirements for the future grain bio-energy industry of W. Canada and as a feed grain energy source.

Rank in order from 1 Best Potential - 15 Least Potential

Q7 Table

RANK BY POTENTIAL	Ranking for bio-energy	Ranking for feed energy
Winter wheat		
Winter trticale		
Fall rye		
CWRS wheat		
CPS wheat		
SWS wheat		
CWES wheat		
CW General Purpose wheat		
Oat (hulled)		
Oat (hulless)		
Spring rye		
Spring triticale		
Corn		
Barley (Hulled)		
Barley (Hulless)		

Q8 If the rankings bio-energy and feed energy shown in Q7 are different, what are the reasons for those differences?

Q9 What specific changes in starch composition or other grain compositional traits are you targeting that will result in greater energy efficiency either in the feed market or in the industrial bio-energy market? Please complete the following table for each such trait identified for this crop class.

Q9 Table

Trait description	Is suitable genetic variation	Ease of breeding 1 Easy 2 Medium ease	Earliest likely year for release of a variety with

	available? **Yes or No**	**3 Hard 4 Very hard**	**significant improvement in this trait, for market use**

Add brief notes here to explain the nature and effect of each trait change in Q9 on the potential grain energy availability or efficiency for feed or other uses

Q10 What unique technologies and capacities make your crop breeding program successful in advancing W. Canadian grain crop production competitiveness?

Q11 Complete the following table describing the human resources available in your program, also indicating Priority areas of HR investment which would benefit from additional capacity

Indicate typical # of persons per year working on the breeding program. Indicate Priority areas for further HR investment by also typing one or more P's in the relevant boxes

Q11 Table

# of personnel in PY	**Publicly funded**	**Privately funded**	**Grant funded**	**Other funding**
PY Team leader(s)				
PY Technical staff				
PY PDF or RA				
PY Summer students				
PY Work transfer interns				
PY Graduate students				
Other				

Q12 Complete the following table describing your current annual budget for breeding this crop type / class. Enter aggregated totals for each kind of funding source

Q12 Table

$ Funding ('000)	**Public funds**	**Private funds**	**Grant funds**	**Royalty income**
Professional staff (program leaders) salary				
All other support staff salaries				
All other operating costs (including project travel)				
Capital funds (average per year)				
Infrastructure support ('overhead' costs etc)				
Total yearly budget				

Type in any comments re budget, here:

Q13 As a breeder and / or developer of crop germ-plasm, what are the criteria by which the effectiveness of your work is evaluated?

Q14 For your organization and breeding program, indicate the extent to which you believe program goals for breeding advances are in good synchrony with the R&D goals and outputs specifically sought by the industries that will use this crop kind for their current and future needs. Select Variable only if there is a very wide range in synchrony

Indicate the overall level of synchrony as (select one with **bold** or underline):

None Poor Good Very good Excellent. Variable.

Q15 What special steps are taken in setting your program goals on an ongoing basis, to ensure that outputs from the breeding program will meet the needs of existing and future markets?

Q16 Do you rate the amount and scope of activity reported in Q15 as (select one by **bold** or underline)?

Not enough About right Excessive

Q17 What are your best collaborations with other researchers and with industry? Please list your responses in the following categories, and provide a very brief indication of the general nature of each of these collaborations

(a) Canadian collaborations

(b) International collaborations

(c) Desirable future collaborations, national or international, that would advance the competitiveness of your program

Q18 To what extent do issues around IP ownership of germ-plasm and technologies limit your ability to develop the collaborations that you would really like to have, nationally and internationally?

Thank you for participating in this review – we much appreciate the time spent on this at a very busy time of year.

Keith G. Briggs P.Ag. (for ACIDF / AARI)

GrainTek Ph/Fax (780) 434-4472 Email graintek@shaw.ca

Appendix VII AAFC Reviewed and approved Science and Innovation Research Projects, starting 2007

Source: March 15, 2007 www.agr.gc.ca/index_e.php?s1=sci&s2=proj07$page=prior

This Appendix lists cereal germ-plasm / breeding related Science and Innovation projects relevant to W. Canada, that were started in 2007 at Agriculture and AgriFood Canada. All projects were reviewed prior to approval by national and international peer scientists expert in the areas of each project, based on four selection criteria

- Scientific excellence of the project scientists
- Scientific merit and originality of the proposals
- Contribution to innovation and to AAFC National Priorities
- Feasibility (potential to achieve objectives and deliver outputs)

It is assumed that this project list provides indication of the priorities within AAFC for achieving urgent novel progress in the areas of plant breeding / germ-plasm development and energy production in cereals, as found in the project listings for (1) Plant Science and (2) Environment and Ecology. Several listed projects relate to the deployment of different genetics in different scenarios, if they might affect energy productivity (Details about individual projects are unavailable from this source listing).

Listings show: Project number and title; Principal researcher; # of team members; Duration; $ allocated.

Projects have also been classified by GrainTek according to the following general groupings:

(A) Primary breeding programs, and germ-plasm improvement / broadening
(B) Biotechnology and molecular support for breeding program objectives
(C) Yield and productivity protection (mainly pathology support for breeding objectives)
(D) Quality and end-use enhancement
(E) Agro-ecosystem aspects around integration of new and existing plant genetics
(F) Regulatory aspects, including biosafety, and marketing systems

Environment and Ecology Projects

EE31-Enhanced capacity to conserve and utilize genetic resources
K. Richards 15 2007-2011 4,477,716 A
EE48-Impact of contrasted production systems – transgenic, organic and conventional – on the components of agro-ecosystem diversity
A. Legere 3 2007-2011 217,850 E
EE96-Impact of climate change on the production of energy crops in western Canada, and coping strategies
H. Wang 4 2007-2011 120,000 D, E
EE103-Global change impacts and adaptation
M.Boehm 17 2007-2011 165,000 E
EE148-Integrated management tactics for weeds, insects and diseases in oilseed, cereal and pulse crops
O.Olfert 14 2007-2008 80,000 D, E
EE164-Adapting to climate variability and change: determination of risks and opportunities for agricultural production systems
D.Neilsen 13 2007-2008 76,000 E
EE182-Farming systems for feeds and fuels
B.Ballcoehlo 2 2007-2008 40,000 D, E

EE215-Host-pathogen interaction at the organismal, genomic and molecular level: Identifying novel strategies for control of Lepidopteran pests in field crops and in the greenhouse

M.Erlandson 5 2007-2008 709,080 A, B

EEE251-Canadian Plant Diversity research and documentation in support of agriculture and native bio-resource protection

P.Catling 3 2007-2011 300,000 A

Plant Science Projects

PS50-Molecular studies of plant virus infection processes and of virus/host interactions, and design of novel strategies for plant virus disease control

H.Sanfacon 5 2007-2011 490,000 C

PS55-Enhancing the corn value chain for food/feed quality, safety and production

L.Reid 10 2007-2011 520,000 A, D, E, F

PS67-Assessment of heavy metals in food and feed crops in the Canadian Prairie agro-ecosystem

M.Schellenberg 4 2007-2009 130,000 A, D, F

PS71-Development of optical sensing technologies as tools for genotype improvement and nutrient best management practices for food and biomass production

B.Ma 13 2007-2011 224,000 B, E

PS72-Introgression of extensive genetic diversity for resistance to biotic and abiotic stresses into new cereal crop germplasm

A.Comeau 11 2007-2011 140,000 A

PS76-Development of feed, forage, food and six-row malting barley cultivars for western Canada

M.Therrien 20 2007-2011 240,000 A, B, C, D

PS81-A systems biology approach to dissecting the Fusarium/cereal interaction: reduction of mycotoxins in food and feed

L.Harris 11 2007-2011 800,000 A, B, C, D, E, F

PS94-Functional proteomics approach to identification of molecular biomarkers for seed dormancy control and regulation in Canadian wheat

N.Bykova 6 2007-2100 196,000 B

PS108-Genetic enhancement of winter wheat for improved environmental sustainability, enhanced feed/food safety and expanded end-use product utilization

R.Graf 15 2007-2011 496,000 A, B, C, D, E

PS113-Traceability of organisms (genera, strains, cereal and tuber crop cultivars) of importance to Canadian food and agriculture, genomically based and for rapid identification on demand

G.Tremblay 7 2007-2008 120,000 E, F

PS116-Genetic improvement of barley

T.Choo 12 2007-2011 60,000 A, B, C, D

PS121-Protection of Canada’s wheat for the food, feed and ethanol industries from the fungus disease Fusarium head blight (FHB)

J.Gilbert 14 2007-2008 50,000 A, B, C, D, E, F

PS144- Gene discovery and deployment in cereals to achieve resistance to plant diseases in wheat and triticale

D.Gaudet 7 2007-2011 225,000 A, B, C

PS146-Canadian Triticale Biorefinery initiative – competitiveness and biosafety of triticale

F.Eudes 10 2007-2009 400,000 A, B, D, E, F

PS171-Functional genomics and proteomics of triticale, the new bio-industrial crop for Canada

A.Laroche 9 2007-2009 440,000 A, B, D

PS208-Genetic protection of wheat from leaf rust

B.McCallum	10	2007-2008	100,000	A, B, C

PS209-Ensuring the security of Canada's food/feed supply through the development of knowledge and best management practices that reduce the impact of plant diseases on field crops

T.Fetch	15	2007-2008	120,000	A, B, C, E

PS211-Potential use of rhizobia for growth enhancement of non-legume crops

D.Prevost	2	2007-2008	15,000	B

PS221-High value seeds for the bio-economy (Crop types not indicated – KGB)

B.Miki	8	2007-2011	965,000	A, B, D

PS224-Development of two-row malting barley cultivars and FHB resistant germplasm for western Canada

W.Legge	23	2007-2011	520,000	A, B, C, E

PS233-Genetic enhancement of wheat that promotes consumer health and wellness, advances economic benefits for all stakeholders, and protects the sustainability of the Canadian agro-ecosystem

S.Fox	28	2007-2011	4,480,000	A, B, C, D, E

PS236-Development and evaluation of tools and strategies to enhance wheat molecular breeding

R.Knox	10	2007-2011	240,000	A, B

PS243-Integrated oat improvement

N.Tinker	13	2007-2011	960,000	A, B, C, D, E

Plant Science Review Panel Members :

- Chair - Deborah Buszard, Ph. D. - McGill University

- Richard Bélanger, Ph. D. - Université Laval
- François Belzile, Ph. D. - Université Laval
- Kirsten Bett, Ph. D. - University of Saskatchewan
- Anita Brûlé-Babel, Ph. D - University of Manitoba
- Bernard Grodzinski, Ph. D. - University of Guelph
- Pierre Hucl, Ph. D. - University of Saskatchewan
- Norman Hüner, Ph. D. - University of Western Ontario
- Ralph Martin, Ph. D. - Nova Scotia Agricultural College
- Donald Smith, Ph. D. - McGill University
- Clarence Swanton, Ph. D. - University of Guelph
- Randall Weselake, Ph. D. - University of Alberta

Environment and Ecology Review Panel Members :

- Chair - Hani Antoun, Ph. D. - Université Laval

- Darwin Anderson, Ph. D. - University of Saskatchewan
- Peter Bretting, Ph. D. - United States Department of Agriculture
- Patricia Chambers, Ph. D. - Environment Canada
- Tim Dickinson, Ph. D. - University of Toronto
- Linda Hall, Ph. D. - University of Alberta
- Vern Harms, Ph. D. - University of Saskatchewan
- Henry Hengeveld - Environment Canada
- Peter J Krell, Ph. D. - University of Guelph
- Marc Laverdière, Ph. D. - The Research and Development Institute for the Agri-Environment
- Jeremy McNeil, Ph. D. - University of Western Ontario
- Léon-Étienne Parent, Ph. D. - Université Laval

Appendix VIII The best levels of resistance known in wheat and triticale to various Priority 1 diseases and the ease of breeding of each of the diseases. (Source PGDC website, April 18, 2007; Website last updated March 2005)

Updated in 2007 by GrainTek to include AC Andrew (SWS, resistant to powdery mildew and stripe rust), and SW52 (resistant to blackpoint)

Best available resistance:

Priority 1 diseases	**Spring wheat**	**Durum wheat**	**Winter wheat**	**Triticale**	**Ease of breeding 1(Easy) – 5 (Hard)**
Leaf rust	R	R	R	R	1
Stem rust (not Ug99)	R	R	R	R	1
Common bunt	R	R	R	R	2
Fusarium head blight	R	MS	MR	-	5
Septoria glume blotch and head blight	I	MR	MS	-	5
Tan spot	MR	MR	MR	-	3
Loose smut	R	R	R	R	3
Root rot	MR	MR	MR	-	4
Powdery mildew	MR	-	-	-	2
Blackpoint	R	-	-	-	3
Stripe rust	R	-	-	-	1
Ergot	I	MR	-	-	5

Appendix IX Highest yielding varieties and breeding lines of cereal grain crops in different W. Canadian provinces

This table uses data drawn from the Alberta/BC, Manitoba and Saskatchewan 2007 Provincial Regional Variety Trial (RVT) Performance publications of ACOAC, SVPG and MCVET. Information concerning potential yields of advanced lines under test, where available, are drawn from the most recent respective institutional annual reports. ( ) indicates very limited station years of data. Indirect check yield comparisons are made as necessary. Note that in most areas there may be numerous other varieties with yield not statistically different from the varieties shown. Named varieties are only presented as the highest in yield rank in each area, to give some indication of relative yield levels in different cereal grain classes.

Appendix IX Table: Highest yielding registered Varieties, and described breeding lines by program source, and by provincial adaptation, relative to check varieties

Province/Area, or Yield Level (AB/BC)	**Crop type**	**Registered Variety Name**	**Breeding Institution**	**% Check**
	Malt or Feed barley			
All MB	Malt barley (2 row) Malt barley (6 row)	Newdale CDC Yorkton	AAFC CDC	107 AC Metcalfe 109 AC Metcalfe
SK Area 1&2	Malt barley (2 row) Malt barley (6 row)	Newdale CDC Laurence	AAFC CDC	112 AC Metcalfe (121) AC Metcalfe
SK Area 3&4	Malt barley (2 row) Malt barley (6 row) Malt barley (6 row)	Newdale CDC Laurence CDC Battleford	AAFC CDC CDC	113 AC Metcalfe (108) AC Metcalfe 108 AC Metcalfe
SK Irrigated	Malt barley (2 row, 6 row)	na	na	na
AB Irrigated	Malt barley (2 row) Malting barley (6 row) Malting barley (6 row) Malting barley (6 row)	Merit Lacey CDC Clyde CDC Battleford	Busch ARI U of Minn. CDC CDC	111 AC Metcalfe (112) AC Metcalfe (116) AC Metcalfe 109 AC Metcalfe
AB Area 1	Malt barley (2 row) Malting barley (2 row) Malting barley (6 row)	Merit Newdale Lacey	BuschARI AAFC U of Minn.	106 AC Metcalfe 105 AC Metcalfe (102) AC Metcalfe
AB Area 2	Malt barley (2 row) Malting barley (6 row)	Calder CDC Battleford	AAFC CDC	106 AC Metcalfe 105 AC Metcalfe
AB Area 3	Malt barley (2 row) Malting barley (6 row)	Calder CDC Clyde	AAFC CDC	105 AC Metcalfe (112) AC Metcalfe
AB Area 4	Malt barley (2 row) Malting barley (6 row)	Calder Lacey	AAFC U of Minn.	104 AC Metcalfe (108) AC Metcalfe
AB Area 5&6	Malt barley (2 row) Malting barley (6 row)	Merit CDC Clyde	BuschARI CDC	111 AC Metcalfe (108) AC Metcalfe
	Feed barley			
All MB	Feed barley (2 row) Feed barley (2 row) Feed barley (6 row)	McLeod CDC Trey AC Rosser	AU/Proven CDC AAFC	110 AC Metcalfe 110 AC Metcalfe 112 AC Metcalfe
SK Area 1&2	Feed barley (2 row) Feed barley (2 row) Feed barley (6 row) Feed barley (6 row)	Xena CDC Coalition Sundre AC Rosser	AU/Proven CDC AAF AAFC	112 AC Metcalfe (117) AC Metcalfe (124) AC Metcalfe 115 AC Metcalfe
SK Area 3&4	Feed barley (2 row) Feed barley (6 row) Feed barley (6 row)	Ponoka Sundre AC Rosser	AAF AAF AAFC	121 AC Metcalfe 115 AC Metcalfe 115 AC Metcalfe
SK Irrigated	Feed barley (2 row, 6 row)	na	na	na
AB Irrigated	Feed barley (2 row) Feed barley (6 row)	Xena Vivar	AU/Proven AAF	116 AC Metcalfe (120) AC Metcalfe
AB Area 1	Feed barley (2 row) Feed barley (6 row)	CDC Bold Trochu	CDC AAF	112 AC Metcalfe 106 AC Metcalfe
AB Area 2	Feed barley (2 row) Feed barley (6 row)	Xena Trochu	AU/Proven AAF	114 AC Metcalfe 107 AC Metcalfe
AB Area 3	Feed barley (2 row) Feed barley (6 row)	Xena Vivar	AU/Proven AAF	112 AC Metcalfe (107) AC Metcalfe
AB Area 4	Feed barley (2 row) Feed barley (6 row)	Xena Sundre	AU/Proven AAF	114 AC Metcalfe (118) AC Metcalfe

Province/Area, **or Yield Level (AB/BC)**	**Crop type**	**Registered** **Variety Name**	**Breeding** **Institution**	**% Check**
AB Area 5&6	Feed barley (2 row) Feed barley (6 row)	Ponoka Sundre	AAF AAF	113 AC Metcalfe (118) AC Metcalfe
	Hulless barley			(NB Hulless yield is about 9-12% < hulled)
All MB	Hulless (2 row) Hulless (6 row)	CDC McGwire AC Bacon	CDC AAFC	100 CDC McGwire 101 CDC McGwire
SK Area 1&2	Hulless (2 row) Hulless (6 row)	CDC McGwire AC Bacon	CDC AAFC	100 CDC McGwire 93 CDC McGwire
SK Area 3&4	Hulless (2 row) Hulless (6 row	CDC McGwire AC Bacon	CDC AAFC	99 CDC McGwire 96 CDC McGwire
SK Irrigated	Hulless (2 row, 6 row)	na	na	na
AB Irrigated	Hulless (6 row)	Tyto	AAF	(91) AC Metcalfe
AB Area 1	Hulless (6 row)	Tyto	AAF	(72) AC Metcalfe
AB Area 2	Hulless (6 row)	Tyto	AAF	(77) AC Metcalfe
AB Area 3	Hulless (6 row)	Tyto	AAF	(89) AC Metcalfe
AB Area 4	Hulless (6 row)	Tyto	AAF	(86) AC Metcalfe
AB Area 5&6	Hulless (6 row)	Tyto	AAF	(81) AC Metcalfe
	Oat, hulled			
All MB	Oat, hulled	Leggett Pinnacle	AAFC AAFC	104 AC Morgan 104 AC Morgan
SK Area 1&2	Oat, hulled	Pinnacle	AAFC	107 AC Morgan
SK Area 3&4	Oat, hulled	Jordan CDC Weaver	AAFC CDC	(115) AC Morgan 108 AC Morgan
SK Irrigated, AB irrigated	Oat, hulled	na	na	na
AB Area 1	Oat, hulled	AC Mustang	AAFC	102 AC Morgan
AB Area 2	Oat, hulled	AC Morgan	AAFC	100 AC Morgan
AB Area 3	Oat, hulled	AC Morgan	AAFC	100 AC Morgan
AB Area 4	Oat, hulled	AC Mustang	AAFC	109 AC Morgan
AB Area 5&6	Oat, hulled	Waldern		102 AC Morgan
	Oat, hulless			
All MB	Oat, hulless	AC Belmont	AAFC	(65 ?) AC Morgan
All SK and AB Areas + Irrig.	Oat, hulless	No data given	No data	No data given
	Fall rye			
All MB	Fall rye	Musketeer	AAFC	108 AC Rifle
SK Area 1&2	Fall rye	Hazlet AC Remington	AAFC AAFC	(118) AC Rifle 107 AC Rifle
SK Area 3	Fall rye	Hazlet Prima	AAFC AAFC	(108) AC Rifle 102 AC Rifle
SK and AB Irrigated	Fall rye	na	na	na
AB Area 1	Fall rye	Dakota	AgricoreUn.	105 AC Rifle
AB Area 2	Fall rye	Dakota	AgricoreUn.	115 AC Rifle

Province/Area, or Yield Level (AB/BC)	Crop type	Registered Variety Name	Breeding Institution	% Check
AB Area 3	Fall rye	na	na	na
AB Area 4	Fall rye	Dakota	AgricoreUn.	126 AC Rifle
AB Area 5&6	Fall rye	Dakota	AgricoreUn.	129 AC Rifle
	Spring rye			
All MB	Spring rye	Gazelle	U of SK	95 (AC Barrie wheat)
SK and AB Areas + Irrig.	Spring rye	No data given	No data	No data given
	CWRS wheat			
All MB	CWRS wheat	CDC Go McKenzie	CDC SWP	111 AC Barrie 110 AC Barrie
SK Area 1&2	CWRS wheat	Superb CDC Alsask	AAFC CDC	107 AC Barrie 107 AC Barrie
SK Area 3&4	CWRS wheat	Superb Infinity	AAFC AAFC	109 AC Barrie 107 AC Barrie
SK Irrigated	CWRS wheat	McKenzie	SWP	109 AC Barrie
AB Irrigated	CWRS wheat	CDC Go	CDC	139 AC Barrie
AB Area 1	CWRS wheat	Lillian	AAFC	148 AC Barrie
AB Area 2	CWRS wheat	Superb	AAFC	116 AC Barrie
AB Area 3	CWRS wheat	Superb Harvest CDC Go	AAFC AAFC CDC	106 AC Barrie 106 AC Barrie 106 AC Barrie
AB Area 4	CWRS wheat	Superb	AAFC	115 AC Barrie
AB Area 5&6	CWRS wheat	CDC Go	CDC	139 AC Barrie
	CPS Red wheat			
All MB	CPS Red wheat	5700PR AC Taber	AgriPro AAFC	113 AC Barrie 113 AC Barrie
SK Area 1&2	CPS Red wheat	AC Foremost AC Taber	AAFC AAFC	121 AC Barrie 120 AC Barrie
SK Area 3&4	CPS Red wheat	AC Foremost AC Taber 5700PR	AAFC AAFC AgriPro	118 AC Barrie 118 AC Barrie 120 AC Barrie
SK Irrigated	CPS Red wheat	AC Taber 5700PR	AAFC AgriPro	116 AC Barrie 115 AC Barrie
AB Irrigated	CPS Red wheat	5701PR	AgriPro	123 AC Barrie
AB Area 1	CPS Red wheat	AC Taber	AAFC	120 AC Barrie
AB Area 2	CPS Red wheat	5700PR 5701PR	AgriPro AgriPro	122 AC Barrie 122 AC Barrie
AB Area 3	CPS Red wheat	5700PR	AgriPro	121 AC Barrie
AB Area 4	CPS Red wheat	5700PR AC Crystal	AgriPro AAFC	123 AC Barrie 123 AC Barrie
AB Area 5&6	CPS Red wheat	5700PR	AgriPro	101 AC Barrie
	CPS White wheat			
All MB	CPS White wheat	AC Vista	AAFC	120 AC Barrie
SK Area 1&2	CPS White wheat	AC Vista	AAFC	122 AC Barrie
SK Area 3&4	CPS White wheat	AC Vista	AAFC	122 AC Barrie
SK Irrigated	CPS White wheat	AC Vista	AAFC	113 AC Barrie

Province/Area, or Yield Level (AB/BC)	**Crop type**	**Registered Variety Name**	**Breeding Institution**	**% Check**
AB Irrigated	CPS White wheat	Snowhite 476	AAFC	122 AC Barrie
AB Area 1	CPS White wheat	Snowhite 476	AAFC	102 AC Barrie
AB Area 2	CPS White wheat	Snowhite 476	AAFC	101 AC Barrie
AB Area 3	CPS White wheat	Snowhite 475	AAFC	95 AC Barrie
AB Area 4	CPS White wheat	Snowhite 476	AAFC	105 AC Barrie
AB Area 5&6	CPS White wheat	Snowhite 476	AAFC	102 AC Barrie
	CWES wheat			
All MB	CWES wheat	Amazon	AAFC	110 AC Barrie
SK Area 1&2	CWES wheat	CDC Rama	AAFC	(107) AC Barrie
SK Area 3&4	CWES wheat	Glenlea	U of Man	109 AC Barrie
SK and AB areas + Irrigated	CWES wheat	na	na	na
	CW Hard white wheat			
All MB	CW Hard white wheat	Snowbird	AAFC	102 AC Barrie
SK Area 1&2	CW Hard white wheat	Snowbird	AAFC	99 AC Barrie
SK Area 3&4	CW Hard white wheat	Snowbird	AAFC	102 AC Barrie
SK Irrigated	CW Hard white wheat	na	na	na
AB Irrigated	CW Hard white wheat	Snowbird	AAFC	114 AC Barrie
AB Area 1	CW Hard white wheat	Snowbird	AAFC	98 AC Barrie
AB Area 2	CW Hard white wheat	Snowbird	AAFC	103 AC Barrie
AB Area 3	CW Hard white wheat	Snowbird	AAFC	105 AC Barrie
AB Area 4	CW Hard white wheat	Snowbird	AAFC	102 AC Barrie
AB Area 5&6	CW Hard white wheat	Snowbird	AAFC	103 AC Barrie
	Soft white spring wheat			
All MB and SK Areas 1 - 4	Soft white spring wheat	na	na	na
SK Irrigated	Soft white spring wheat	AC Andrew	AAFC	125 AC Barrie
AB Area 1 + Irrigated	Soft white spring wheat	AC Andrew	AAFC	135 AC Barrie
AB Areas 2 - 6	Soft white spring wheat	na	na	na
	Durum wheat			
All MB	Durum wheat	Plenty	AAFC	(135) AC Avonlea
SK Area 1&2	Durum wheat	Commander	AAFC	(112) AC Avonlea
SK Area 3&4	Durum wheat	Strongfield	AAFC	105 AC Avonlea
SK Irrigated	Durum wheat	AC Avonlea	AAFC	100 AC Avonlea
AB Irrigated	Durum wheat	Strongfield	AAFC	108 AC Avonlea
AB Area 1	Durum wheat	Strongfield	AAFC	105 AC Avonlea
AB Area 2	Durum wheat	Commander	AAFC	112 AC Avonlea
AB Area 3	Durum wheat	Commander	AAFC	107 AC Avonlea
	Spring triticale			
All MB	Spring triticale	Sandro	SwissFAR	108 Pronghorn
SK Area 1&2	Spring triticale	Sandro AC Alta	SwissFAR AAFC	106 Pronghorn 106 Pronghorn
SK Area 3	Spring triticale	Sandro Pronghorn AC Ultima	SwissFAR AAF AAFC	103 Pronghorn 103 Pronghorn 103 Pronghorn

Province/Area, or Yield Level (AB/BC)	Crop type	Registered Variety Name	Breeding Institution	% Check
SK Irrigated	Spring triticale	na	na	na
AB Irrigated	Spring triticale	AC Ultima	AAFC	137 AC Barrie wh.
AB Area 1	Spring triticale	AC Ultima	AAFC	137 AC Barrie wh.
AB Area 2	Spring triticale	AC Alta	AAFC	134 AC Barrie wh.
AB Area 3	Spring triticale	AC Ultima	AAFC	135 AC Barrie wh.
AB Area 4	Spring triticale	AC Ultima	AAFC	133 AC Barrie wh.
AB Area 5&6	Spring triticale	AC Ultima	AAFC	130 AC Barrie wh.
	Winter wheat			
All MB	Winter wheat	CDC Harrier	CDC	102 CDC Falcon
SK Area 1&2	Winter wheat	CDC Harrier CDC Kestrel	CDC CDC	104 CDC Falcon 103 CDC Falcon
SK Area 3&4	Winter wheat	CDC Kestrel CDC Raptor CDC Clair	CDC CDC CDC	106 CDC Falcon 105 CDC Falcon 105 CDC Falcon
SK Irrigated	Winter wheat	CDC Falcon	CDC	100 CDC Falcon
AB Irrigated	Winter wheat	CDC Harrier	CDC	110 CDC Falcon
AB Area 1	Winter wheat	CDC Harrier	CDC	104 CDC Falcon
AB Area 2	Winter wheat	CDC Harrier CDC Clair	CDC CDC	111 CDC Falcon 111 CDC Falcon
AB Area 3	Winter wheat	na	na	na
AB Area 4	Winter wheat	CDC Clair	CDC	107 CDC Falcon
AB Area 5&6	Winter wheat	AC Bellatrix	AAFC	109 CDC Osprey

<u>Appendix X University of Manitoba Wheat Research Program, Dr. A. L. Brûlé-Babel, April 2007</u>

1) Hard Red Winter Wheat Cultivar Development

The main objective of the winter wheat breeding program is to develop disease resistant, semi-dwarf, high yielding, cold hardy, hard red winter wheat cultivars that are suited to the higher moisture regions of the eastern prairies. Dr. Lamari and Dr. Fernando are collaborators on this program. Diseases of main concern are stem and leaf rust, leaf spotting diseases such as tan spot and Septoria leaf blotch, and Fusarium Head Blight.

The breeding program contains a continuum of material from the most advanced lines in the cooperative testing system to crosses that are currently being made. The most advanced materials have stem and leaf rust resistance, short strong straw, good winter survival, and good agronomic traits. Field nurseries are conducted annually to evaluate stem and leaf rust resistance and winter hardiness. Replicated field trials are conducted to determine the agronomic performance of more advanced lines. Replicated field trials are also conducted for the Central Winter Wheat Coop, the Western Winter Wheat Coop and the Regional evaluation trial for MCVET.

We also conduct rust nursery testing for Dr. Rob Graf, a winter wheat breeder, from the Lethbridge Research Centre – AAFC.

2) Germplasm Development

Funds administered by the Western Grains Research Foundation from the Canadian Wheat Board wheat check-off have been provided for germplasm development of leaf spot resistant spring wheat. This work involves evaluation of materials for tan spot and Septoria tritici blotch resistance. Large mapping populations are being screened for these diseases in preparation of further research in mapping resistance genes.

3) Disease resistance in spring and winter wheat.

Incorporation of disease resistance is a major objective of the breeding program. Therefore, research into host resistance to pathogens is a primary focus of my research. The identification of genetic sources of resistance, incorporation of resistance genes into adapted winter wheat backgrounds, and research into the genetic control and expression of identified sources of resistance form the basis of this work. To date, the main diseases of interest have been leaf and stem rust, tan spot and Septoria leaf blotch. Dr. Lamari has been a key collaborator for the tan spot and Septoria leaf blotch work.

One of the major projects in this area is the mapping of Septoria tritici blotch resistance genes. In 2005, we successfully mapped two resistance genes, Stb13 and and Stb14. Stb13 confers resistance to both race 1 and race 2 isolates of *Mycosphaerella graminicola* while Stb14 confers resistance to only race 2 isolates. These genes appear to be unique and distinct from other genes reported in the literature. Further work in this area is underway through my NSERC discovery grant. In 2006 a new graduate student (Mr. Richard Cuthbert) began screening additional mapping populations for a durum wheat cross that carried two FHB resistance genes. We also developed a larger mapping population and began screening the population to try to identify the third resistance gene in Salamouni. We also plan to develop fine maps of Stb13 and Stb14.

Fusarium Head Blight (FHB) is a serious residue-borne disease of wheat. Very little work has been conducted in western Canada on FHB resistance in winter wheat. In 2006 we screened several “new” sources of FHB resistance for potential incorporation into the breeding program. We also evaluated the FHB resistance of winter wheat doubled haploids from crosses between FHB resistance germplasm and our adapted material. Resistance doubled haploids were backcrossed to the adapted parent to ensure reconstitution of desirable agronomic and end-use quality characteristics. Doubled haploid production was conducted on some of the backcrossed materials. This project is ongoing and is being expanded to address the research objectives of the NSERC/Husky Energy Inc. initiative in Biofuels research.

In addition to the existing work on FHB we have initiated work related to a Canadian-German collaboration in plant genomics related to FHB. This involves haplotyping winter wheat germplasm, identification of new sources of resistance, introgression of new resistance genes into adapted winter wheat backgrounds and mapping of new sources of resistance. An ARDI application to fund this work has been successful.

4) Herbicide resistance in weeds.

The discovery of wild oat populations that are resistant to herbicides in three or four different herbicide groups renewed interest in the study of herbicide resistance in weeds. As a result, I worked in collaboration with Dr. Van Acker. My role in the project was to examine the inheritance of herbicide resistance in wild oat populations that are resistant to multiple herbicide groups and to determine the genetic relationships among multiple herbicide resistant wild oat populations collected throughout Manitoba. This work was conducted through an MSc project conducted by Ms. Jocelyn Karlowsky. Ms. Karlowsky completed her MSc in 2004 and was published in 2006. Ms. Karlowsky’s research led to some significant discoveries. She found that resistance to each of the three herbicides in the wild oat populations was controlled by different genes. A single partially dominant gene conferred resistance to each of the herbicides. Linkage between the resistance genes explained how resistance to multiple herbicides occurred in the populations of wild oat even when only one of the three herbicides had been applied to the population.

As part of my ongoing work in modelling herbicide resistance, I prepared and published a manuscript to Crop Science reviewing the effect of gene flow of GE traits in crop populations.

5) Fusarium Head Blight Screening Nursery

In 2000, a permanent FHB screening nursery was established at the Carman research station to evaluate the FHB reaction of coop lines and advanced breeding lines from all breeding programs in western Canada. I am the main coordinator of this nursery and work in collaboration with Dr. Fernando and Dr. Gilbert to provide much needed data to breeders. Roger Larios is the main technician involved in this work. In 2006 we conducted the sixth year of this nursery. Approximately 13000 plots were evaluated. This nursery has proven to be a valuable resource for western Canada.

6) Crop rotation as a viable management strategy for Fusarium head blight of wheat.

This project is an extension of a project that received approval for funding from ARDI in 2001. It is a collaboration lead by Dr. Fernando and Dr. Gilbert (see list of grants above). The main objectives of this project are to investigate the epidemiology of the FHB, and to assess the effect of different crop rotations and management strategies on FHB. In 2006 we completed another year of the rotation studies and completed epidemiological studies.

7) Development of hard white spring wheat with superior pre-harvest sprouting resistance through new genetic sources and molecular markers.

This is a joint project with Dr. Humphreys and Dr. Somers. The objectives of this project are to identify and evaluate new sources of pre-harvest sprouting resistance in a range of white seeded wheat lines and to evaluate pre-harvest sprouting in two mapping populations to identify QTL associated with pre-harvest resistance. This project is being conducted through an MSc student project conducted by Mr. Golam Rasul. I co-supervise Mr. Rasul with Dr. Humphreys. In 2006 the final laboratory data were collected and Mr. Rasul began writing his thesis.

8) Innovation in biofuels research

This project was initiated in 2006 through an NSERC/Husky Energy CRD grant. The overall objective of the project is to develop high yielding, disease resistant winter wheat cultivars for specific end use in the ethanol industry, adapted for production in the higher moisture regions of the prairies. This will ensure that producers can produce grain profitably and provide a consistent supply of good quality feedstock for the ethanol industry. New technologies in tissue culture and molecular genetics will be applied to enhance traditional breeding efforts and to explore novel manipulations of physiological processes that can enhance grain yield and fermentable products for ethanol production. Well adapted, disease resistant germplasm from the existing breeding program will be used as the foundation for adapted traits. The traditional breeding approaches will lead to a yield increase of 5% in the short term and a 15% yield increase in the mid-term. Incorporation of knowledge gained from physiological manipulations has the potential to increase yields beyond 15% in the long term.

Appendix XI University of Saskatchewan Winter wheat breeding report (Dr. Brian Fowler Program. Note that this program is no longer within the current CDC mandate, because of withdrawal of SADF funds several years ago)

Crop Development Centre
Canadian Western Red Winter Wheat Breeding Program

Brian Fowler

April 3, 2007

Objective

The over-all objective of this program has been to develop winter hardy, agronomically adapted, high yielding, drought tolerant, disease resistant, high quality winter wheat cultivars for use in conservation production systems designed for the central and eastern prairies. Specifically, the program has placed significant emphasis on the development of strong-strawed high yielding semidwarf lines adapted to higher moisture growth conditions and agronomically superior standard height cultivars with acceptable quality and winter hardiness for lower moisture environments. Collaborative molecular genetics research is aimed at identifying specific genes associated with low-temperature tolerance with the ultimate objective of manipulating the expression of those genes to further increase winter hardiness.

Background

In the past several years, the CDC winter wheat breeding program has acquired an excellent database for most agronomic and disease characters under selection. This has allowed for heavy culling in our doubled haploid and conventional breeding programs and 577, 336, and 13 superior lines were identified and moved forward into advanced, pre-coop, and cooperative trials, respectively, for further evaluation in 2005-06.

However, the impact of KVD requirements has been to render all recent winter wheat breeding efforts in the western Canada irrelevant by creating an impenetrable barrier that has prevented further evaluation in collaborative trials and the release of improved winter wheat cultivars. These limitations and other concerns have been addressed by the winter wheat breeders in western Canada and motions with supporting data have been put forward to the Wheat, Rye and Triticale (WRT) subcommittee on 1) winter wheat quality types, 2) KVD, 3) composite samples, and 4) disease reaction.

Progress 05-06

Collaborative molecular genetics research, which is part of the large scale Genome Canada III project on the “Functional genomics of abiotic stress in crops”, has identified and mapped the superior cold-hardiness

QTL in winter wheat. Low-temperature tolerance determinations on winter wheat breeding lines for comparison of marker assisted breeding (MAB) and conventional breeding are also in progress as part of this project.

The high stress winter of 2003-04 allowed us to clearly identify entries with superior winter hardiness and a good spread in the disease nursery in 2004 permitted heavy culling for rust resistance in our advanced winter wheat lines before they went in the ground in the fall of 2004. Favorable growing season weather conditions in both 2003 and 2004 facilitated selection for straw strength, grain yield and other agronomic characters. A cool damp summer, slow maturing spring crops, and a late wet harvest meant that the commercial seeding intentions for winter wheat were delayed and greatly reduced in the fall of 2004, especially in the eastern prairies. The adverse fall seeding conditions had less of an impact on our breeding program and the usual August/September push was successful in ensuring that selected lines made it back into the ground. Even though some of our trials were planted under less than optimum conditions, excellent winter survival followed by favorable spring and summer growing conditions provided an effective screen for plant height and straw strength and better than average grain yields were realized in our 2005 nurseries. Based on the data collected on advanced lines over the last several years; 577, 336, and 13 superior lines were moved forward into advanced, pre-coop, and cooperative trials, respectively, for further evaluation in 2005-06.

Progress 06-07

Two lines were brought to the Recommending Committee in February 2007 for consideration for recommendation.

DH99-37-100 CHRW, showing yield of 118% of CDC Osprey (the grain quality check) and 107% of CDC Falcon , winterhardiness better than CDC Falcon, and good straw strength, was rejected on the basis of not meeting KVD requirements.

S86-375, also known as CDC Ptarmigan, with yields of 109% of CDC Kestrel and 116% of Norstar, showing short straw and strong straw strength, lower protein than CDC Kestrel and Norstar, and 2% higher starch content than current dominant hard red winter wheat cultivars, was recommended for registration by the Committee.

Currently there are approximately 500 lines in pre-coop screening trials, and 22 lines in the Central Coop Trial.

Work Plan 2007

The HRW program at the University of Saskatchewan is currently under review. A decision must be made in 2007 as to whether to continue or close this program. Resources are currently a limiting factor, and the Principal Investigator, Dr. Brian Fowler, is close to retirement. The CDC is in process of consultation with stakeholders and funding agencies on this subject.