# Crop Genetic Improvement:
# Genetics, Plant Breeding and Pathology
## Crop Development Centre
## University of Saskatchewan
## Strategic Research Program
## 2013-2018

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**1. Introduction**

Crop production is the basis for all agriculture. About $8 billion of farm cash receipts in Saskatchewan in 2011 were derived directly from the sale of crops, whereas the livestock industry accounted for $1.7 billion or 16% of total farm cash receipts. The total cropping area was 14.7 million ha. Saskatchewan accounts for 47% of the arable cropland in Canada and is a major producer, processor and exporter of wheat, durum, barley, oat, flax, chickpea, lentil, pea, canola, canaryseed, and mustard.

The Crop Development Centre (CDC) provides genetic research and breeding platforms for developing improved crop varieties of most of the major crop kinds and classes grown that are important to Saskatchewan and western Canadian farm and industry stakeholders. The CDC has been undertaking this role since 1971 and has a significant track record, releasing over 390 crop varieties and developing significant new crop kinds in that time period, thereby materially contributing to farm and industry diversification, sustainability, and profitability.
The CDC Mission Statement is:

**The Crop Development Centre is a field crop research organization which seeks to increase the diversification of crops and their products by improving existing crops, creating new uses for traditional crops and introducing new crops**

From 2013-2018, the CDC Strategic Research Program (SRP) will allow CDC scientists to focus on improving the agronomic and the food and nutritional quality characteristics of pulse crops, cereals and flax for food, feed, and industrial uses. Tied to this objective is diversification within these crops to allow for development of new crop kinds, specialty varieties and market classes that add value and provide the basis for value added processing and marketing to specialty end-users. The CDC recognizes that even with significant success in developing new crop kinds such as spelt and pigmented wheat, traditional field crops (cereals, pulses, and oilseed) will continue to dominate the arable landscape of the province, thus research aimed at the major market classes will also constitute the majority of research effort.

Plant diseases are a serious constraint to crop production in Saskatchewan and, as a result, CDC plant breeding programs place a high priority on breeding for disease resistance. Genetic resistance to diseases improves crop yield and quality, reduces the cost of production by reducing the application of chemical fungicides, minimizes production risk and contributes to long-term economic and environmental sustainability. The current complement of one plant pathologist for cereals and flax and one for pulse crops is providing scientific support to the breeding programs.

All CDC breeding programs are utilizing genomic tools to facilitate the development and deployment of agronomic and quality traits into their germplasm to accelerate the development of improved varieties. Funding from a variety of sources and collaborations with national and international institutions provide the financial and technical resources for developing genomic tools.

## 2. CDC Overall Strategic Goal

CDC's long term strategic goal is to increase the profitability and sustainability of crop production in Saskatchewan by utilizing the relevant leading-edge scientific and technological tools to develop new and improved crop varieties, and contribute to the provincial government's objective of increasing crop production by 10 million tonnes, an increase of 38% from the 2012 production output of 26.6 million tonnes.

## 3. General Research and Program Activities 2013-2018

### 3.1 Plant Breeders

- Crop breeding with general breeding objectives to improve agronomic traits – disease and insect resistance, earlier maturity, resistance to lodging and shattering, enhanced yield potential, improved stress tolerance.
- Crop breeding with general breeding objectives to improve quality traits – to enhance levels of desirable macro and micronutrients in the seed, reduce levels of undesirable quality factors and modify chemical composition to develop new uses for crops and crop components.
- Introduction and evaluation of new and unique germplasm.
- Development and/or evaluation of new plant breeding populations and biotechnology methods and equipment that are highly relevant to crop breeding.
- Collaboration with scientists at the University of Saskatchewan and other scientific institutions, where appropriate, in basic scientific research and plant breeding programs.
- Collaboration in technology transfer in crop management and variety commercialization to the Saskatchewan and Canadian industry.
- Participation in scholarly activities related to scientific advancement, scientific publication, and training of new scientists.
- Participation in industry committees and advisory boards where applicable and appropriate.
- Investigation of new funding opportunities and management of existing funding including reporting requirements.
- Teaching of undergraduate and grade courses as appropriate.

### 3.2 Plant Pathologists

- Research to gain a better understanding of disease biology, pathogenic variation, disease epidemiology and pathogen-host relationships.
- Identification of new and suitable sources of resistance for use in the CDC plant breeding programs.
- Screening of CDC breeding material for disease resistance.
- Development and refinement of integrated disease management strategies, including fungicide timing and rotation studies.
- Collaboration with scientists at the University of Saskatchewan and other scientific institutions, where appropriate, including the provincial disease specialist, in basic scientific research, disease surveillance and plant breeding programs.
- Collaboration in technology transfer in crop management and variety commercialization to the Saskatchewan and Canadian industry.
- Participation in scholarly activities related to scientific advancement, scientific publication, and training of new scientists.
- Participation in industry committees and advisory boards where applicable and appropriate.
- Investigation of new funding opportunities and management of existing funding including reporting requirements.
- Teaching undergraduate and graduate courses.

## 4. Specific Research and Program Objectives by Crop Kind and Class 2013-2018

### 4.1 Pulse Crops

- Evaluate potential for other pulse crops.

#### 4.1.1 Field Pea

- Develop early maturing, high yielding yellow, green and specialty market class field pea cultivars with resistance to powdery mildew, mycosphaerella blight and new and emerging diseases, as well as resistance to lodging and improved quality for export and domestic markets. Disease resistance work will be conducted in collaboration with the CDC Pulse Pathologist, as well as with national and international collaborators.

- Research to identify pea germplasm with enhanced resistance to abiotic stresses such as heat, drought, cold, and flooding.

- Crop quality research to improve the value of field pea in terms of visual appearance, proximate analysis, density of micronutrients and secondary metabolites, flavour profile, and functional properties including milling and cooking.

- Development of genomic tools including high density genetic maps, whole genome sequence, and effective and efficient molecular markers for use in marker assisted selection for key traits of interest in breeding.

### 4.1.2 Soybean

- In collaboration with other interested parties, develop extra-early maturing soybean cultivars for Saskatchewan and western Canada.
- Conduct variety and agronomic research to improve the adaptation of extra-early maturing soybean germplasm for Saskatchewan.

### 4.1.3 Chickpea

- *Chickpea breeding is supervised by Dr. Bunyamin Taran, who is the Agri-Food Innovation Fund (AFIF) Chair.*
- Develop high yielding chickpea cultivars with improved resistance to ascochyta blight and new and emerging diseases, early maturity and acceptable visual seed quality characteristics for export and domestic markets. Disease resistance work will be conducted in collaboration with the CDC Pulse Pathologist.
- Develop herbicide tolerance.
- Examine and apply where appropriate genomic/molecular breeding platform.
- Explore the potential for improvement of nutritional profile.

Kabuli chickpea specific objectives:

- Develop cultivars with improved seed size, acceptable visual seed characteristics and canning/cooking quality.
- Develop specialty kabuli chickpeas for niche markets.

Desi chickpea specific objectives:

- Develop cultivars with acceptable visual seed characteristics (shape, size, and colour) and acceptable dehulling and milling quality.
- Develop specialty desi chickpeas for niche markets.

### 4.1.4 Lentil

- *Lentil breeding is being supervised by Dr. Bert Vandenberg of the CDC, as an Industry Research Chair funded by NSERC and Saskatchewan Pulse Growers.*
- Genetic improvement of yield, adaptation, lodging tolerance, and herbicide tolerance.
- Genetic improvement of biotic stresses including resistance to ascochyta blight, anthracnose, stemphylium blight, and other emerging pathogens in all commercial market classes of green, red and specialty lentil classes. Disease resistance work will be conducted in collaboration with the CDC Pulse Pathologist.
- Genetic improvement of culinary, physical and nutritional quality traits appropriate for specific lentil market classes in global markets.
- Develop and apply where appropriate genomic/molecular breeding and rapid generation advance technologies.
- Develop appropriate genetic resources for use in future lentil crop improvement strategies.

### 4.1.5 Faba Bean

- *Faba bean breeding is being co-supervised by Dr. Bert Vandenberg and Dr. Kirsten Bett under the Pulse Crop Breeding program at the CDC and funded by the Saskatchewan Pulse Growers.*
- Genetic improvement of yield, adaptation, early maturity, lodging tolerance and culinary, physical and nutritional quality traits of non-traditional small-seeded faba beans and large-seeded food type faba beans for global markets.
- Develop a breeding strategy for development of low vicine/ convicine faba beans.
- Investigation of nitrogen fixation capability in farm rotations.
- With global partners, develop molecular breeding capability and rapid generation technologies.

### 4.1.6 Dry Bean

- *Dry Bean breeding is being supervised by Dr. Kirstin Bett from the Dept. of Plant Sciences as an integral part of the Pulse Crop Breeding program at the CDC.*
- Genetic improvement of yield, adaptation, early maturity with Type II growth habit, high pod clearance, cold tolerance as well as resistance to common bacterial blight, anthracnose and other emerging pathogens. Emphasis will remain on pinto, black, and yellow bean but will include others based on commercial interest.
- Disease resistance work will be conducted in collaboration with the CDC Pulse Pathologist.
- Genetic improvement of culinary, physical and nutritional quality traits that are specific to each market class.
- Development and use of molecular markers for traits such as disease resistance (common bacterial blight and anthracnose) as well as seed coat quality traits (colour and colour retention).
- Development of additional genomic tools for more reliable marker screening for various traits of interest. A lot of this work is done in collaboration with American collaborators and colleagues at the University of Guelph.
- Studies into the use of tepary bean as a source of biotic and abiotic stress tolerance for dry bean via interspecies hybridization. Exploration of the possibility of developing tepary bean as a possible substitute for dry bean in more marginal areas.

### 4.1.7 Pulse Pathology

- Support efforts in continuously improving resistance to the major diseases, in developing varieties with resistance to the secondary diseases, and in screening for resistance to potentially new diseases.
- Monitor changes in pathogen populations in order to develop suitable screening protocols for disease resistance screening, and adapt disease management strategies accordingly.
- Investigate the biology of newly emerging diseases with the objective to support breeding efforts, assess the economic importance of these diseases and lay the foundation for further research into disease management strategies, if required.

- Research the host-pathogen interactions in pulse crops to gain a better understanding on how resistance in pulse crops function and why it can break down.
- Develop disease management strategies for pathogens of economic importance in Saskatchewan.

**4.2 Flax**

- Develop varieties with improved agronomic traits, including yield, earlier maturity, larger seed size, disease resistance, and quality. Disease resistance investigations will be carried out in collaboration with the CDC Cereal and Flax Pathologist.
- Genetics and molecular breeding – continue development of genomic tools in conjunction with other partners. Begin using molecular markers and other genomics-based technologies for faster trait incorporation or stacking in the breeding program.

Commodity type oilseed flax

- Provide continuous genetic improvement in commodity flax varieties.
- Obtain and evaluate novel germplasm to generate new sources of variation for northern adapted linseed and other varieties.
- Continue development and testing of breeding methodologies for selection of straw and seed yield in oilseed flax. Explore the potential of dual-use (fibre and oilseed) flax types.

Specialty oilseed flax, functional food / nutraceuticals / biofortification

- Develop yellow linseed varieties for the human and animal consumption market.
- Investigate different fatty acid profiles in oilseed flax (linseed) and initiate variety development when feasible from a market perspective.
- In conjunction with other partners, investigate and understand characteristics such as seed size, seed coat colour, fibre, lignans, mucilage, oils and other factors of flaxseed, their inheritance and selectability. Develop knowledge of lines, molecular markers, alleles and genes associated with these traits to enable their rapid incorporation into elite lines to meet changing market demands.
- Explore variation in cyanogenic glycoside levels in flaxseed and investigate their inheritance and selectability.

**4.3 Spring Wheat**

- Develop Canada Western Red Spring (CWRS) and Canada Western Hard Wheat (CWHW) wheat cultivars adapted to Saskatchewan and adjoining regions with improved yield-maturity relationships, quality and disease resistance.
- Develop shorter-strawed, medium maturity varieties.
- Incorporate new sources of disease and insect resistance into the existing CDC germplasm base. Incorporate and evaluate new and existing sources of fusarium head blight, stripe rust and wheat midge resistance. Disease resistance investigations will be carried out in collaboration with the CDC Cereal Pathologist.
- Investigate, develop and utilize molecular breeding techniques where applicable and appropriate.

### 4.4 Specialty wheat and Canaryseed

- Introduce and evaluate unique wheat germplasm for alternate end-use suitability and adaptation to Saskatchewan growing conditions.
- Develop specialty wheat and canaryseed cultivars adapted to Saskatchewan and adjoining regions with improved yield-maturity relationships and quality characteristics that enhance marketability.
- Specific objectives will vary with each species depending upon the major agronomic and quality constraints.

### 4.5 High yielding wheat

- Develop red-seeded high yielding wheat cultivars adapted to Saskatchewan with milling grade quality (medium protein, acceptable gluten strength, superior flour colour) with acceptable maturity, and improved disease resistance (particularly fusarium head blight resistance). Disease resistance investigations will be carried out in collaboration with the CDC Cereal Pathologist;
- Continue incorporation of leaf, stripe and stem rust resistance, and resistance to fusarium head blight into high yielding wheat genetic backgrounds;
- Develop General purpose wheat cultivars with lower protein (2% lower than current CWRS varieties) and yield potential similar to AC Andrew soft wheat, but earlier maturity for production in the high rain-fed regions of Saskatchewan. Improvement of pre-harvest sprouting resistance will also be a priority;
- Develop and utilize molecular/genomic strategies to improve selection efficiency through marker assisted selection and novel strategies (genomic selection).

### 4.6 Durum wheat

- Develop low cadmium uptake durum wheat cultivars adapted to Saskatchewan with high grain yield potential, appropriate maturity, superior end-use and nutritional qualities, and acceptable disease resistance. Improvement of pre-harvest sprouting resistance will continue.
- Develop durum cultivars with extra-strong gluten properties for production in traditional durum growing regions and under irrigation production.
- Develop durum wheat cultivars with improved pest resistance, with emphasis on leaf, stem and stripe rust and leaf spotting diseases and the wheat stem sawfly (western Saskatchewan), and Fusarium head blight and midge resistance (eastern prairies). Disease resistance investigations will be carried out in collaboration with the CDC Cereal Pathologist.
- Develop and utilize molecular/genomic strategies to improve selection efficiency through marker assisted selection and other novel strategies (genomic selection).

### 4.7 Malt, Food, Feed and Forage Barley

- Focus on two row malt barley. Feed barley breeding will continue at a gradually decreasing rate. Small opportunistic programs will continue in barley for feed, annual forage and hulless barley as a food and malt crop.

- Develop improved cultivars to maximize and diversify barley productivity in western Canada, and to maximize the marketability and value of western Canadian barley in domestic and export markets.
- Improvements will include agronomic traits (e.g. yield, maturity, lodging and shattering resistance, and improved stress tolerance) and quality traits (e.g. test weight, grain plumpness, colour, peeling and sprouting resistance, malting quality; for hulless barley: malt quality, food quality, maximizing threshability, minimizing embryo damage, improving protein content, manipulating viscosity and β-glucan, lowering phytate, and developing specialty starch food types). Disease resistance investigations will be carried out in collaboration with the CDC Cereal Pathologist.
- Develop and utilize improved breeding methods including marker-assisted selection, genomic selection and other molecular tools where appropriate.

**4.8 Milling and Feed Oat**

- Focus primarily on milling oats, including high dietary fibre food oat and other specialty food oats as opportunities arise.
- Feed oat including low acid detergent lignin hull, high groat fat (LLH-HOG) oat and annual forage oat for ruminants.
- Develop improved varieties and management practices for Saskatchewan oat to maximize value and marketability in export and domestic markets.
- Develop improved oat varieties adapted to Saskatchewan with high grain yield potential, appropriate maturity, acceptable straw strength and adequate levels of disease resistance (rust, smut, Barley Yellow Dwarf Virus, BYDV), 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 acid detergent lignin content and groat breakage and combining low acid detergent lignin hull with high groat fat. Internal chemical quality factors such as protein, oil fat and β-glucan (dietary fibre) content are to be maintained at optimal levels. Disease resistance investigations will be carried out in collaboration with the CDC Cereal Pathologist.
- Develop and utilize improved breeding methods including marker-assisted selection, genomic selection and other molecular tools where appropriate.

**4.9 Cereal and Flax Pathology**

- The overall objective of the cereal and flax pathology program is to advance knowledge of host-pathogen genetic interactions and integrated disease management, and to apply this information in the development of cereal and flax cultivars, and as a basis for best management practices for production of these crops in Saskatchewan and western Canada.

**Specific objectives**

- Support breeding efforts to improve or maintain host resistance to the major diseases, improve resistance to the secondary diseases, and to identify resistance to potentially new diseases.

- Identify sources of resistance, study the inheritance of host resistance, and transfer resistance into elite germplasm.
- Assess virulence variability in pathogen populations, and monitor virulence over time to ensure the deployment of effective resistance genes.
- Investigate the economic importance of new diseases, study the epidemiology, investigate control measures, and develop protocols for germplasm screening.
- Study the genetic basis of host-pathogen interactions with the goal of understanding plant pathogenesis and developing cultivars with durable disease resistance.
- Develop integrated disease management strategies (cultural and chemical, as well as varietal resistance) for pathogens of economic importance in Saskatchewan.
- Contribute to the surveillance of existing pathogens and identify new pathogens as they arise in Saskatchewan.

## 5. Program Outputs

### 5.1 Program Outputs for Plant Breeders

- New crop cultivars with improved agronomic and quality traits.
- Greater understanding of crop genetics.
- Molecular marker assisted selection (MMAS) and other molecular breeding tools for key traits in the crop where appropriate and applicable.
- Scientific and peer reviewed manuscripts.
- Outreach and technology transfer activities through presentations at producer meetings and scientific conferences.
- Involvement in training of new scientists.
- Undergraduate and graduate student supervision.
- Teaching of undergraduate and graduate level courses, as assigned.

### 5.2 Program Outputs for Plant Pathologists

- Contribute to the development of new crop cultivars with improved disease resistance.
- Greater understanding of disease biology, pathogenic variation, disease epidemiology and pathogen-host relationships.
- Selection strategies and techniques for use in breeding resistance to existing and emerging disease threats to pulses, flax and cereals.
- Contribute to molecular marker development for key diseases in relevant crops.
- Scientific and peer reviewed manuscripts.
- Outreach and technology transfer activities through presentations at producer meetings and scientific conferences.
- Scholarly activities including scientific publications and presentations.
- Undergraduate and graduate student supervision.
- Teaching of undergraduate and graduate level courses, as assigned.
- Contribute to provincial disease surveys where appropriate.

## 6. Program Outcomes

### 6.1 Program Outcomes for Plant Breeders

- Increased economic activity within Saskatchewan through continued release of cereal, flax and pulse crop varieties.

- Enhanced crop productivity and reduced crop production costs and risk.
- Increased demand for Saskatchewan grains in export markets
- Profitable crop and livestock production and increased value-added processing within the province.
- Greater diversification of crop kinds, specialty varieties, market classes and quality profiles to expand domestic and export market opportunities.

**6.2 Program Outcomes for Plant Pathologists**

- Increased profitability and sustainability of crop production in Saskatchewan.
- Enhanced crop productivity and reduced crop production costs and risk.
- Enhanced understanding of the major diseases affecting pulse, flax and cereal crops.
- Integrated disease management approaches to pulse, flax and cereal disease mitigation in Saskatchewan.