Canadian Field Crop Genetics Improvement Cluster
Summary Report

Growing Forward 2 - AgriInnovation Program (2013-2018)

CFCRA
CANADIAN FIELD CROP RESEARCH ALLIANCE

ARCCC
ALLIANCE DE RECHERCHE SUR LES CULTURES COMMERCIALES DU CANADA

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Growing Forward | Cultivons l'avenir

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* Project 1 was a *Project Management* Activity and does not appear in this report, as there are no research results associated with this activity.

Message from the President
Salah Zoghlami, Producteurs de grains du Québec

I am very proud to present the results of the Canadian Field Crop Genetics Improvement Cluster. This report highlights the results of 12 Canadian Field Crop Research Alliance (CFCRA) research activities completed from 2013-2018 on Canadian soybean and corn, and eastern Canadian barley and oat.

"Every project has succeeded in expanding the opportunities available to Canadian farmers."

Canadian agriculture relies on plant breeding to drive innovation and address the needs of field crop growers across the country, to provide the tools and technology to keep our industry competitive in domestic and global markets.

The body of research covered through the CFCRA program has addressed challenges and opened new opportunities in field crop research. Using genomic selection, we've made advances in plant breeding for disease tolerance, end use markets and overall nutritional profile.

Every project has succeeded in expanding the opportunities available to Canadian farmers for soybean, barley, oat, wheat and corn. When we can provide new varieties, faster, we are responding to the needs of growers so they can take advantage of new crop options, better performing varieties and new market opportunities.

The team of CFCRA researchers have discovered genetics for improved FHB tolerance and SCN resistance, bred new food grade soybeans to feed export markets, developed new soybean varieties adapted to shorter growing regions, and bred several new barley and oat varieties.

The true benefits of this work will be realized by Canadian farmers who will gain access to new genetics and market opportunities to help keep our industry innovative, responsive and competitive in a global market.

The overall goal of the CFCRA program was to advance genetics and open new opportunities for growers and the Canadian field crop industry. Along the way, some unexpected and exciting outcomes occurred – collaboration and the ability to leverage this research into future funding opportunities.

On the collaboration front, several of the projects involved multiple disciplines working in various parts of the country. As a result, a national corn research network has been established, bringing researchers, private and public programs and institutions together to share new information. There is also the prospect of a new barley breeding program in eastern Canada, based on research done to boost the value of this crop.

Research is a continuous process, and some of the CFCRA soybean researchers successfully leveraged their genetic advancements in this program to secure funding through Genome Canada for the Soyagen project. This highlights the quality of work and the benefits of collaboration between researchers, for a common goal of advancing opportunities for the Canadian soybean industry. Many of the researchers will be continuing their work through new *Canadian Agricultural Partnership (CAP)* funding to continue advancing field crop genetics across Canada.

Executive Summary

Plant breeding research has driven Canada's agricultural sector to become a leader in field crop productivity and innovation.

> $10.3 million research investment to develop and release improved barley, oat, and soybean varieties, and corn inbreds.

For the period of 2013-2018, the Canadian Field Crop Genetics Improvement Cluster facilitated 12 research projects covering soybean and corn across Canada, and eastern Canadian barley and oat. The Cluster is a collaboration between the Canadian Field Crop Research Alliance (CFCRA) and Agriculture and Agri-Food Canada (AAFC) under the *Growing Forward 2 (GF2)* Cluster program.

This research initiative brought together researchers from across the country to advance the genetic capacity of field crops in Canada. The goal of this five-year, $10.3 million research investment was to develop and release improved barley, soybean and oat varieties, and corn inbreds desired by Canadian farmers and the value chains they serve.

Each research project was selected with Canadian farmers in mind, to deliver high yielding, disease-resistant varieties, lines with enhanced processing and health quality characteristics, soybean and corn lines adapted to short-season growing regions, and the development of advanced selection tools to improve breeding efficiency and effectiveness.

Research efforts of the Canadian Field Crop Genetics Improvement Cluster resulted in:

- 8 new barley varieties
- 24 new corn inbreds
- 9 new oat varieties
- 42 new soybean varieties

These new field crop varieties and genetics are now available to the Canadian industry.

Barley
Genetic research conducted through the Cluster promised to deliver new varieties to eastern Canadian growers and accelerate the advancement of barley breeding methods. Eight new barley varieties were developed and released for grower use through the Cluster research.

Fusarium head blight (FHB) is a major disease threatening barley in eastern Canada. Traditionally, plant breeders have had limited success finding barley germplasm with FHB resistance.

Research conducted through the Cluster focused on breeding improved FHB tolerance in barley using *in vitro* and genomic selection. Early data from these projects suggests the genomic selection model will provide a good basis to select future FHB-resistant barley lines.

> Research efforts of the Canadian Field Crop Genetics Improvement Cluster resulted in 8 new barley varieties, 24 new corn inbreds, 9 new oat varieties and 42 new soybean varieties.

Corn
Corn research conducted through the Cluster was designed to drive continuous improvements in the rate of advances in corn genetics and improve response time to grower needs by developing novel adapted corn germplasm for the seed corn industry to incorporate into their corn hybrid breeding programs.

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Executive Summary, continued

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Through this research project, a national corn research network was established that will create new opportunities for information sharing and expand the corn growing regions across Canada.

> Eight new barley varieties were developed and released for grower use through the Cluster research.

Twenty four new corn inbreds were developed and released through the Cluster research. The genetics provide improved disease resistance for Canadian growing regions and early maturity to continue the expansion of Canadian corn growing areas to cooler growing regions and western Canada.

Oats

Two oat projects were conducted through the research Cluster that set out to improve Canadian oat varieties for agricultural production and end use markets.

The research results delivered nine new oat varieties that were released for production in eastern Canada and offer improved disease resistance and higher yields. Several new oat varieties also offer an improved nutrition profile to meet the needs of the milling industry and provide a more nutritious oat product for consumers.

New agronomic recommendations for nitrogen application for oat growers were also discovered as part of the breeding research.

Genomic selection was introduced to the oat breeding program for the first time through this research, and laid the foundation for the oat breeding program to use genetic markers to develop varieties with desirable qualities, like distinctive value-added health benefits for Canadian and international markets.

Some of the oat research conducted was in response to the revised protein quality requirements for human health released by the Food and Agriculture Organization (FAO) of the United Nations. The results will drive further breeding for desirable oat proteins.

Soybeans

Soybeans have been an important crop in southwestern Ontario for almost 100 years, and plant breeding efforts have since demonstrated that soybean can be adapted to growing regions across Canada. Soybeans are currently grown to varying extents from the Maritimes to Alberta, but there is a significant opportunity to improve adaptability to northern and western regions of Canada. Many areas of Canada still lack suitable short season varieties. Through plant breeding, the development of early maturity soybean varieties will open new crop rotation and market opportunities for farmers across Canada.

Eight soybean breeding research projects were conducted through the Cluster program that focused on developing soybean cyst nematode (SCN) resistant, early maturing, short season varieties, and improved food grade soybean varieties for high value export markets. Research was aimed at accelerating the genetic improvements in soybean breeding across Canada to offer new crop rotation

> Twenty four new corn inbreds were developed and released through the Cluster research. The genetics provide improved disease resistance for Canadian growing regions and early maturity to continue the expansion of Canadian corn growing areas to cooler growing regions and western Canada.

> The research results delivered nine new oat varieties that were released for production in eastern Canada and offer improved disease resistance and higher yields.

opportunities for more growers across the country and to maintain and build Canada's competitive advantage in the global market.

One of the biggest threats to soybean production is SCN – a disease considered to be the most devastating pathogen of soybeans around the world. SCN is present in most soybean growing areas of southern Ontario and is expected to spread throughout Canadian soybean growing regions.

Through the Cluster research project, researchers found two new soybean lines that are resistant to SCN and have good agronomic potential for early maturity soybean varieties. Research also identified genetic markers for SCN resistance and it is expected that the use of genomic selection will be a more efficient way to develop new resistant lines. Providing new SCN-resistant varieties, especially in early maturing material, will help Canadian growers keep ahead of SCN.

As a result of Cluster research, field crop researchers developed varieties adapted to short season growing areas of Canada that combined specialty traits with good agronomic characteristics and they can now use genomic selection to develop more efficient breeding programs for better adapted, early maturiting, and high yielding soybean varieties.

Approximately one third of Canadian soybeans are destined for the value-added food grade export market. To maintain and expand Canada's food grade export market, genetic research through the Cluster focused on developing varieties with competitive yield, resistance to diseases, and nutritional profiles that are desirable for processors and consumers.

New global genetics were introduced to Canadian soybean breeding programs through the Cluster research program to increase yield and seed quality of Canadian soybeans.

New genetic materials were also developed that have proven beneficial to southern Ontario growing conditions and are performing well in central and eastern Europe. As a result, many of the seed varieties developed through the research project are being sold to European countries and are driving a new demand for Canadian soybean genetics.

A total of 42 new soybean varieties were developed through the Cluster research, delivering positive food qualities, higher yields and SCN resistance that will expand Canadian growers' ability and options to compete in the world soybean market.

Wheat

Based on new FAO protein measurements, research conducted through the Cluster assessed how 30 different Canadian wheat varieties vary in protein quality and digestibility, and compared the nutritional quality with new FAO measurements. These results will help Canadian growers and processors access market opportunities for wheat with desirable protein levels and characteristics.

Looking Ahead

As part of this project, a two-day Research Summit was hosted in late 2016 to determine the future direction of research for the target field crop sectors in Canada. The purpose of the Summit was to expand on the successes of the *GF2* Cluster projects and collaborations. By bringing together researchers, industry, end-users and government officials from across the Canadian field crop value chains, the Summit set the tone for the future direction of field crop research that would bring more unity and collaboration to strengthen the value of the next generation of research outcomes.

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Project 2

Improved corn genetics for the Canadian corn industry

Lead Researcher
Lana Reid,
Agriculture and Agri-Food Canada

Region

Background

Corn is one of Canada's largest field crops, and is primarily grown in Ontario and Quebec with production rapidly expanding in western Canada and cooler growing regions. The production of corn in heat limited environments of less than 2500 crop heat units (CHU) is growing as demand for grain corn increases, and the use of corn for industrial and food purposes is also increasing. Some growers still find corn economically challenging, especially in early maturity growing regions where a lack of suitable early maturity corn hybrids with acceptable early season cold tolerance are available. In all regions, drying the harvested grain can be very expensive, and as yields have increased substantially, more energy is required to dry corn for storage. The rising cost of energy has farmers looking for hybrids with improved kernel dry down.

Corn disease pressure is significantly increasing throughout all growing regions, where the severity and incidence of all diseases, including the mycotoxin producing Gibberella ear rot caused by *Fusarium graminearum,* is a significant threat to the value chain. Improving the resistance to these and other common corn diseases will improve yields, grain quality and profitability for Canadian growers.

This corn research project is a nationally focused, long-term breeding project. The project aims to develop new inbred lines of corn for use in the seed corn industry to produce new commercial hybrids to meet grower needs or as a source of new genetics in their own breeding program. The inbreds developed through this project are also being used by public and private researchers for further research in corn breeding, disease resistance and production.

Field Crop:
Corn

Project Objectives

1. Develop corn inbreds with early maturity
2. Develop corn inbreds with improved disease resistance to Gibberella ear rot (*Fusarium graminearum*) and other existing and emerging diseases
3. Develop corn inbreds with rapid kernel dry down
4. Develop corn inbreds for new markets and with improved agronomic traits including early season cold tolerance

Successes

Twenty four new corn inbreds were developed and released through the research project, offering improved disease resistance for Canadian corn growing regions and early maturity for expansion to cooler growing regions and western Canada. A new type of corn was also developed, sugarcorn.

The establishment of a national corn research network is an unexpected highlight of this project. More people are conducting corn research across Canada as a direct result of the new information, technologies and corn genetics developed through this research project. This surge of corn research is bringing researchers, private and public programs and institutions together to share new information.

The project has also established a new network of early maturity research locations in western Canada.

Some of the first public sources of corn genetics with resistance to Gibberella ear rot, eyespot, common rust and northern corn leaf blight were developed and released. Many of these inbreds are already being extensively used in further studies on these diseases and incorporated into private breeding programs to develop new corn hybrids.

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Improved corn genetics for the Canadian corn industry

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Project 2

Project Results

NEW GENETICS

A total of 24 corn inbreds have been developed through the research project and more than 20 field trials across Canada were conducted through the project each year. While the final results of the inbreds developed have yet to be seen (corn inbreds are used to develop hybrids), the practical implications for farmers will be beneficial. Higher disease resistance, improved cold tolerance, faster kernel dry down and early maturity are all traits Canadian corn growers are looking for.

The new inbreds developed through this research project included new disease resistance, early maturity and dry down qualities. Disease resistance against Gibberella ear rot, eyespot, northern corn leaf blight and common rust were developed, along with identified sources of high resistance to Goss's wilt in some of the inbreds bred for blight resistance. Early maturity inbreds are 2300-2500 CHU and have been developed to flower approximately 60-65 days from planting. Developing inbreds with faster dry down rates will offer growers new production advantages. Sufficient time for grain fill is important in plant maturity, and improved dry down qualities will allow plants to maximize grain fill while drying fast enough for harvest. The research project has shown developing inbreds with faster dry down rates have eight week moisture levels of less than 20% and some ranging 14%-16%.

NEW TECHNOLOGY

A new moisture meter was developed through this research project to test kernel moisture right in the field and prior to harvest without removing the ear from the plant. Previous moisture tests required kernel samples to be tested at a lab or grain elevator, but this new in-field test offers new efficiencies for researchers and growers. The moisture meter is already being used in public and private corn breeding programs across Canada. While primarily used for research purposes, the moisture meter can also be used by corn growers in their own fields.

Additional in-field testing methods were developed through the project for evaluating inbreds and hybrids for resistance to several diseases including Gibberella ear rot, eyespot, northern corn leaf blight and common rust. This method involves inoculating the plants with the fungi and then returning several weeks later to assess resistance. These techniques have now been standardized for routine use and have been adopted by many private and public researchers.

A new type of corn was developed: sugarcorn. This corn has levels of sucrose sugar in the stalk juice that exceed those found in sugarcane, the number one biofuel crop in the world.

FASTER RESULTS

Using double haploid technology to replace some traditional breeding methods, this project has been able to cut years off the development of new corn inbreds. Researchers can now produce inbreds in two to three years rather than the traditional 10 years. Project researchers are confident this new breeding technique will deliver accurate and faster results to help breeders quickly respond to disease pressure and grower needs.

Using molecular gene mapping techniques, the project has identified parts of the corn chromosomes that may be responsible for resistance to Gibberella ear rot, common smut and kernel dry down. These results are the start of the development of molecular markers for these traits that can be used to further accelerate the breeding process.

TRAINING OPPORTUNITIES

As a result of this project, the Ottawa Research and Development Centre (ORDC) hosts visitors interested in learning about corn breeding and disease research techniques. Many of the visitors come from other research institutions and field crop companies.

Many students also received field crop development training through the project, including a graduate student in western Canada.

Additional Key Highlights

Results of the research and release of corn inbreds are being used by researchers across Canada for additional research and trials, and the development of additional corn inbreds and in general, expanding the opportunities for Canadian corn production.

Future Opportunities

The public corn breeding program conducted at AAFC's Ottawa Research and Development Centre is one of two public corn breeding programs in Canada and lead researcher for this CFCRA project, Dr. Lana Reid is the only person releasing new public corn inbreds in Canada. Results of this research project are vital to the ongoing development and expansion of Canada's corn industry.

The results of this project are also being used as the basis for additional graduate student research at the University of Guelph, University of Manitoba and Western University. Some of these projects involve furthering the development of a new crop for Canada, sugarcorn. This new type of corn has been developed by ORDC to have stalk sugar levels as high as, or higher than that of sugarcane. Canada's sugarcorn may be used for biofuel as well as the harvest of sugar for many different industrial uses.

In Their Words

"The objectives of this research program all meet one collective need – to continuously improve our ability to develop corn genetics more rapidly, and respond faster to grower needs."
- Lana Reid

"The results of many of the inbreds developed through this project will form the basis of additional research, allowing people to answer other scientific problems."
- Lana Reid

Project 3

Develop food quality soybean cultivars and germplasm with improved yield and pest resistance for domestic and export markets

Region

Lead Researchers
Kangfu Yu and Lorna Woodrow,
Agriculture and Agri-Food Canada

Background

Canada has a global reputation for producing high quality food grade soybeans that represent 25-30% of our total soybean production and generate more than $500 million in annual revenue. With key exports to Asia-Pacific and European markets, the demand for Canadian soybeans continues to grow. As demand grows, so does the competition looking to take part in this value-added category. There is growing competition from around the world, putting additional pressure on Canadian exports, trying to gain market share in the food grade soybean export market. For Canada to retain and expand this market segment, Canadian growers need continued access to superior food grade soybeans that deliver competitive yields in a quality and nutritional profile that processors and consumers want.

Soybeans have been in continuous production in Ontario for 100 years. This longevity results in long-term pest pressure that must be considered in the development of new high yielding, pest-resistant, food type soybean varieties for Ontario.

Field Crop:
Soybeans

Project Objectives

1. Develop food quality soybean varieties and germplasm with improved yield and pest resistance in the maturity group (MG) 1.8 and later maturity areas in Ontario, for domestic and export markets
2. Develop and apply breeding technologies to facilitate selection for improved food quality
3. Evaluate food type soybean germplasm for resistance to soybean cyst nematode (SCN), soybean aphids (SA) and sudden death syndrome (SDS)

Successes

This project released two new varieties – AAC Stern and AAC26-15 that are now commercially available, offering growers new varieties with good food qualities, high yields and SCN resistance.

This project also developed and registered five specialty soybean germplasm sources for private and public breeding programs. The germplasm has characteristics of lipoxygenase free (HS-151), making softer tofu (HS 161) and firmer tofu (HS 162), large seed edamame (HS 171) and black seed for douche (HS-172).

A new coagulant (M_gCl_2) was introduced for screening advanced soybean lines that will help end users (Japan, China) evaluate new Canadian soybean varieties for tofu processing in markets that use this coagulant. And a new criterion to evaluate tofu quality — springiness — was incorporated into the evaluation protocol of the breeding program to effectively distinguish texture quality in soybeans.

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Develop food quality soybean cultivars and germplasm with improved yield and pest resistance for domestic and export markets

Project 3

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Project Results

VARIETY DEVELOPMENT

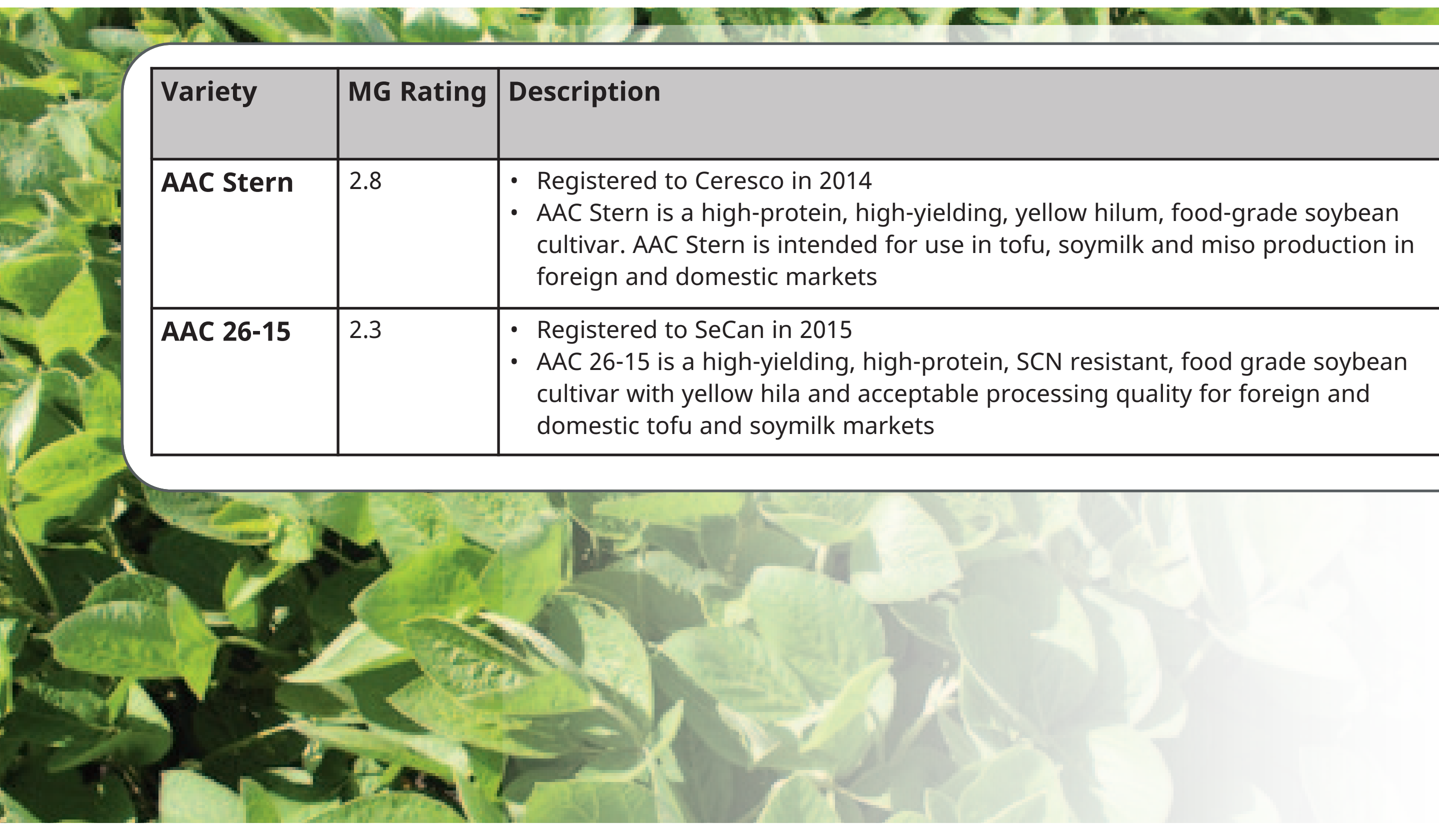
New soybean varieties were developed and released through Agriculture and Agri-Food Canada's (AAFC) Material Transfer Agreement (MTA) and Request for Proposal (RFP) programs, as well as a few varieties released for commercial development.

BREEDING TECHNOLOGY

Four new molecular markers were developed to determine soybean protein profiles. The markers were used to screen hundreds of soybean lines for protein profiles that affect tofu and soy milk quality, and significantly speed up the ability to select and breed for specific proteins. The new process improves the plant breeding process by eliminating the need to wait until plant seeds are harvested in the fall to isolate the seed storage protein of a soybean line.

PEST RESISTANCE

Two soybean lines with potential resistance to soybean aphids were obtained from several breeders and tested against biotypes present in southwestern Ontario. Eleven soybean lines released through AAFC MTA and/or RFP had SCN resistance.



Variety	MG Rating	Description
AAC Stern	2.8	• Registered to Ceresco in 2014 • AAC Stern is a high-protein, high-yielding, yellow hilum, food-grade soybean cultivar. AAC Stern is intended for use in tofu, soymilk and miso production in foreign and domestic markets
AAC 26-15	2.3	• Registered to SeCan in 2015 • AAC 26-15 is a high-yielding, high-protein, SCN resistant, food grade soybean cultivar with yellow hila and acceptable processing quality for foreign and domestic tofu and soymilk markets

Future Opportunities

Breeding material developed during this project provided the foundation for a new project proposal submitted for funding under the new *Canadian Agricultural Partnership (CAP)* program. The next phase of this research will include developing food grade soybean varieties with improved yield, performance and SCN resistance, as well as specialty food grade soybean germplasm to improve soy milk flavour.

In Their Words

"Developing new soybean varieties with positive food qualities, higher yield and SCN resistance gives Canadian growers the ability and option to compete in the world soybean market. These new varieties help Canadian farmers remain competitive in the world food grade soybean market, and contribute to the overall Canadian economy and strength of the agriculture industry."

- *Kangfu Yu*

Project 4

Genetic improvement of soybeans for yield, disease resistance and value-added seed components

Lead Researcher
Istvan Rajcan,
University of Guelph

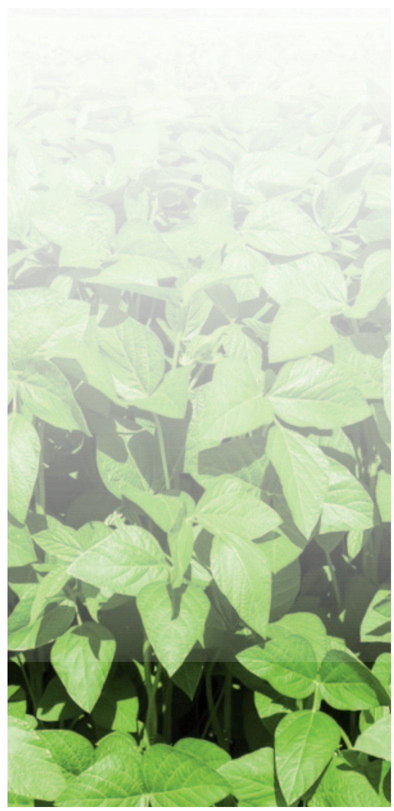
Region

Background

Canadian soybeans are known worldwide for their superior quality, yield, genetics, quality assurance and Identity Preserved (IP) growing programs. While soybean yields have been slow to increase, most yield increases are a direct result of improved soybean genetics. As growers strive for new soybean genetics to improve their quality and yields, meet consumer demand, manage diseases like soybean cyst nematode (SCN) and develop new global market opportunities, soybean breeding will never be more important. Continued investments in soybean breeding will lead to continued improvements and growth for the Canadian soybean industry.

Canadian soybean genetics are narrowing, making the expansion of the genetic makeup of varieties available to Canadian farmers a growing need. Adding genetic diversity to Canadian soybean varieties is expected to create new varieties and market opportunities for growers. This is a very unique approach to soybean breeding, with few domestic breeding programs incorporating exotic genetics.

Field Crop:
Soybeans



Project Objectives

1. Develop high yielding conventional food grade (non-GM) and glyphosate-tolerant (GM) soybean varieties for food grade markets including tofu, natto and miso, and oil crush markets
2. Incorporate new alleles from Chinese elite soybean varieties using marker assisted selection for SCN and white mold resistance, higher yields, oil content and quality protein
3. Develop new SCN-resistant varieties using Canadian and U.S. sources
4. Evaluate genetic diversity for soy saponins for their astringency and anti-cancer attributes and work towards increasing the beneficial saponins in food grade soybeans
5. Develop new varieties with increased oil content to improve the efficiency of oil production for edible oil and bioproducts including biodiesel

Successes

Twenty-nine registered soybean varieties were developed and Canadian soybean growers now have access to new and improved soybean varieties. This project also expanded research on Type B soy saponin for anti-cancer benefits. Opportunities for Canadian soybeans have also been expanded by the introduction of exotic germplasm from China to further increase yield and improve seed quality of Canadian soybeans.

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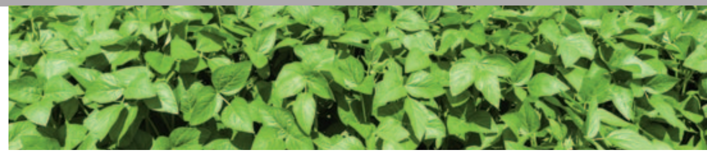

Genetic improvement of soybeans for yield, disease resistance, and value-added seed components

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Project Results

Five objectives were set for the soybean research project and they all focused on meeting the needs of Canadian soybean growers and creating new varieties that will be desirable for farmers to grow.

VARIETY DEVELOPMENT

Twenty nine soybean varieties were developed during the five-year project.

Many of the conventional soybean varieties were bred for food markets. Small seed varieties were bred for natto soybean production. Specific soybean varieties were developed for miso food production, including higher sucrose levels. Larger seed and higher protein varieties were developed for tofu production. Varieties were tested for suitability in their target food markets and the results of these tests were presented to international buyers, supporting the export market for Canadian food grade soybeans. Many of the commercial varieties released throughout the five-year project also delivered higher yields. The continuous improvement in food grade soybean genetics is a significant market driver, benefiting Canadian growers, seed companies, transportation providers and export companies.

GENETIC DIVERSIFICATION

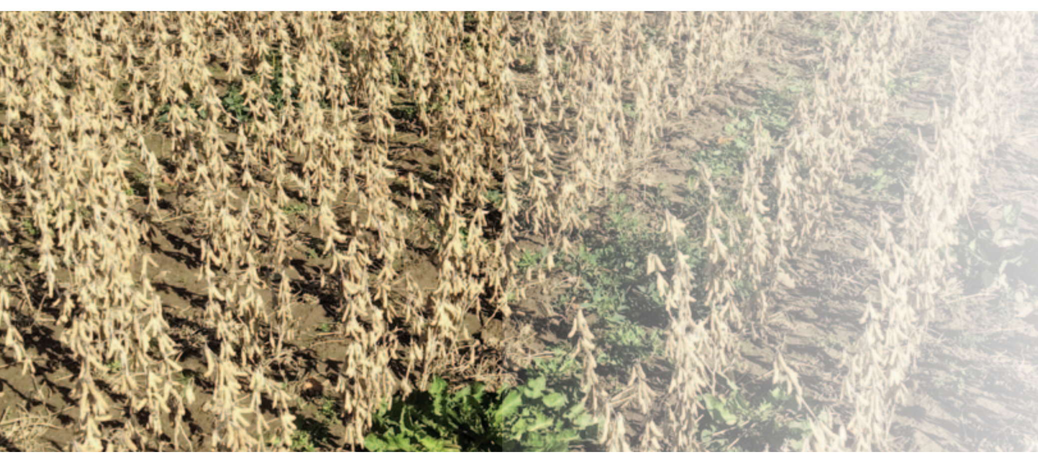
This project was one of a few soybean breeding programs introducing exotic germplasm (unadapted genetics from a different country or growing region). The exotic germplasm incorporated into the project was from China, the centre of origin and diversity for soybean into domestic soybean varieties, which addressed the narrowing of soybean genetic diversity in Canada. Results are promising and experimental lines developed from hybridization using elite Chinese and Canadian parents are in the final stages of testing. The genetic crosses were made to address traits such as increased yield, high protein content and quality, improved disease resistance and higher oil content.

SCN RESISTANCE

As SCN continues to spread, the importance of breeding SCN-resistant varieties continues to grow. This research project focused on breeding resistant varieties for new areas with SCN infestation in Ontario and Quebec, with Manitoba likely being the next target in the future. Approximately 230 genetic crosses were made through the research project annually with roughly 66% of those crosses involving potential SCN resistance. Eight new SCN-resistant varieties were developed and results continue with new material that is ‘in the pipeline’. These resistant varieties are vital for growers to be able to manage the disease before it appears.

HEALTH BENEFITS

Anti-cancer attributes have been identified in soy saponins. This research focused on identifying genes that affect the saturation and accumulation of the desirable Type B saponins in soybeans. The genetic makeup of Type B saponins were studied, including mapping the quantitative trait loci (QTL). The research project successfully identified QTL on three different chromosomes. The outcomes of this research will help



soybean breeders select for higher Type B soy saponin in future crosses and breeding programs, which may impart anti-cancer and antioxidant attributes to soy foods.

HIGHER OIL CONTENT

The fifth objective focused on increasing soybean oil content for desirable markets like edible oils and bioproducts. The average soybean oil concentration is 19%. Through the CFCRA program soybean varieties were developed with oil concentrations as high as 22-23%. While the increase in oil concentration is only a few percentage points, the increase can be significant to farmers who are growing for specific end-use products like edible oils or biodiesel production. The new high oil varieties are in the process of commercialization and will be available to growers and the value-added industry.

RESEARCH TRAINING

The CFCRA funding allowed for the hiring of highly qualified personnel, including one graduate student and summer students throughout the five-year program. The graduate student focused on evaluating soy saponins, helping breeders to identify desirable genetic crosses and map the QTL of Type B soy saponins. Each summer student received training in all aspects of soybean breeding as they assisted the staff and technicians. The research project also benefited full-time staff and technicians who gained valuable experience while improving their skills and knowledge in soybean genetics and breeding.

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Licenced Variety	Licenced to	Characteristics / Qualities
OAC 13-50C-ZL	Huron Commodities Inc.	• High yielding • Zero lipoxygenase • Food grade • MG 1
SeCan 13-15C	SeCan	• High yielding • High protein • MG 0
SC 3313N	SeCan	• High yielding • High protein • SCN resistant • MG 2.2
SC 3413N	SeCan	• High yielding • High protein • SCN resistant • MG 1.6
OAC 11-02C	Huron Commodities Inc.	• High yielding • Manitoba and European markets • MG 00
SeCan 14-11C	SeCan	• High yielding • High protein • MG 0.7
SeCan 14-21C-SCN	SeCan	• High yielding • High protein • MG 1
SC 7415N	SeCan	• High yielding • High protein • SCN resistant • MG 1.8
SC 8415N	SeCan	• High yielding • High protein • SCN resistant • MG 2.4
SC 8515N	SeCan	• High yielding • High protein • SCN resistant • MG 2.3
SVX 16T0G1	Sevita International	• High yielding • High protein • MG 0.1

Genetic improvement of soybeans for yield, disease resistance, and value-added seed components

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Project 4

Commercialized Variety	Licenced to	Characteristics / Qualities
OAC Strive	SeCan	• High yielding • Early maturity • Higher than normal protein levels • Imperfect yellow (IY) hilum • Food grade • MG 0.4
OAC Prosper	SeCan	• High yielding • SCN resistant • Large seed size • Increased protein • Yellow hilum • Food grade • MG 1.8
Neptune	Sevita International	• High yielding • IY hilum • MG 0.8
Factor	Sevita International	• High yielding • Grey hilum • Slightly higher than average protein • MG 0.7
OAC Morden	Huron Commodities Inc.	• High yielding – especially in Manitoba • Light Buff hilum • MG 00
OAC Eve	SeCan	• High yielding • IY hilum • MG 1
OAC Durham	SeCan	• High yielding • Yellow hilum • MG 0.8
OAC Prescott	SeCan	• Very high yielding • Grey hilum • MG 0.7
DS143C0	Dow Agro Sciences	• Very high yielding • MG 0

Commercialized Variety	Licenced to	Characteristics / Qualities
OAC Challenger R2	SeCan	• High yielding • RR2Y • The only RR2Y soybean variety developed by a public breeding program in Canada • MG 0
TN-G1	Takano Foods	• High yielding • Natto variety • MG 0.6
OAC Adare	SeCan	• High yielding • High protein • MG 1.2
TN-G3	Takano Foods	• High yielding • Natto variety • MG 0
TN-G2	Takano Foods	• High yielding • Tofu variety • MG 1
OAC Evolution	SeCan	• High yielding • High protein • MG 0
SC 5714N	SeCan	• High yielding • High protein • SCN resistant • MG 1.8
SC 6014N	SeCan	• High yielding • High protein • SCN resistant • MG 2.3
SVX 16T0G4	Sevita International	• High yielding • High protein • MG 0.4

Future Opportunities

An unexpected but significant opportunity from this soybean breeding research is the growth of Canadian soybeans suitable for central and eastern Europe. With similar growing conditions and latitudes, countries like Germany, Austria, Ukraine and Russia are now sourcing Canadian soybean seed. Very few soybean breeding programs exist in Europe. Many of the varieties developed in this project for southern Ontario growing conditions are also performing well, especially in the Ukraine and Russia. These countries have grown their soybean acres from zero to thousands of hectares during this five-year research project. The opportunities to export soybean seed to these countries couldn't have been predicted, but many of the seed varieties developed through the CFCRA research project are being sold to these European countries that continue to expand production and drive demand for Canadian soybean genetics. This new market development is a win-win for Canadian soybean breeders, farmers growing the seed and growers overseas who are able to plant superior varieties designed for their growing conditions.

The European market opportunities for Canadian soybean seed weren't identified as research project goals, but support the overall objective of delivering new varieties to support Canadian growers and Canada's domestic and export markets.

In Their Words

"I really appreciate and am grateful for the funding. Without it, we wouldn't have this program that is so significant to the Canadian soybean industry. Industry and government funding programs like the Canadian Field Crop Genetics Improvement Cluster are critical to the success of our industry."

- Istvan Rajcan

Project 5

Short season soybean improvement

Region

Lead Researcher
Elroy Cober,
Agriculture and Agri-Food Canada

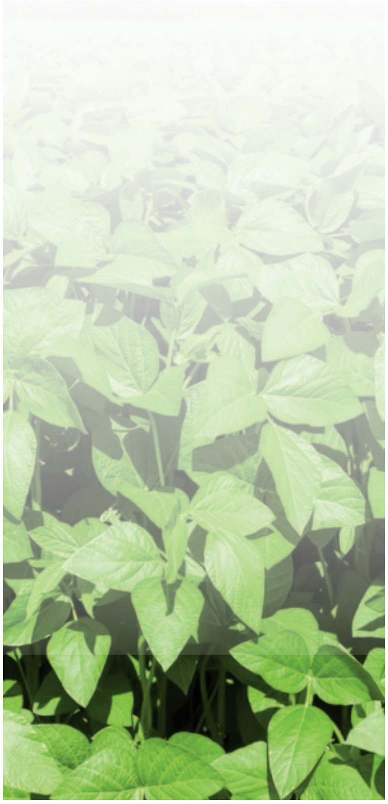
Background

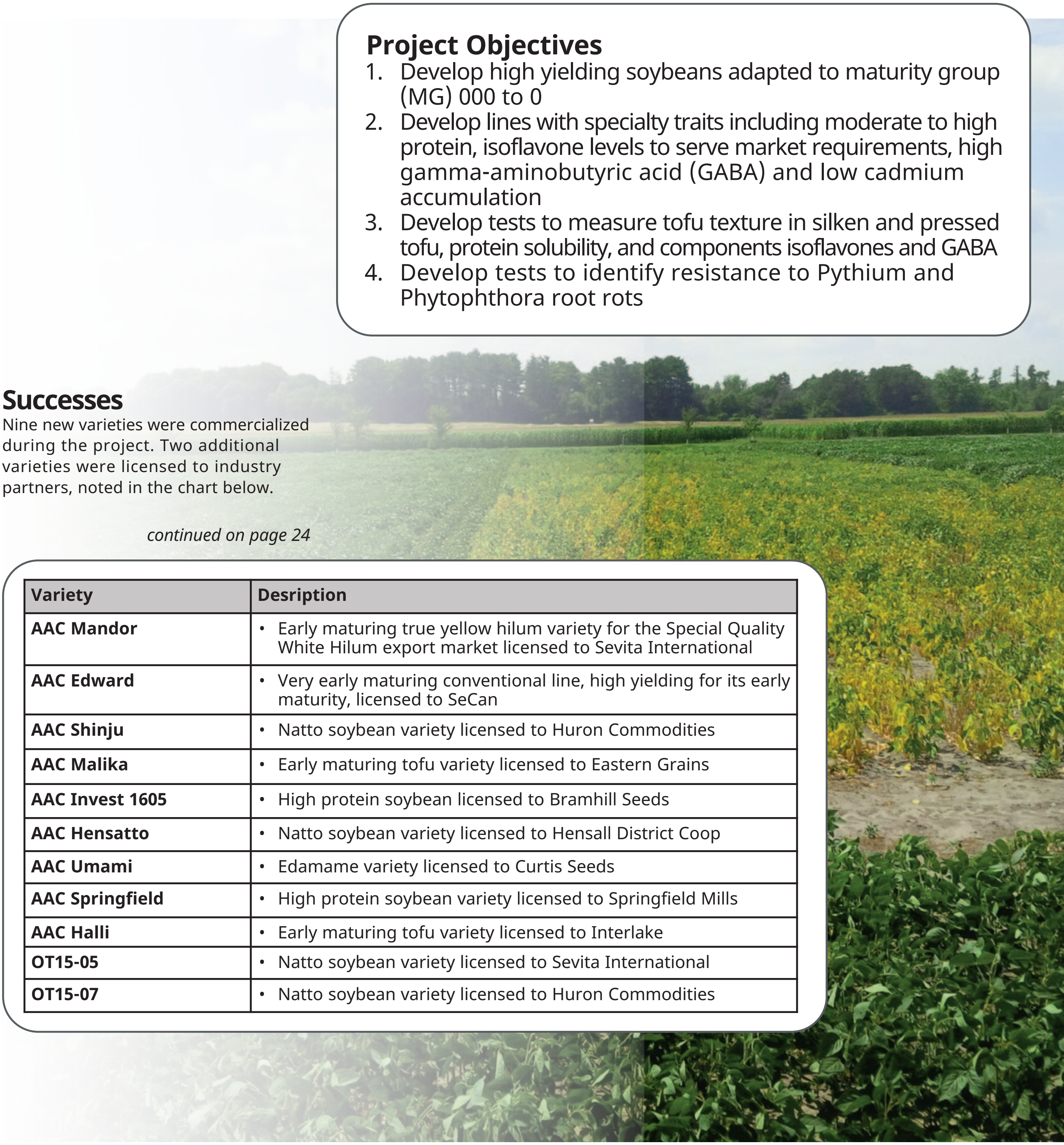
Soybeans are an important Canadian crop, grown from Alberta to the Maritimes, with approximately one third of soybeans destined for value-added, food grade export markets. Regions with short growing seasons provide the opportunity to expand soybean production across the country.

End use function traits are a critical component for the success of soybean varieties for premium export markets in Asia, but diseases pose a significant constraint to soybean production in Canada. Soybean cyst nematode, white mold, root rots caused by *Phytophthora*, *Pythium*, *Fusarium* and *Rhizoctonia*, plus Phomopsis seed decay cause yield losses of more than 30% in years with significant disease pressure. Enhancing disease resistance of food type soybeans to root rots will bring new opportunities for farmers in eastern and western Canada to grow specialty soybeans.

It is important to continue developing soybean varieties adapted to short season areas of Canada that combine specialty traits (food grade export market quality) with stress tolerance and pest resistance in an agronomically-competitive variety. Improving food type soybeans for short season areas of Canada will allow for the expansion of specialty soybeans, provide greater market access for growers, and improve Canada's competitiveness in the global market.

Field Crop:
Soybeans





Project Objectives

1. Develop high yielding soybeans adapted to maturity group (MG) 000 to 0
2. Develop lines with specialty traits including moderate to high protein, isoflavone levels to serve market requirements, high gamma-aminobutyric acid (GABA) and low cadmium accumulation
3. Develop tests to measure tofu texture in silken and pressed tofu, protein solubility, and components isoflavones and GABA
4. Develop tests to identify resistance to Pythium and Phytophthora root rots

Successes

Nine new varieties were commercialized during the project. Two additional varieties were licensed to industry partners, noted in the chart below.

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Variety	Desription
AAC Mandor	• Early maturing true yellow hilum variety for the Special Quality White Hilum export market licensed to Sevita International
AAC Edward	• Very early maturing conventional line, high yielding for its early maturity, licensed to SeCan
AAC Shinju	• Natto soybean variety licensed to Huron Commodities
AAC Malika	• Early maturing tofu variety licensed to Eastern Grains
AAC Invest 1605	• High protein soybean licensed to Bramhill Seeds
AAC Hensatto	• Natto soybean variety licensed to Hensall District Coop
AAC Umami	• Edamame variety licensed to Curtis Seeds
AAC Springfield	• High protein soybean variety licensed to Springfield Mills
AAC Halli	• Early maturing tofu variety licensed to Interlake
OT15-05	• Natto soybean variety licensed to Sevita International
OT15-07	• Natto soybean variety licensed to Huron Commodities

Short season soybean improvement

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Project 5

Project Results

VARIETY DEVELOPMENT

Eleven new soybean varieties developed through the project were picked up by seed companies for commercialization in the identity preserved (IP) market. All the varieties are suited for food, soy milk or tofu export markets in Asia or Europe.

- 3 early season, special quality white hilum varieties
- 5 natto varieties
- 2 high protein, food grade varieties
- 1 edamame variety

TOFU QUALITY

The project validated a small scale tofu test to test firm tofu for texture. The Harrow research station carries out larger scale testing and its protocol for tofu testing is considered the industry standard for the export market. As part of this research project, researchers worked with Harrow to ensure comparable results were achieved with the small scale testing. Miniaturizing the tofu texture test — which involves making tofu from the soybean variety and testing the texture for export quality — allows researchers to test more experimental lines.

DISEASE RESISTANCE

Root rots are very weather dependent and often manifest as dead plants throughout the season, causing yield but not quality losses.

Researchers updated information on the races of Phytophthora root rot in Ontario fields and discovered race 25 has become the predominant race in Ontario. They also found that race structures in Ontario fields have become more complex than when they were last surveyed 10 years ago.

Since there are single genes responsible for resistance to a few races of *Phytophthora*, it is important to know which race is prevalent in fields so that the information can be used by breeders when picking parents to develop new soybean varieties. This helps ensure that the disease resistance genes in the soybean varieties are effective against the pathogen races present in farmers' fields. The resistance information identified in this project is now publicly available for soybean breeders to use in their breeding programs.

Existing methods for detecting *Phytophthora* from soil samples were successfully adapted but require more work to be able to quantify the actual pathogen load in the soil.

Future Opportunities

There are a lot of players in the soybean industry because it's a multinational industry. Developing new soy food type varieties helps Canadian growers participate in this value-added soybean export market.

Researchers are planning to use the pipeline of work developed in this project — with some tweaking for the focus based on feedback from industry partners — to continue developing improved varieties over the next five years of the *Canadian Agricultural Partnership*.

In Their Words

"We are continuously developing new soybean varieties that help make the export market model sustainable and give Canadian growers an opportunity to participate in this market."
- *Elroy Cober*

"It has been surprising to see the range of companies involved in commercializing the new varieties we have developed. There were nine different companies from New Brunswick to Manitoba who have picked up varieties we developed."
- *Elroy Cober*

Project 6

Breeding soybeans for adaptation to environment and emerging pests and concurrent development of molecular marker selection tools: development of high yielding early maturity soybeans

Lead Researcher
Louise O'Donoughue,
CÉROM

Region

Background

Many areas of Canada have suitable conditions for soybean production, but are hindered by the lack of very early, short season varieties available. Eastern and northern Quebec, northern Ontario, Manitoba and the Maritimes are key areas where soybean production is a possibility.

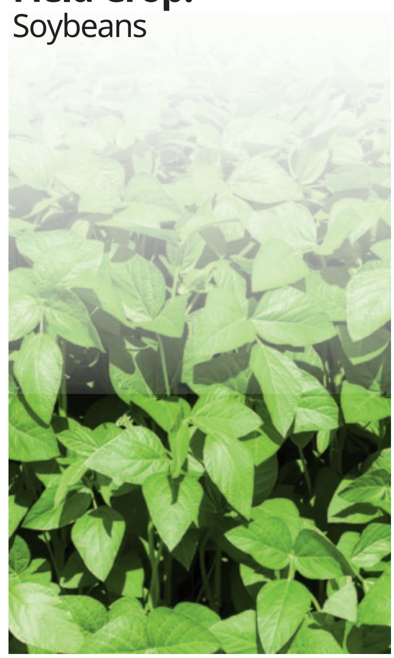
Selecting soybeans for early maturity is currently done by phenotypic selection after plants are mature. Advances in sequencing and genotyping technologies means soybean lines can now be characterized by earliness (E) genes using markers to select for these genes before the field season begins.

The recent development of a new marker strategy called genomic selection, which can assess traits like yield, may hold promise for breeding very early maturity soybeans and address the negative relationship between yield and maturity.

This research project looked at the rapid integration of new selection tools into practical soybean breeding programs, leading to more efficient breeding for very early maturity, high yielding soybean varieties. A better understanding of the genetic basis for maturity in soybeans, and the development of selection tools to allow breeders to respond more quickly to emerging issues will help breeders produce varieties adapted to all existing and potential soybean growing regions in Canada.

Developing very early maturity soybeans also has the potential to open new markets and opportunities for farmers across Canada and allow for diversified crop rotations in short season environments.

Field Crop:
Soybeans



Project Objectives

1. Develop soybean varieties, mostly for animal feed, adapted to maturity group (MG) 00 and less
2. Characterize the genetic basis of maturity in eastern Canadian soybean germplasm
3. Develop molecular marker selection tools to manipulate genes in the breeding program
4. Evaluate a new genomic selection strategy for yield and early maturity

Successes

In characterizing existing early maturity genes in the Canadian gene pool, researchers discovered some sources of early maturity soybean genes that had not been used, or were underutilized in current breeding programs, and some germplasm has been exchanged with Agriculture and Agri-Food Canada researchers. Another surprising discovery was finding early maturing loci in the global gene bank that were previously unknown.

Two advanced soybean lines have been identified that performed well and were superior to checks over two years of testing in Quebec and Manitoba, and if there is commercial interest in these lines they will be registered and licensed for commercialization.

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Breeding soybeans for adaptation to environment and emerging pests and concurrent development of molecular marker selection tools: Development of high yielding early maturity soybeans

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6 Project

Project Results

NEW VARIETIES

There are several combinations of genes that can lead to early maturity or short season soybean varieties, and this project looked for gene combinations that are better suited to different environments (soil, climate).

Five advanced lines have been tested in Quebec provincial trials (MG 000 to 00), and three of the lines were also tested in Manitoba. Three new early maturity soybean varieties are expected to be available for commercial registration in 2018.

GENETIC CHARACTERIZATION

The eastern Canadian soybean gene collection chosen for this project (100 lines, four E genes) was characterized and the early parental collection for E1 to E4 loci was completed. One of the key findings of this project was that some early maturity genes have been underutilized in the Canadian gene pool. Loci have also been identified that were not previously reported for maturity, flowering and time to pod filling. These new loci will be studied further under the Genome Canada Soyagen project.

NEW SELECTION TOOLS

A fully equipped marker assisted selection/ molecular biology lab, including a liquid handling robot, has been developed as part of this project. A haploid typing tool was also developed through this project that streamlines the characterization of gene collections — reviewing Canadian and global gene banks for genotypic data that will help make faster selections for early maturity breeding programs.

GENOMIC SELECTION

After discovering the prediction model intended for this project was less than optimal, this research objective was changed. From two target populations in Quebec, 200 previously genotyped lines were randomly selected, and phenotypic data was collected on yield, maturity, flowering time, seed weight, and oil and protein content. Phenotypic and genotypic data are being used to evaluate the efficiency of different prediction models. Results are expected after the 2018 field season.

Future Opportunities

This *Growing Forward 2* activity has already been leveraged through the Genome Canada Soyagen project to build on this breeding work.

The results of this project in eastern Canada can be adapted and are useful for other environments across the country to develop material suitable for growing conditions in western Canada. Some of the early maturity gene combinations identified under this project are now being grown in eight environments across Canada (Quebec, Ontario, Manitoba and Saskatchewan) to verify if some of them are suited to other environments in Canada. Expanding the early maturity breeding program to western Canada is part of funding proposed under the new *Canadian Agriculture Partnership (CAP)* program.

In Their Words

> We are developing better adapted, higher yielding soybean varieties that can be grown in crop rotations in areas where early season varieties have not been available.
> \- *Louise O'Donoughue*

> A better understanding of the genetic base of early maturing genes in Canadian material has opened new opportunities for us to explore in soybean breeding.
> \- *Louise O'Donoughue*

> Without the *GF2* funding for this project, we would not have been able to secure additional funding through Genome Canada to continue our work and generate a much more balanced collection of 100 lines. We are now testing this collection in eight locations across Canada.
> \- *Louise O'Donoughue*

Breeding soybeans for adaptation to environment and emerging pests and concurrent development of molecular marker selection tools: development of soybean cyst nematode (SCN) resistant early maturity soybeans

Region

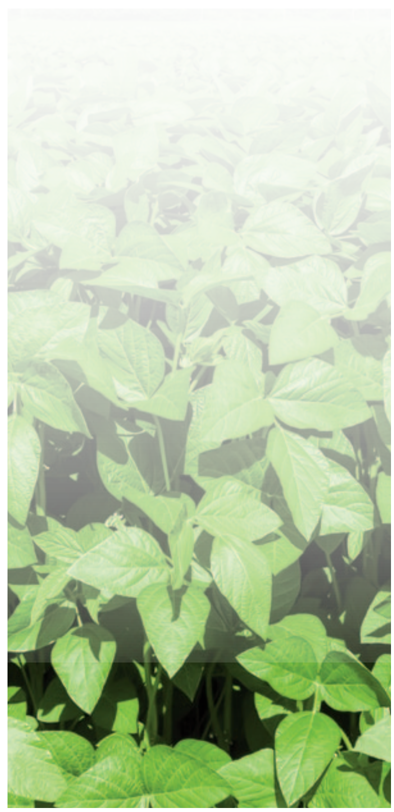
Lead Researcher
Louise O'Donoughue,
CÉROM

Background

Soybean cyst nematode (SCN) is the most devastating pathogen of soybeans around the world. SCN is found in most soybean growing areas of southern Ontario and has recently been identified in Quebec. The only effective SCN control is the use of naturally-resistant varieties combined with non-host crop rotations. Some resistant varieties have been bred for areas of southern Ontario, but very few are available for earlier maturity regions.

The same SCN resistance source (PI 88788) has been used for more than 90% of resistant varieties in North America, and a breakdown of resistance has shown up in several U.S. states and Ontario. There is an urgent need to identify new sources of resistance that will be effective against SCN populations in Ontario and Quebec to maintain the competitiveness of soybean production in Canada.

Field Crop:
Soybeans



Project Objectives

1. Identify and validate new sources of resistance that will be resistant to soybean cyst nematode (SCN)
2. Develop breeding populations and advanced lines by crossing agronomically-superior early maturity lines with the best sources of SCN resistance

Successes

Through this project, researchers found two new lines that are SCN resistant and have good agronomic potential for early maturity soybean varieties.

Providing more choices for SCN-resistant varieties, especially in early maturing material, will help growers keep ahead of SCN — a disease that can be “dormant” in the soil for 20 years without impacting a crop.

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Breeding soybeans for adaptation to environment and emerging pests and concurrent development of molecular marker selection tools: development of soybean cyst nematode (SCN) resistant early maturity soybeans

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Project 7

Project Results

NEW SOURCES OF RESISTANCE
Existing gene banks were searched for potential sources of SCN resistance in early maturity soybean lines. Nematologists evaluated the sources with populations of nematodes that cause significant damage in Ontario fields to determine if the new sources were resistant.

Twelve sources of SCN resistance that have not been used in Canadian breeding programs have been identified as being resistant to SCN populations in Ontario. Seven of the lines are effective against SCN HG type 2.5.7 and provide superior resistance to PI 88788 — the most commonly used source of SCN resistance.

BREEDING POPULATIONS
Researchers have now developed more than 75 populations from crosses made between good agronomic cultivars of various maturities and one or more of the 12 sources of resistance.

From these crosses, some of the new varieties with new SCN-resistance sources will become available for breeding but may take up to five years before any of the new soybean varieties are commercially available.

Future Opportunities

Developing SCN-resistant soybean lines that are adapted to early maturity areas, using different resistance sources than those that are already breaking down, has the potential for any soybean growing region in Canada to have better yields and remain competitive.

The use of genetic markers for SCN resistance will be a more efficient way to help find potential new lines. *Growing Forward 2* funding for this project was leveraged to secure additional funding through Genome Canada's Soyagen project to develop genetic markers for SCN resistance in soybeans.

If additional funding is secured through the new *Canadian Agriculture Partnership (CAP)* program, researchers will implement marker assisted selection for SCN and develop agronomically strong, SCN-resistant soybean varieties using more adapted advanced lines from the populations developed under this project.

In Their Words

"SCN has been identified in Quebec, but damage has not been reported. It is important to anticipate what growers will need in the future because it takes years to develop new varieties."
- *Louise O'Donoughue*

"Breeding new soybean varieties that are early maturing with SCN resistance will help growers be more competitive and have better yields."
- *Louise O'Donoughue*

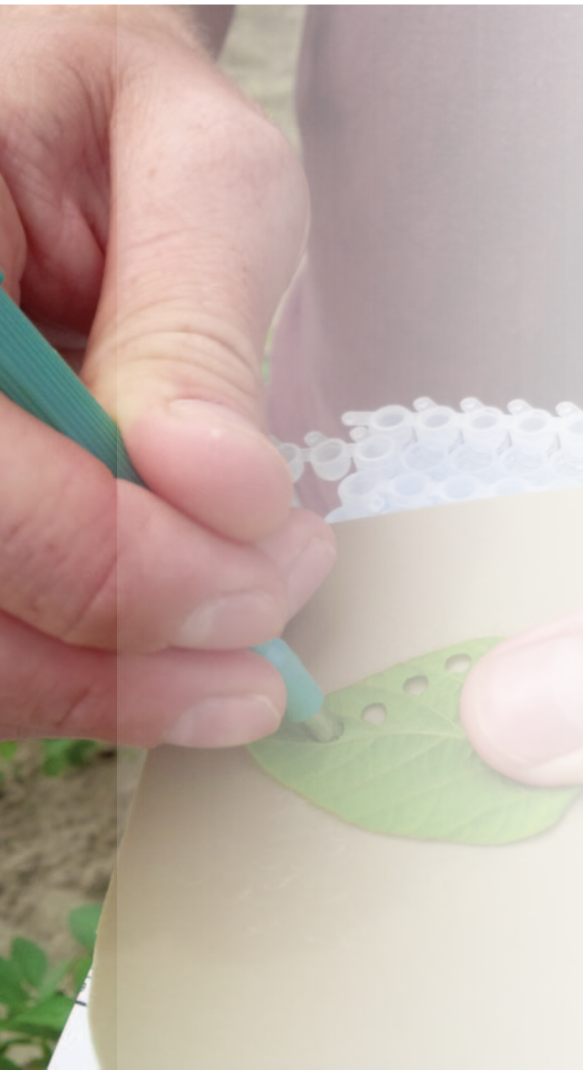
"It is critical to protect soybean yields in Canada from SCN, and be proactive in regions where the impact of this devastating pest has not yet been felt."
- *Louise O'Donoughue*

Project 8

Very short season herbicide tolerant soybean varieties adapted to the Canadian prairies

Region

Lead Researcher
Elroy Cober,
Agriculture and Agri-Food Canada



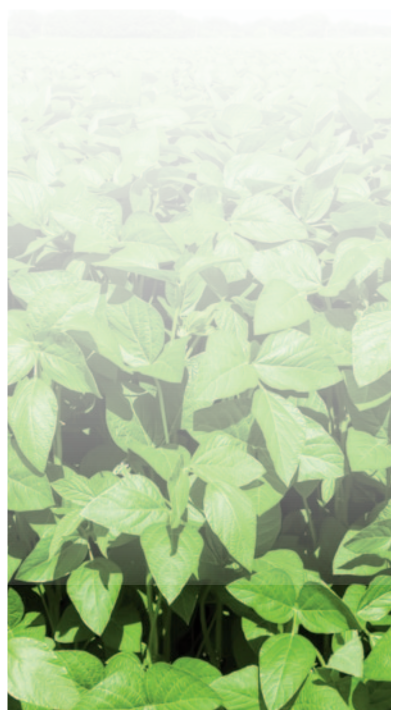
Background

Soybeans are grown from the Maritimes to Alberta in Canada. Breeding new short season varieties offers an opportunity to expand soybean acres into northern and western Manitoba, southeastern Saskatchewan and southern Alberta. These new growing areas require soybean varieties adapted to long days and able to handle the stress of a continental climate. In western Canada, soybeans must be able to adapt to low night temperatures during flowering. Soybeans are photoperiod sensitive and long days delay flowering and maturity. Individual soybean varieties are limited to a narrow band of latitude, and do not perform well if they move very far north or south of their area of adaptation.

A number of genes that control time of flowering and maturity have been identified in soybeans, which is expected to help the development of breeding very short season soybeans. The development of molecular markers that target early maturity may allow for rapid breeding of short season adapted soybean varieties.

There are currently limited public or private soybean breeding activities in western Canada, and this project will fill a gap to develop progeny selections for northern areas to help develop very short season soybean varieties, specifically for Saskatchewan and Manitoba. It is estimated that 90-95% of soybeans grown in Manitoba are herbicide tolerant varieties, and it would be beneficial to develop herbicide tolerant, very short season soybean varieties.

Field Crop:
Soybeans



Project Objectives

1. Cross herbicide tolerant and conventional parents, and advance to F3 using single seed descents
2. Evaluate conventional parental lines for early maturity at known maturity loci using conventional approaches and molecular markers
3. Develop new molecular markers for marker assisted selection
4. Perform preliminary yield trials in Saskatoon, SK and Morden, MB
5. Perform replicated trials on experimental lines grown in Saskatoon, SK and Morden, MB, and retain adapted lines for further multiple location testing

Successes

The original intent of this project was to license a herbicide tolerant trait as part of the work on short season soybean varieties, given the predominant use of herbicide tolerant soybeans in western Canada. However, international market acceptance delayed this step and as a result, all the breeding work was done on conventional soybeans. The good news is that the early maturing varieties that were developed represent transferable knowledge, and can be used as parents for any soybean system — conventional or herbicide tolerant.

It will take 3-4 more years for any of the short season lines developed to be available commercially, but when they are they will be better adapted and offer more choices for soybean growers in western Canada.

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Very short season herbicide tolerant soybean varieties adapted to the Canadian prairies

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Project 8

Project Results

POPULATION DEVELOPMENT

In the absence of a public soybean breeding program in western Canada, researchers in Ottawa made all the initial cross selections for this project, sending unselected populations to western Canada to allow selection and advancement to yield trials in western Canada.

Seven parents were selected for early maturity (maturity group 000), photoperiod sensitivity and/or earliness genes that were used to generate 12 new short season breeding crosses in Ottawa. Single plant selections from these populations were made for short season adaptation at Saskatoon and Morden.

Preliminary yield trials were grown in multiple locations in Saskatoon and Morden during the 2017 season with 23 promising lines showing days to maturity in the range of the checks, including a few on the early end of the range.

MOLECULAR MARKERS

A DNA molecular marker (Maturity Diagnostic Toolbox) developed by AAFC Ottawa was used to determine flowering and maturity in soybeans. Researchers used the molecular markers to investigate multiple loci and allelic variations in a single tube to identify markers that control time to flowering and maturity. Genotyping was completed for 20 potential parental lines using DNA markers.

Through this process, a new maturity loci (E10) was discovered that matures 5-10 days earlier. This is rare in Canadian soybean lines and may prove useful in breeding programs for western Canada.

The allele-specific markers developed for this new locus are now available for soybean breeders to use to efficiently develop earlier maturing varieties using molecular marker assisted breeding.

Future Opportunities

There are no public soybean breeding programs in western Canada, and when this project began in 2013, commercial companies in the area were not making any initial genetic selection. The goal of this project was to take as much genetic material to field testing in western Canada as possible. With the discovery of a new marker for maturity, and the extensive field testing conducted in Saskatoon and Morden, the future establishment of a public soybean breeding program in western Canada is now a possibility.

The next step for this research will be to create more integration between making the crosses in Ontario and testing them in western Canada, to make it more of a two-way process, where selection, crosses and testing happens in both parts of the country.

In Their Words

"The goal of this project was to fill the pipeline with short season genetic material. It was a pilot project, and the next step will be asking for a full activity as part of the *Canadian Agricultural Partnership* AgriScience program."
- *Elroy Cober*

"There is an opportunity to expand the soybean market into Saskatchewan and Alberta. To be able to spread soybean acres further west would be a huge opportunity for farmers to put another crop in rotation, and would be beneficial for disease control, especially for growers doing a wheat/canola rotation."
- *Elroy Cober*

Canadian research consortium for next generation selection in soybean

Region

Lead Researcher
François Belzile,
Université Laval

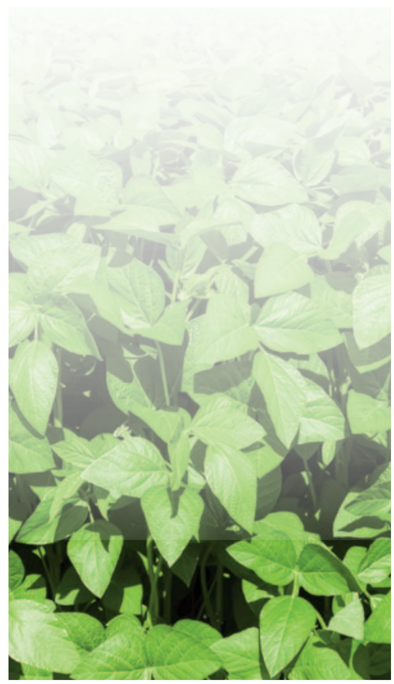
Background

One of the key challenges with plant breeding is identifying the best progeny obtained in a cross. In advanced generations, information from extensive field testing is available to provide a good basis for selection. But in early generations, breeders must make decisions based on the appearance of a single plant, and work with very limited information to make decisions about whether to keep or discard a line.

Recent technology advances in DNA sequencing and genotyping now make it possible to quickly and cost effectively examine genetic markers in individual plants. This technology is a radical innovation for how marker information, or genomic selection, can support breeding efforts. The premise with genomic selection is that the performance of a line can be predicted from genetic makeup only, when there is sufficient marker information and a good model linking genetic information with agronomic performance.

This project set out to test this premise using genomic selection by collaborating with three public soybean breeding programs in Guelph and Ottawa, ON and Beloeil, QC. This work has the potential to help breeders more accurately predict the field performance of a new soybean line for yield and protein and oil content, based on its genetic makeup. The ability to improve the genetic characterization process for large numbers of individual soybean plants may lead to commercialization of superior soybean varieties.

Field Crop:
Soybeans



Project Objectives

1. Develop a genomic selection model in soybean germplasm that can accurately infer field performance strictly through genetic information
2. Optimize high throughput methods to genotype 1,000 individual plants and to retain the individuals in each cross that have the highest predicted yield
3. Compare how the lines selected strictly on genotype compare with those selected by the breeder based on individual plant selections in field trials for two years to determine yield

Successes

This project demonstrated a great collaborative effort between plant breeders and genomicists, working together to develop a work flow to very rapidly produce predictions for soybean breeders.

Through this project, researchers have performed the most extensive characterization of a relevant collection of soybean lines in eastern Canada, and have improved the efficiency of the genomic selection process at all stages. These improvements hold future promise for soybean growers to have access to new superior soybean varieties.

Researchers are waiting for final field results to demonstrate whether the genomic selection approach has potential as an alternative means to identify the most promising lines in a soybean breeding program.

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Canadian Research Consortium for Next Generation Selection in Soybean

Project 9

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Project Results

GENOMIC SELECTION MODEL
Using field trial and genetic marker data from a total of 275 soybean lines, researchers built a genomic selection model to predict six traits solely on genotype — yield, maturity, height, seed weight, seed protein content and seed oil content.

GENOTYPE PLANTS
More than 10,000 individual plants have been genotyped, from three different breeding programs. Individuals have been selected in each cross with the highest predicted performance.

FIELD TRIALS
Progeny from the individual plants selected were field tested to determine their agronomic performance based on six traits — yield, maturity, height, seed weight, seed protein content and seed oil content. Comparisons will then be made on the performance of lines selected only on genotype, compared with those selected by the breeder based on individual plant selection.

Because only preliminary yield trials will have been completed by March 2018, this will only allow for a preliminary assessment of the two breeding approaches. However, in the context of the Genome Canada project described below, this work will be continued and allow for a more definitive assessment by the end of 2019.

TRAINING
One PhD candidate worked on this project, and a research assistant gained valuable experience in genomic selection.

Future Opportunities

The cost of gene testing and predicting varietal performance is currently about $15-$20, and a future target would be to find ways to bring this price down significantly to make this technology more affordable. A new research project has been proposed for the new *Canadian Agricultural Partnership (CAP)* program aimed at finding ways to reduce the cost of genotypic characterization to under $2 per sample.

Researchers were able to leverage this work into a much larger Genome Canada Soyagen project to expand the scope of this work into new areas. Specifically, the work was expanded to provide breeders with enhanced tools to develop adapted varieties for western Canada (early maturity) and to address Phytophthora root rot, soybean cyst nematode and white mold related issues as well. This additional funding has resulted in much broader outcomes of this genomic selection project.

While this project was anchored in eastern Canada, if it becomes a promising approach to soybean breeding, it could be initiated in western Canada with western germplasm.

In Their Words

“Our new process may not change how long it takes from original cross to a commercial soybean variety, but we expect to make more progress each time new material becomes available to growers.”
- *François Belzile*

“It has been a very eye-opening process to show the soybean breeders from three public breeding programs involved in this project the amount of information that can be provided on soybean genetic material.”
- *François Belzile*

“To ensure soybeans remain a competitive crop for growers, we must develop varieties that have better gains in every breeding cycle.”
- *François Belzile*

Project 10

Oat genetic improvement

Region

Lead Researcher
Weikai Yan,
Agriculture and Agri-Food Canada

Background

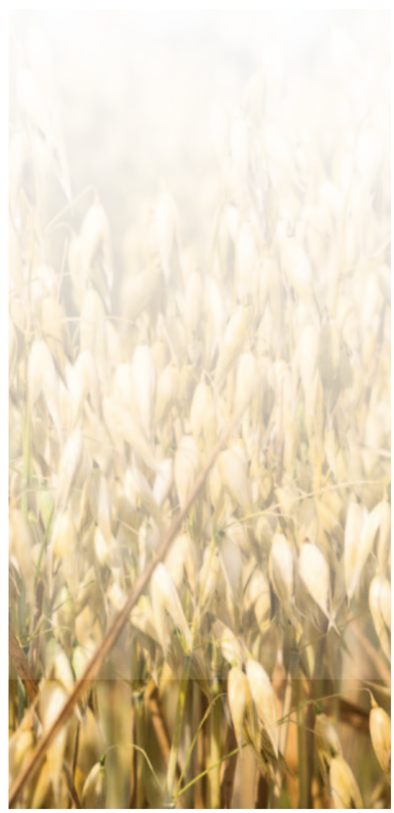
Canadian oats are primarily grown for human consumption and also for animal feed. As a result, much of the current oat plant breeding and research is driven by the oat milling industry that focuses on the nutritional benefits to market oats as a healthy food choice. To ensure oats meet the required standards as a healthy food choice for consumers, they must contain at least 4% beta-glucan, a soluble fibre with proven benefits on cardiovascular diseases and diabetes, and less than 7.5% fat.

Canadian oat growers rely on research and development of new oat varieties to maintain high yields, deliver high quality product to millers, combat disease pressure and manage variable growing conditions.

The biggest challenge in developing new oat varieties is to combine high and reliable yield in Canadian growing conditions while meeting milling requirements for beta-glucan and oil contents.

Another challenge with oat breeding and research is the lengthy process. This research builds on years of previous oat breeding and research, and aims to incorporate new methods to streamline selection and breeding techniques. Genomic selection is a data-driven approach to plant breeding, offering a new method for early generation selection that could improve the oat breeding practice.

Field Crop:
Oats



Project Objectives

1. Develop new oat varieties with improved yield and quality for eastern Canada
2. Determine the effects of agronomic practices like nitrogen fertilizer application and plant density on oat grain yield and quality
3. Test and implement genomic selection for use in early genetic screening for oat quality, disease resistance and agronomic traits
4. Identify oat breeding lines resistant to crown rust races

Successes

Nine new oat varieties were developed through this research project for growers and food processors, offering new opportunities to improve the yield and quality of oats grown in eastern Canada.

Specific varieties were bred to for crown rust resistance — AAC Banner, AAC Torrent and OA1426-2 have superior to good resistance to crown rust. Additional lines expected to be released in future years, including OA1453-2, OA14444-4 and OA1439-1 also have superior to good resistance to crown rust.

Genomic selection was introduced to oat breeding for the first time through this project. While conclusive results of genomic research applications won't be realized for a few years, the introduction of genomics will take genetic oat selection to a new level. Previous breeding selection methods relied solely on the individual breeder's selection that saw variations across fields and test plots, climate fluctuations and growing environments. The genomic selection approach has the potential to offer a new, streamlined selection method for early generation selection and is not affected by environmental factors.

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Oat Genetic Improvement

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Project 10

Project Results

VARIETY DEVELOPMENT

Seven new oat cultivars were released and licensed by Agriculture and Agri-Food Canada to seed companies from 2013 to 2018.

Climate fluctuations seen during the 2016 and 2017 growing conditions were challenging. The 2016 season was very dry, with limited disease pressure, while 2017 conditions were extremely wet, presenting high disease pressure. The variations between the growing seasons led to challenges in early generation selection.

Variety	Year released	Licenced to	Characteristics / Qualities
AAC Nicolas	**2014**	**SeCan**	• High yields across eastern Canada • High groat and ß-glucan levels • Quaker approved milling oat
AAC Pontiac	**2015**	**SemiCan**	• Short, lodging resistant, and rust resistant • Good milling quality • Good yield in southern Ontario
AAC Blake	**2015**	**SeCan**	• High yield • Moderately high ß-glucan
AAC Noranda	**2015**	**SemiCan**	• High ß-glucan (5%) • Good yield and groat levels • Quaker approved milling oat
AAC Kolosse	**2015**	**William Houde**	• Exceptionally good lodging resistance • Good yield, groat content, and crown rust resistance
AAC Banner	**2017**	**SeCan**	• High ß-glucan (5%) • Good yield and groat levels • Superior crown rust resistance and resistance to stem break • Quaker approved milling oat
AAC Torrent	**2017**	**Advantage Seeds**	• High ß-glucan (5%) • High yield and groat levels • Resistant to lodging and stem break
OA1426-2	**2018**	**SeCan**	• Very good yield • Exceptionally high test weight • Good levels of groat and ß-glucan • Highly resistant to crown rust
OA1436-1	**2018**	**SemiCan**	• Very good yield • Exceptionally high test weight • Low ß-glucan (good for feed)

MANAGEMENT RECOMMENDATIONS

New information on nitrogen application has resulted in better application recommendations for oat growers. A nitrogen rate study conducted at Ottawa, ON, Normandin, QC and Melfort, SK for nine diverse oat varieties (coordinated by Dr. Bao-luo Ma) indicated that nitrogen fertilizer up to 150 kg ha^{-1} led to not only higher grain yield and protein content but also higher beta-glucan content and lower oil content.

GENOMIC SELECTION

Considerable progress was made in oat genomics and bioinformatics such that procedures, tools and methods have been developed (in Dr. Nick Tinker's lab) and ready to use in genomic selection. The first test of this approach in oat breeding occurred in 2017 with encouraging results.

This oat breeding and research project took a multidisciplinary approach with a team of 10 scientists across Canada specializing in breeding, agronomy, pathology, genomics and grain quality. More than 10 test locations across Canada were used to conduct this project.

TRAINING

Post doctorate research scientist Dr. Wubishet Bekele in Dr. Nick Tinker's lab led the genomics research and will continue to analyze the results as he builds his expertise in this specialized genetic practice. Three additional doctoral students from China participated in the project as part of an agreement between Agriculture and Agri-Food Canada and the Chinese Ministry of Agriculture. More than 50 summer students were also hired and trained to assist with the breeding and research project.

Future Opportunities

High performing oat cultivars are important to oat growers and the development of new and superior varieties is extremely important to farm profits. The new varieties developed through this project have provided and will continue to provide oat growers in eastern Canada with higher yielding, reliable, productive and profitable oat crops that can be used as food, feed or cover crops.

New varieties developed also meet the needs of the value chain and the oat milling industry, with desired levels of beta-glucan content that provide consumers with healthier, more nutritious oat products.

Genomic selection was introduced to this oat breeding program for the first time through this project. It's expected this new breeding selection technology will be widely used and continue to improve as the science matures.

In Their Words

> "The multidisciplinary, nationwide collaboration was essential for developing superior varieties and oat management recommendations."
> - *Weikai Yan*

Project 11

Barley genetics

Lead Researcher
Alek Choo (retired) and Raja Khanal,
Agriculture and Agri-Food Canada

Region

Background

Barley is a major crop grown in eastern Canada as a source of energy for livestock, bedding for livestock and an ingredient for the malting industry. More than 150,000 hectares of barley are grown across the Maritime provinces, Quebec and Ontario, but that number is declining for reasons such as the greater rate of return from corn, soybeans, and wheat, as well as disease pressure and low yields.

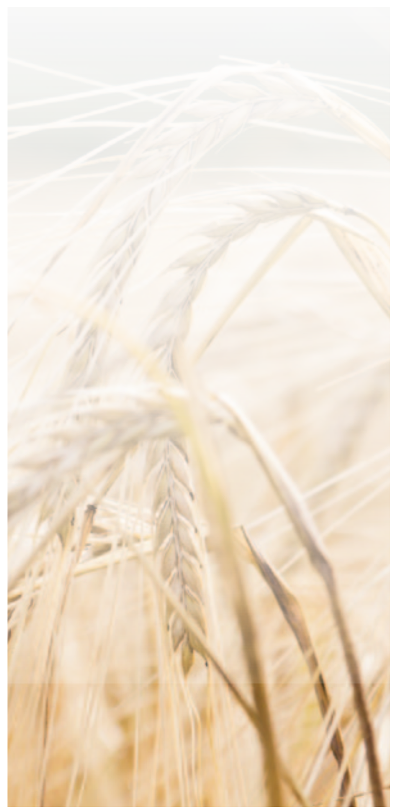
Producing malt barley for the popular microbrewery industry is a huge opportunity for growers, but many of the malt barley varieties have been developed for western Canada and do not perform as well in eastern Canada.

Fusarium head blight (FHB) is the biggest threat to barley grown in eastern Canada. This destructive fungal disease produces multiple mycotoxins, including deoxynivalenol (DON) that are harmful to human and animal health.

DON contamination occurs frequently across eastern Canada, making the development of high yielding, FHB resistant barley varieties urgently important.

Current methods of FHB resistance barley breeding selection are expensive and labour intensive. That is why this research project aimed to develop a new technique for screening breeding lines for low DON content.

Field Crop:
Barley



Project Objectives

1. Develop barley varieties for high yield and FHB resistance
2. Develop genetic biomarkers for selecting FHB resistance and desirable agronomic traits
3. Explore beneficial micronutrients and the potential development of functional foods and nutraceuticals from barley

Successes

Eight new barley varieties were released to growers in eastern Canada. The varieties offer growers new disease resistance and higher yields.

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Variety	Year Released	Licenced to	Characteristics / Qualities
AAC Mirabel	**2013**	**SeCan**	• Six-row spring feed barley • High grain yield and moderate resistance to barley yellow dwarf virus, powdery mildew, leaf rust, and loose smuts
AAC Starbuck	**2014**	**SeCan**	• Two-row hulless spring feed barley • High grain yield, high test weight, high seed weight, low DON accumulation
AAC Purpose	**2014**	**Bramhill Seeds**	• Two-row spring feed barley • High grain yield, very high seed weight, and resistance to powdery mildew and leaf rust
AAC Vitality	**2015**	**Advantage Seed Growers**	• Six-row spring feed barley • High grain yield, good resistance to lodging, good resistance to straw break • Late in heading and maturity • Moderately resistant to net blotch and spot blotch
AAC Montrose	**2015**	**SeCan**	• Six-row spring feed barley • Good standability and above average resistance to scald and DON accumulation
AAC Bloomfield	**2017**	**La Coop Fédérée**	• Six-row spring feed barley • High yield, high test weight, high seed weight, and good lodging resistance
AAC Bell	**2018**	**SeCan**	• Two-row spring barley • High yield, high straw yield, great lodging resistance • Resistant to powdery mildew, better resistance to smuts than checks in Maritime trials
AAC Ling	**2018**	**SeCan**	• Two-row spring barley • High yield, high straw yield, good lodging resistance • Resistant to powdery mildew, better resistance to smuts than checks in Maritime trials

Barley genetics

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Project 11

Project Results

VARIETY DEVELOPMENT

Eight new barley varieties have been released as a result of the research project, along with a number of advanced breeding lines waiting in the pipeline for variety development. Most of the varieties are bred to suit defined geographies — specifically eastern Canada.

Maritime and Quebec growers tend to prefer 2-row over 6-row barley. This shift in variety preferences is a result of the performance of 2-row varieties that are less susceptible to FHB and consistently deliver high yields. In Ontario, growers are still interested in planting 6-row barley to meet end-user preferences. The conclusion is that 2-row barley varieties perform better in the Maritimes and Quebec growing climates, leading to a shift in breeding and research efforts throughout the project to develop 2-row and 6-row barley varieties to meet grower demand.

DEVELOPMENT OF FUNCTIONAL FOODS

Advanced lines derived from the CDC Rattan/CDC Fibar cross were assessed on beta-glucan. The results indicate that beta-glucan viscosity would be more effective in the development of functional food barley due to its wider and distinct characteristics as compared to beta-glucan content. The current barley beta-glucan health claim is based on beta-glucan content that does not differentiate among low-, intermediate- or high-molecular weight beta-glucans. However, viscosity does differentiate among low-, intermediate- or high-molecular weight beta-glucan because it relates to molecular weight and concentration of beta-glucan. The result is that viscosity measurements reflect wider and distinct characteristics of beta-glucan and could aid in the development of functional food barley. Three lines were advanced to Maritime 2-row Barley Registration Test in 2017.

TRAINING

Research students were hired and trained each year throughout the project. Specific skills and training included in-field FHB evaluation, variety trial measurements and accurate disease and height scoring.

Additional Key Highlights

The new knowledge, outcomes and findings from this project have already been shared and published through a number of journals, including 14 reference papers.

Future Opportunities

The results of this barley breeding research project will be the foundation for further research in marker assisted selection and molecular breeding. The continuation of this breeding research will deliver more varieties to eastern Canadian growers and accelerate the advancement of barley breeding methods.

In Their Words

> Through this project we tried to help barley growers in eastern Canada overcome disease barriers and production challenges. We have a good sense of what growers are looking for and are delivering results.
>
> \- *Raja Khanal*

> We always want to improve our barley genetics and offer growers better seed for their fields. Access to the new varieties released through this project will directly help growers increase their barley yields and improve disease resistance.
>
> \- *Raja Khanal*

Project 12

In vitro and genomic selection to increase yield and FHB tolerance in barley for eastern Canada

Lead Researcher
François Belzile,
Université Laval

Region

Background

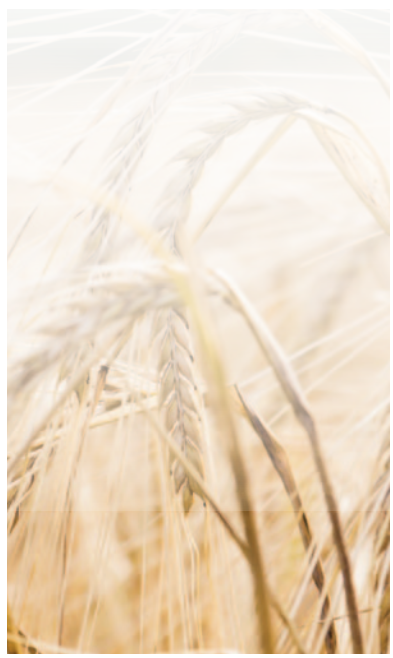
Fusarium head blight (FHB) is a devastating disease in barley and wheat for farmers in eastern Canada, and is most commonly caused by *Fusarium graminearum*. Researchers have had better results identifying wheat germplasm to offer some FHB resistance, but it has been difficult to find similar barley germplasm and this has led to a major decline in barley acres in eastern Canada.

FHB produces a potent mycotoxin (deoxynivalenol or DON) that helps it infect its host. DON is highly toxic to humans and animals when present in grain. In barley, one of the biggest impediments to breeding for increased resistance to FHB is the absence of known resistance genes that are able to provide a high degree of resistance or tolerance to the disease.

Another challenge in breeding for an FHB resistance trait is that measuring tolerance by DON content in grain is difficult and costly, and the sheer number of individual lines to test means testing can only be done on a limited scale. Testing results are also highly impacted by environmental conditions and only provide an approximate idea of a plant's reaction to the disease.

This project explored two new approaches to improve FHB tolerance in barley – *in vitro* selection and genomic selection. The goal of this work was to develop new selection methods for breeding barley lines with greater resistance to FHB, and to gain a better understanding of the genetic determinants for greater resistance to the accumulation of DON during FHB infection.

Field Crop:
Barley



Project Objectives

1. Explore two novel approaches for achieving improved tolerance to FHB in barley
   i. The first strategy focuses on the use of *in vitro* selection where barley microspores (immature pollen) are challenged with the mycotoxin DON in cell culture and some of the surviving microspores produce double haploid lines
   ii. The second strategy focuses on the use of genomic selection — identification of superior progeny on the basis of its genetic makeup and predicted performance

Successes

Based on very preliminary results, the severity of FHB and DON in barley lines selected by applying *in vitro* selection showed a slight reduction in FHB symptoms, and much lower levels of disease compared to lines from a traditional breeding program. The early data also suggests the genomic selection model will provide a good basis to select FHB-resistant lines of barley, which may help strengthen the opportunity for barley production in eastern Canada.

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In vitro and genomic selection to increase yield and FHB tolerance in barley for Eastern Canada

Project 12

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Project Results

The first two years of the project focused on selecting genetic material — through *in vitro* and genomic selection — to be used in research trials in the final years of the project to test whether the selected lines exhibit improved FHB tolerance in the field. As of March 2018, researchers are still evaluating DON level results.

IN VITRO SELECTION

Researchers examined 30-40 existing barley varieties to select those for *in vitro* resistance (IVR) to FHB, and only found one that had the level of FHB resistance they were expecting. This line was then crossed with non-IVR lines that had good field resistance to FHB. Crossing these lines combines different FHB resistance mechanisms that will be helpful for developing future barley varieties with a better package for FHB resistance. Preliminary results suggest that IV-selected progeny have superior field tolerance for FHB. On average, the IV-selected lines exhibited a lower severity of disease and a lower level of DON than the control lines derived from the same cross but that had not undergone IVS.

GENOMIC SELECTION

Through this project, researchers finalized their genomic selection model and used it to test 300 individual plants and select 30 lines for testing in field trials. Preliminary results are encouraging and demonstrate a correlation between FHB-tolerant performance based strictly on genetic makeup, and observed performance in trials.

Four advanced barley lines have been entered into official provincial registration trials, and researchers expect at least one will meet the required performance standards to be registered as a new FHB-tolerant barley variety in the future. These advanced lines are the product of the barley breeding program at Université Laval and were developed through conventional breeding. Superior lines derived from either *in vitro* selection or genomic selection work will continue to be advanced through the on-going breeding efforts.

TRAINING

One PhD student was recruited to work on this research project, and it constituted a significant portion of her project. A post-doctoral researcher was involved in the early *in vitro* culture work.

Future Opportunities

Researchers are coordinating efforts to develop a new barley breeding program in eastern Canada using lessons learned from this project, which will help boost the value of this crop. Colleagues in western Canada have expressed interest in this research project, and some researchers may integrate aspects of this work to establish a 2-row barley program.

There is a consensus among the research community that 6-row barley is more susceptible to FHB, and given the challenges of developing FHB-resistant varieties, researchers are considering work on 2-row barley by transferring the technology developed through this research project.

In Their Words

> "Developing new barley varieties with improved FHB resistance is difficult, but these two new strategies – *in vitro* and genomic selection – are showing promise."
> - *François Belzile*

> "Any improvements we can make in barley genetics to develop varieties with better FHB resistance will be very much appreciated by farmers and help keep this crop alive."
> - *François Belzile*

Project 13

In vitro and *in vivo* amino acid digestibility of selected soybean, oat and wheat varieties to identify targets with high protein quality and digestibility for future variety development

Region

Lead Researcher
Lamia L'Hocine,
Agriculture and Agri-Food Canada

Background

Protein is a vital part of a balanced diet, promoting health and providing essential amino acids. Canadians are fortunate to have access to a wide variety of protein food sources, but that is not the case in many countries around the world where health and environmental conditions create challenges for people to maintain a balanced diet that includes protein. This growing demand for protein provides an opportunity to develop high quality Canadian plant protein for export to developing and emerging global markets. Canada already exports grains and field crops to countries that struggle to access protein in their diets, and to many countries like China and India where plants serve as an important or sole source of protein. Improving plant protein quality is also a domestic opportunity where the interests of ethical and health conscious consumers are looking for a balance between animal and vegetable protein products.

In response to the growing global demand for plant protein and maintenance of protein levels, the Food and Agriculture Organization (FAO) of the United Nations released a newly revised protein quality measure recommendation for human health — the Digestible Indispensable Amino Acid Score (DIAAS). The new DIASS method of measuring protein quality requires the analysis of individual amino acids and has recently replaced the previous recommended measurement method. This new measurement will assess the nutritional value of a protein by its contribution to amino acid and nitrogen requirements and the amounts of amino acids absorbed by the body.

Plant proteins have lower digestibility than animal proteins and the new DIAAS measurement could dramatically change the protein quality rating. Protein quality is affected by the presence of anti-nutritional factors like trypsin inhibitors, phytic acid and tannins.

As a result of the new FAO protein measurement, an overview and re-evaluation of the protein quality and assessment of the impact of varietal differences on protein quality and digestibility of Canadian oat, soybean and wheat was needed. This research project assessed the nutritional quality of select Canadian oat, soybean and wheat varieties, and compared them to the new FAO measurements.

This assessment will guide future variety development work for these crops, focusing on protein quality and levels. The resulting field crop research and variety development will enable Canadian growers and processors to pursue domestic and export market opportunities by offering quality oat, soybean and wheat with desirable protein levels.

Field Crop:
Oat, soybean, wheat

Project Objectives

1. Assess the effect of varietal differences of Canadian oat, soybean and wheat on protein quality and digestibility using the revised FAO recommendations.
2. Identify oat, soybean and wheat varieties with bioactive peptide and prebiotic potential that can be marketed for their promotion of digestive health
3. Study the functional properties of varieties with the most promising traits to identify targets for future variety development

Successes

The results of this project will lead to improvements in the nutritional quality of Canadian oat, soybean and wheat. New data on the nutritional quality of 30 wheat varieties, 30 oat varieties and 26 soybean varieties were generated on the basis of amino acid composition and *in vitro* digestibility. In general, despite variations in certain amino acid concentrations between the varieties studied similar amino acid distribution patterns were observed from one variety to another. The highest variability was observed among oat varieties, and a strong effect of growing location on amino acid concentrations was also observed on a "per gram of flour" and a "per gram of protein" basis. These results suggest an impact not only on the grain protein content, but also on its composition.

As a result of the research project, potential amino acid profiles and amino acid digestibility coefficients can now be evaluated and used as a strategy to screen and classify oat, soybean and wheat varieties for distinctive protein quality traits.

Protein quality is not just a nutritional aspect, it is also functional, offering health benefits like antioxidant peptides. The project results now provide researchers with additional information to evaluate oat, soybean and wheat varietal influences and thermal treatments on protein bioactive properties for their potential incorporation in functional and nutraceutical foods. A process to evaluate grains for prebiotic potential to market the products for the promotion of digestive health is now available as a result of this research project.

Oat, soybean and wheat are important economic crops to Canadian growers, seed companies, processors and exporters. This research work provides the agricultural industry with crucial information and science-based knowledge of protein nutrition, biological and health properties. The study revealed that the growth of selected probiotics is affected by the type of grain and by cooking. The project research suggests that beyond the nutrition value, grains can also have prebiotic effects that can be modified by processing. Consumer interest in the effects of food and food components on health continues to grow, offering significant potential for value-added grains by identifying and enhancing the functional components.

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In vitro and *in vivo* amino acid digestibility of selected soybean, oat and wheat varieties to identify targets with high protein quality and digestibility for future variety development

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Project 13

Project Results

EVALUATION PROCESS

A selection of Canadian oat, soybean and wheat varieties with high and low protein content was acquired from plant breeders to:

1. Assess the nutritional quality of the selected varieties for amino acid composition, digestibility using an *in vitro* method (lab system to model human digestibility) and the calculation of the new DIAAS.
2. Perform *in vitro, in vivo* (animal digestibility testing) protein and ileal digestibility tests on selected varieties.
3. To simulate real-life samples of the processed products, raw and uncooked flours were also analyzed to assess the impact of processing (thermal treatment) on protein and amino acid digestibility.

NEW INFORMATION

This research project delivered new information on the composition, physicochemical and nutritional properties of 30 oat, 26 soybean and 30 wheat varieties.

The project also worked with oat varieties grown in different locations to evaluate the gene (G) x environment (E) (variety x location) effect, collecting valuable data on the impact of these factors on their nutritional properties. Data obtained from the growing location (GxE) subset of samples shows the important impact environmental conditions have on the nutritional profile of the crops tested. The results of this information, including amino acid profiles and protein nutritional quality scores, can be useful in nutritional considerations for future variety development.

The project was able to evaluate the oat, soybean and wheat varieties using the new DIAAS method, and compare the results to the previous FAO recommended methods for assessing protein quality. The *in vitro* method offers a more rapid and affordable option when compared to the currently recommended *in vivo* bioassays, or former PDCAS testing methods.

RESULTS COMPARISON

The cost of *in vivo* testing is significantly higher than *in vitro*. Both tests were performed through the project to assess and identify a more streamlined, cost effective research process for future projects assessing digestibility.

The evaluation of the efficacy of affordable and convenient *in vitro* methods was conducted to accurately estimate protein nutritional quality when compared to the FAO's recommended *in vivo* method.

Selected varieties with higher protein quality and digestibility were identified and subjected to both *in vitro* and conventional *in vivo* protein digestibility tests.

Improvements of an *in vitro* human digestion model were made by the development of an ileal digestion step to assist with the prediction of true ileal protein and amino acid digestibility, which is now the new recommended method for protein quality assessment. Ileal digestion measures amino acid digestion at the end of the small intestine rather than the overall digestibility of a protein over the total digestive tract.

THERMAL PROCESSING EVALUATION

For the first time, information on protein quality and protein and amino acid digestibility of processed oat, soybean and wheat products is available as a result of the thermal testing conducted through the project. Final food products typically undergo thermal treatments like cooking, baking and boiling before being eaten and digested. Thermal process testing was used to simulate common food products from selected varieties of each crop to determine if protein quality and digestibility changed through the thermal process.

A preliminary evaluation of the bioactive and prebiotic potential was undertaken for selected oat, soybean and wheat varieties, which can be marketed for their promotion of digestive health.

The research project also trained several national and international highly qualified personal, including four post-doctorate researchers and three undergraduate trainees.

Additional Key Highlights

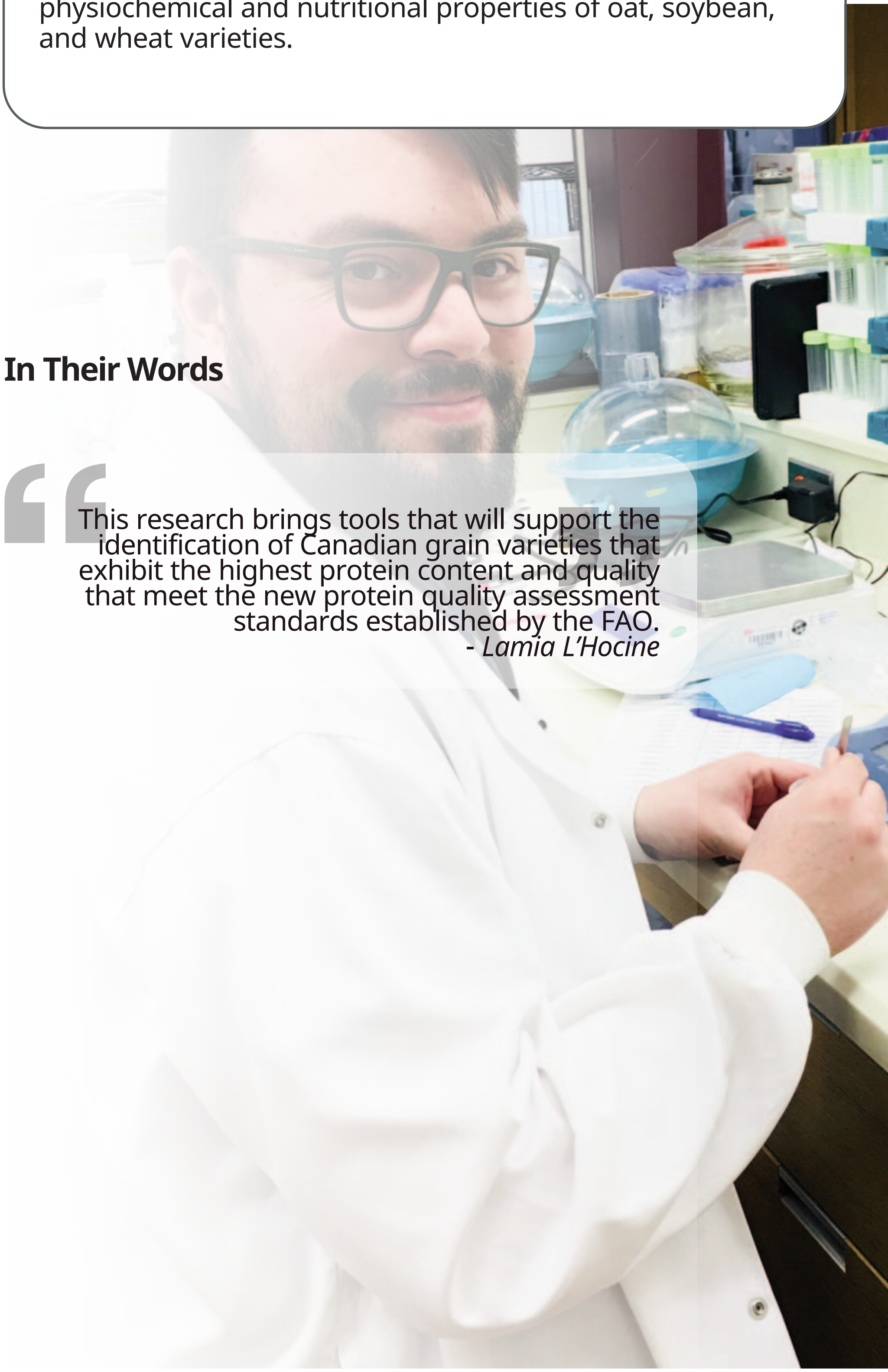
This project delivered new information on the composition, physiochemical and nutritional properties of oat, soybean, and wheat varieties.

Future Opportunities

This research will allow plant breeders to develop markers for screening and develop crop varieties with distinctive value-added health benefits, resulting in leading edge marketability for domestic and international markets. This information also opens opportunities for Canadian growers and processors to capture new and growing global needs for functional foods. The profitability and sustainability of the Canadian agri-food industry is also enhanced with the ability to provide highly nutritional and functional quality protein sources to the market.

A new complementary but different research project is already underway, studying the impact of oat varieties on the generation of antioxidant peptides during *in vitro* simulated human digestion.

In Their Words



"This research brings tools that will support the identification of Canadian grain varieties that exhibit the highest protein content and quality that meet the new protein quality assessment standards established by the FAO."

- *Lamia L'Hocine*

Canadian Field Crop Research Alliance Research Summit

Region

Overview

In November 2016, the Canadian Field Crop Research Alliance (CFCRA) invited more than 50 researchers, industry representatives, end-users and government officials from across the value chains that make up the Canadian field crop sectors for corn, soybean, oat and eastern Canadian barley, to discuss and evaluate the research gaps for these Canadian field crops and to set the direction for future research. The strategic brainstorming session was held in Gatineau, QC on November 1-2, 2016 and the outcome was a set of research priorities for each crop.

The Summit was the first event of its kind for these field crop sectors, creating a unique opportunity to support the CFCRA's overall goal to advance the genetic capacity of field crops in Canada. The event provided valuable input for the CFCRA on research that can fulfill market needs and support Canadian farmers.

Through a series of engaging panel discussions, end user presentations, and interactive case studies, the Summit provided a unique process to ensure future agri-food industry research is relevant and adds value to Canadian farmers and today's marketplace. Attendees were consulted on how to maximize the value of research through market share, profitability, investment levels, increasing research talent, improving research capacity, and the practical research application to Canadian farmers and consumers.

A key focus of the event was collaboration and networking to drive Canadian research and the field crop sectors forward over the next 5-10 years. Working toward common goals aligns funding and research priorities and maximizes the value of research outcomes.

Read the full list of Summit outcomes and research priorities at www.fieldcropresearch.ca.

Field Crop:
Barley, Corn, Oats, Soybeans

Summit Outcomes

The CFCRA Research Summit demonstrated a true collaboration between the Canadian agri-food industry and the research community. The event was the first time research cluster representatives came together with the industry and research community to collectively discuss the future direction of Canadian field crops research to benefit Canadian farmers and the value chains they serve. The CFCRA Summit created an opportunity that would not otherwise have been possible.

The objective of the Summit was achieved with the development of a list of research priorities for barley, corn, oat and soybean for the next decade that will help achieve the CFCRA's overall goal of advancing the genetic capacity of field crops in Canada. The priority list is available at www.fieldcropresearch.ca.

The open discussion format and collaborative approach to the Summit helped eliminate silos and research duplication among and within the research community, government and agri-food industry.

The Summit also facilitated a new network of relationships across the agri-food industry, government and research communities. The open format and dynamics of group participants provided the opportunity to debate, discuss and develop collaborations for plant breeding and field crop research in general.

The Summit was a flagship event for the CFCRA, leveraging industry, researcher and government expertise to develop a path that should drive the field crop sectors forward over the next 5-10 years.

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Canadian Field Crop Research Alliance Research Summit

Project 14

Summit Highlights

GAP ANALYSIS

The two-day Summit opened with a review of research priorities for barley, corn, oat and soybean. The CFCRA surveyed the research community and Canadian agri-food industry representatives prior to the Summit to develop a working list of research priorities for the Summit.

A facilitated gap analysis discussion identified any gaps in current and proposed priorities. Breeding targets were developed for each crop and key research gaps were identified in the areas of weed, insect pest, disease management, management of nutrients, and other agronomic and environmental management considerations.

PANEL DISCUSSIONS

Commodity experts and food processing representatives participated in a panel discussion, helping Summit attendees understand the needs of the current consumer food and feed marketplaces and how the market is expected to change. Insights from the industry-based panel brought the food processor, feed processor, consumer, and end-user perspectives into the discussion, emphasizing the need for research and suggesting areas where research could make improvements.

CASE STUDIES

Crop-specific and general research case studies were presented, reviewed and discussed. Attendees were asked to identify approaches and targets for each of the case studies. Crop-specific case study topics:

- Enhancing barley yields and Fusarium head blight resistance
- Enhancing oat yields
- Enhancing corn yields with improved agronomic attributes adapted for western Canada
- Enhancing soybean yields in conventional varieties
- Enhancing soybean yields in short-season varieties
- Improving nitrogen management in multiple crops
- Coordinated disease, insect pest and weed surveys

Participants also reviewed and assessed general research case studies, providing feedback and recommendations to the CFCRA. Research case study topics:

- Enhancing knowledge transfer results
- Proactively addressing environmental and climate change risks
- The potential for using 'Big Data'
- Measuring return on research investment

STRETCH QUESTIONS

A series of six 'stretch questions' were posed to Summit participants. The questions were designed to encourage 'out of the box' thinking about future priorities for field crops research.

1. What is the best opportunity for achieving cross-commodity efficiencies in CFCRA-funded research?
2. What is the best opportunity for achieving efficiencies in commodity needs across geographies including provincial boundaries?
3. What have you learned from other competitive granting processes for research projects in this sector that will help achieve these priorities?
4. What is one high impact outcome that you believe a national research investment can achieve?
5. What do you anticipate will be "the next big thing" in our sector?
6. Why can't the private sector fund these research priorities on its own? Why is it appropriate and necessary for public funds to be used as well?

For more details on the outcomes of the CFCRA Research Summit, please visit www.fieldcropresearch.ca.

Acknowledgements

About the CFCRA

The Canadian Field Crop Research Alliance (CFCRA) is a not-for-profit entity founded in 2010 with an interest in advancing the genetic capacity of field crops in Canada, particularly barley, corn, oats, soybeans, and wheat. The CFCRA is comprised of provincial farm organizations and industry partners, including: Atlantic Grains Council; Producteurs de grains du Québec; Grain Farmers of Ontario; Manitoba Corn Growers Association; Manitoba Pulse and Soybean Growers; Saskatchewan Pulse Growers; Prairie Oat Growers Association, SeCan Association; and FP Genetics.

Industry funders of the Canadian Field Crop Genetics Improvement Cluster included: Atlantic Grains Council, Producteurs de grains du Québec; Grain Farmers of Ontario; Manitoba Corn Growers Association; Manitoba Pulse and Soybean Growers; Saskatchewan Pulse Growers; SeCan Association, and PepsiCo Global R&D.

More information is available at www.fieldcropresearch.ca.

Acknowledgements

The Canadian Field Crop Genetics Improvement Cluster was a collaboration between the Canadian Field Crop Research Alliance (CFCRA) and Agriculture and Agri-Food Canada (AAFC).

Funding for this project has been provided by Agriculture and Agri-Food Canada through the *Growing Forward 2 (GF2)* AgriInnovation Program.

Growing Forward | Cultivons l'avenir

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada