CTAG
Canadian Triticum Advancement through Genomics

Increasing Canada’s Contribution to Food Security: From Genome to Farmers Fields
THE HISTORY OF WHEAT BREEDING IN CANADA

Wheat domestication took place in the Middle East around ten thousand years ago.

It wasn’t until 1605 that wheat made its way to Canada where it was first produced in Nova Scotia. It is thought that production made its way west to the Manitoba region in the early 1800s with the Selkirk Scottish settlers. The first few attempts at production did not succeed due to weather, inexperience, grasshoppers, and unsuitable varieties. It was not until farmers travelled to Wisconsin to purchase new seed that they started to see some success. The arrival of the Ukrainian wheat variety known as Red Fife in 1842 saw dreams of large scale production become a reality. Advancements in milling technology and rail lines allowed Canada’s production to take off and in 1882, production finally started to exceed demand. Red Fife soon became known as the best variety available and was the top choice for producers for about 20 years.
In the late 1800s, government officials recognized the need for new and improved varieties and started to collect and test wheat varieties from around the world. Traits such as higher yield and early maturity were targeted, while still maintaining the high quality flour that Red Fife was known for. After many years of disappointing results, it was decided to return to Red Fife and cross it with other varieties to create a new one. In 1888, the first crosses were made in Ottawa. By 1892, the team of scientists moved out west and started crossing experiments in Manitoba, Saskatchewan, and British Columbia and in 1901, 58 lines showed desirable traits and would go on for further testing in the hopes that they could become new varieties. After successful field scale trials, the variety Marquis was publicly distributed in 1909. By 1918, Marquis was grown on 20 million acres and totaled more than 300 million bushels in production from southern Nebraska to northern Saskatchewan. At US$2/bushel, the harvest of Marquis in 1918 was valued at over US$600 million making it known as one of the greatest agricultural triumphs of all time. If calculated at $7.50 per bushel, this would work out to a value of over $2.5 billion from one variety for a single year of production.

DID YOU KNOW

One bushel of CWRS wheat:

» weighs 60 pounds or 27.22 kilograms
» yields 45.5 pounds or 20.64 kilograms of white flour
» yields 57 pounds or 25.85 kilograms of whole wheat flour
» makes 70 loaves of white bread baked weight of 1 pound
» makes 90 loaves of whole wheat bread baked weight of 1 pound

Source: Canadian International Grains Institute

Cutting Marquis Wheat in Beatty, Saskatchewan
As breeding efforts continued, so did the increase in wheat acres in the Prairie Provinces. Between 1910 and 1952, Alberta, Saskatchewan, and Manitoba generated over $22.8 billion of income from wheat. Canada quickly became known for its high quality, high protein wheat and by 1916, Canada overtook the United States as the world’s number one exporter of wheat.

In 1981, several farmer organizations got together with Agriculture and Agri-Food Canada to create a research funding organization to manage producer dollars. Western Grains Research Foundation was created and started to collect the wheat and barley check-offs in the 1993-94 crop year. Funds are leveraged to attain additional investment from government programs and are used to support many public research projects and breeding programs. The increased funds for wheat breeding has led to an increase in the genetic diversity of wheat varieties, which was on a steady decline since the 1950s.

In 2013, total wheat acres seeded for Canada were about 25.9 million, with 14 million of those acres in Saskatchewan. Approximately 70% of all wheat planted in Canada is Canadian Western Red Spring (CWRS), 16% is winter wheat, and the remaining amount is distributed between other spring wheat classes. Canada exports about 70% of its production which over 10 years (2001 to 2011) is an average of over 11 million tonnes. Major importing countries of Canadian wheat include Mexico, Japan, Iraq, United States, and Columbia.
A group of Canada’s top wheat breeders and researchers have joined together to take part in the international effort to sequence the wheat genome.

Canada’s contribution, called Canadian Triticum Advancement through Genomics, or CTAG, started in 2011 and is led by the University of Saskatchewan. CTAG is part of the collective international group, the International Wheat Genome Sequencing Consortium (IWGSC), which is made up of over 20 different countries. The goal of the IWGSC is to create a high quality reference genome sequence of the bread wheat genome using DNA from the variety Chinese Spring. Canada’s contribution will be to sequence chromosome 1A and to develop a database of all the genes which can be used for marker assisted selection and genome-wide selection strategies. The project will also look at public-private partnerships in wheat genomics and breeding and which models show the best return on investments.
With the recent advancements in genomics, this type of research will give breeders more tools to use in their breeding programs. This will not only speed up the development of new lines, but will make the breeding process more efficient.

**THE PROJECT HAS THE FOLLOWING KEY OBJECTIVES:**

**OBJECTIVE 01**

**TO SEQUENCE CHROMOSOME 1A OF WHEAT**

The structure of the wheat genome allows each one of the 21 chromosomes to be sequenced separately. Researchers on the CTAG project are focusing on chromosome 1A and are working with researchers in Switzerland and Turkey to complete the sequence. Chromosome 1A contains important genes that determine dough strength and disease resistance. Being part of the international consortium, Canadian breeders also have access to information found on other chromosomes. The breeding program at the University of Saskatchewan’s Crop Development Centre has already been making use of genes found on other chromosomes. Chromosome 3B contains genes that are responsible for stem thickness, which in turn provides resistance to the wheat stem sawfly. In addition to work on chromosome 1A, the CTAG team has also contributed to the sequencing of chromosome 6D.
TO SEQUENCE THE EXOME OF KEY CANADIAN WHEAT CULTIVARS

Currently 69 wheat cultivar exomes that have been sequenced as part of the CTAG project. International collaborations will result in the sequencing of over 100 wheat lines which will lead to a greater understanding of the genetic diversity in the global collection of wheat germplasm.

TO IDENTIFY SINGLE NUCLEOTIDE POLYMORPHISM (SNP) MARKERS FROM CANADIAN WHEAT CULTIVARS AND ASSOCIATE THESE SNPS WITH TRAITS RELEVANT TO THE CANADIAN WHEAT INDUSTRY.

SNP is when there is variation in the DNA sequence at the nucleotide level between members of the same species. It is one of the most common types of genetic variation and is what makes each wheat cultivar unique from another. Over 100,000 SNPs have been identified to date and both bread and durum SNPs are being identified. This data has led to the development of several useful markers that have already been deployed for marker-assisted selection in Canadian wheat breeding programs.
DEPLOYMENT OF HIGH THROUGHPUT SNP GENOTYPING FOR WHEAT BREEDING AND TO DEVELOP A HIGH THROUGHPUT SNP PLATFORM FOR CANADIAN WHEAT.

SNP markers will be used in the wheat breeding program to help select parents for crossing and for early identification of lines to be advanced. Each marker is associated with a particular trait and when identified, can be used to quickly screen lines for the desired traits. The CTAG team has compiled a phenotypic database from a series of mapping populations that have been genotyped for many important agronomic, disease, and end use quality traits. To do this, lines are grown out and their phenotypes, or observable properties, are recorded. This is then compared to the genotype, or genetic information.
TO EXAMINE THE ROLE OF PUBLIC BREEDING INSTITUTIONS

France, UK, Germany, Brazil, Australia and USA models of public-private relationships are being compared to see what model would provide the greatest benefit to Canada economically, socially and environmentally. It will also provide wheat breeders with information on availability, ownership, and accessibility of trait and genomic technologies that could potentially be used within Canadian breeding programs.

The ultimate goal of the CTAG project is to use these new technologies to release new, higher yielding sustainable cultivars adapted to Canadian environments to improve producer returns and ensure a stable food supply in Canada and globally.

Source: www.wheatgenome.org
BENEFITS TO PLANT BREEDING

Cultivars must continually be improved to cope with changes in the production environment.

Virulent new races of existing pests and appearance of new biotic agents requires constant breeding and evaluation of new lines. All major wheat growing regions, including Canada, are at risk from the development of new races of stem rust. The virulent stem rust race UG99 is a current example of how mutations in a pathogen can overcome host resistance. While adequate resistance to UG99 was found in some Canadian common and durum wheat cultivars, selection to carry this resistance into future cultivars is largely a matter of chance unless appropriate DNA tools can be applied for selection given that phenotypic selection is not possible in Canada as long as UG99 has not reached the North American continent.

Newly designed markers for resistance to the orange wheat blossom midge and the wheat stem sawfly will have immediate impacts on developing new cultivars that express this resistance. The markers that we have developed from SNPs are much more closely linked to the resistance genes, so that marker-assisted selection (MAS) will provide larger populations of resistant lines to move forward
Wheat has the potential to be a platform to deliver health benefits to Canadians because it is a widely-consumed food.

Genetic resistance offers the most cost-effective and environmentally acceptable means of reducing economic losses and food safety hazards caused by diseases or pests. Genetic resistance is a major public good in that it encourages the use of IPM (Integrated Pest Management), reducing our dependence on pesticides for stable wheat production. For producers, it means reduced production costs - extremely important in the non-subsidized Canadian industry, and a marketing advantage due to low residues of agricultural chemicals on harvested grain, which is attractive to both
Canadian consumers and export customers. Genetic resistance to major insect pests such as the orange wheat blossom midge and wheat stem sawfly is a current example, selection for which has been facilitated by the outcomes of this project.

Climate change will likely affect agricultural production in Canada in the future. Models suggest that western Canada will become drier, and that winters are likely to be less severe, so that pests may over-winter and attack crops earlier in the growing season. A recent model suggests that average precipitation may not change in western Canada but drought severity may increase. Our ability to overcome these abiotic and biotic stresses in a timely manner will be greatly enhanced by the wheat genome information and tools created in this project.
Dr. Curtis Pozniak (left), durum and CPS wheat breeder, and Dr. Pierre Hucl (right), spring wheat breeder.
CTAG is led by the two wheat breeders at the University of Saskatchewan’s Crop Development Centre.

Dr. Curtis Pozniak, durum and CPS wheat breeder, and Dr. Pierre Hucl, spring wheat breeder, are the project leaders and have brought together more than 20 researchers from across Canada and the world.
Dr. Curtis Pozniak
Project Leader
University of Saskatchewan, Associate Professor and Durum and CPS wheat breeder

Dr. Pozniak completed his Bachelor of Science in Agriculture at the University of Saskatchewan and went on to complete his PhD. under Dr. Pierre Hucl’s supervision. He is an expert in wheat breeding and genetics is the co-lead for SNP identification and mapping efforts for CTAG.

Dr. Andrew Sharpe
Co-Primary Investigator
National Research Council, Research Officer

Dr. Sharpe is the project lead for the high-through-put sequencing and bioinformatics.

Dr. Dean Spaner
Co-Primary Investigator
University of Alberta, Professor in Wheat Breeding and Genetics

Dr. Spaner is an expert in wheat breeding, genetic mapping and will contribute to field based phenotyping experiments.

Dr. Mark Jordan
Co-Primary Investigator
Agriculture and Agri-Food Canada, Research Scientist

Dr. Jordan is an expert in and will contribute to SNP discovery and mapping and comparative genomics.

Dr. Curt McCartney
Co-Primary Investigator
Agriculture and Agri-Food Canada, Research Scientist

Dr. McCartney is an expert in and will contribute to SNP discovery and mapping and comparative genomics.

Dr. Faouzi Bekkaoui
Co-Primary Investigator
National Research Council, Executive Director of Wheat Improvement Flagship Program

Dr. Bekkaoui is an expert in project and bioinformatics management.

Dr. Pierre Hucl
Project Co-leader
University of Saskatchewan, Professor and Spring wheat breeder

Dr. Pierre Hucl completed his Bachelor of Science and Masters of Science at the University of Guelph. He then came to the University of Saskatchewan to complete his PhD. He is an expert in wheat breeding and genetics as well as canary seed. He is the project lead for the phenotyping components.

Dr. Harpinder Randhawa
Co-Primary Investigator
Agriculture and Agri-Food Canada, Research Scientist

Dr. Randhawa is an expert in wheat expressed sequence tag (EST) mapping and breeding. He will also contribute to SNP mapping efforts.

Dr. Ron Knox
Co-Primary Investigator
Agriculture and Agri-Food Canada, Research Scientist

Dr. Knox is an expert in genetic mapping and application of genetic technology to wheat breeding. He will contribute to SNP mapping and trait associations.

Dr. Viktoriya Galushko
Co-Primary Investigator
University of Regina, Assistant Professor

Dr. Galushko is the co-lead to the research on public-private partnerships and socio-economic impact of wheat breeding and has expertise in intellectual property related to cereal breeding.

Dr. Richard Gray
Co-Primary Investigator
University of Saskatchewan, Professor

Dr. Gray is the co-lead to the research on public-private partnerships and socio-economic impact of wheat breeding and has extensive experience in biotechnology policy.
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CHRIS BARKER
Scientific Advisory Board Member and Chief Scientific Officer for Genome Prairie

THE INTERNATIONAL WHEAT GENOME SEQUENCING CONSORTIUM (IWGSC)

The IWGSC is a group of scientists, breeders and growers that are dedicated to sequencing the wheat genome. Their role is to develop strategic plans, goals, and to facilitate research projects at a national and international level. By sequencing the wheat genome, the group hopes to create new molecular tools that any breeder can use to accelerate the breeding process. The IWGSC is governed by six co-chairs, a Coordinating Committee, and an executive director.
Sequencing the entire wheat genome is estimated to cost about $21.6 million CAD and will be completed by 2016.

The CTAG project alone will receive $8.5 million CAD in funding with $1.6 million going towards the sequencing and assembly of chromosome 1A.

FINANCIAL SUPPORT IS RECEIVED FROM THE FOLLOWING ORGANIZATIONS:

GENOME CANADA

Together with its six Genome Centre’s and with other partners, Genome Canada invests in and manages large-scale research projects in key selected areas such as agriculture, environment, fisheries, forestry, health and new technology development.

Genome Canada also supports research projects aimed at studying and analyzing the ethical, environmental, economic, legal and social issues related to genomics research (GE3LS). Genome Canada has provided the CTAG project with $4.1 million in funding.
GENOME PRAIRIE

Genome Prairie supports stakeholders across Manitoba and Saskatchewan in capturing and maximizing the benefits of advanced research in genomics and related biosciences.

This role is achieved by aligning the partners and resources needed to develop and manage targeted projects addressing regional priorities. Genome Prairie also enables participation among regional researchers in Genome Canada’s competitive granting process for large-scale projects.

SASKATCHEWAN MINISTRY OF AGRICULTURE

The Ministry fosters a commercially viable self-sufficient and sustainable agriculture and food sector.

The Ministry encourages farmers, ranchers and communities to develop higher value-added production and processing and promotes sustainable economic development in rural Saskatchewan through better risk management. Funding of $1.5 million has been received from Saskatchewan Ministry of Agriculture.

ALBERTA CROP INDUSTRY DEVELOPMENT FUND

ACIDFs mission is to provide resources to increase the competitiveness of Alberta farmers through leadership in innovation, market development and research.

This role is achieved by aligning the partners and resources needed to develop and manage targeted projects addressing regional priorities. Genome Prairie also enables participation among regional researchers in Genome Canada’s competitive granting process for large-scale projects.
WESTERN GRAINS RESEARCH FOUNDATION

The benefits from the Western Grains Research Foundation (WGRF) wheat check-off, a voluntary producer contribution to supplement funding for wheat breeding, show that every dollar invested in wheat research generates $4.40 in benefits.

The corresponding rate of return to wheat breeding was at 23.8%. The WGRF has committed over 1.2 million dollars of co-funding to this project, showing that producers recognize the need and value to implement the latest in technologies into breeding programs.

ALBERTA INNOVATES

Alberta Innovates is a service organization for technical industries, to accelerate the growth of prosperous business in Alberta.

It facilitates the commercialization of new technologies, the development of new knowledge-based industry clusters, and the establishment of an entrepreneurial-based culture across the province.

VITERRA

Viterra is a leading grain and oilseeds marketer and handler.

They partner with growers in Canada and the USA to help them market and deliver their grains in more ways and to more markets, than any other company in the business.
The research that is being done through the CTAG projects will help Canada remain competitive in the global market and will help Canadian producers meet increasing demands for Canadian wheat.

Long term economic benefits include food safety, security, public health and sustainable production practices that protect the environment. The tools that will come out of this research will assist breeders and scientists in continually improving varieties through trait selection. These were important aspects of the projects proposal - not only finding the information but making sure it can be applied.

The CTAG project is also helping to secure future research through training and education opportunities for new scientists. Within CTAG, there are 8 graduate students and 5 Postdoctoral fellows that are learning these new methods of genomic research.