THE HARVEST

CANADIAN NATIONAL WHEAT IMPROVEMENT PROGRAM

RESEARCH SUMMARY

What's inside:

Meet the researchers

Success stories

Advances in pest and disease resistance

Harnessing breeding technology and tools

Next generation wheat breeders

Varieties developed through the Wheat Cluster will contribute to the continued success of producers and have an important impact on Canadian and rural economies.

NATIONAL WHEAT CLUSTER DELIVERS INNOVATION TO CANADIAN PRODUCERS

Canadian growers will soon have access to 61 new wheat varieties offering higher yields, better quality and improved disease resistance. This surge in wheat innovation is thanks to the Canadian National Wheat Improvement Program (Wheat Cluster) – an initiative under the federal AgriInnovation Program – Industry-led Research and Development Stream, Agri-science cluster.

The total investment of more than $25 million was funded by Agriculture and Agri-Food Canada (AAFC) combined with industry contributions from the Western Grains Research Foundation (WGRF), the Alberta Wheat Commission (AWC) and the Canadian Field Crop Research Alliance (CFCRA) CFCRA partners supporting wheat research include: Atlantic Grains Council, Grain Farmers of Ontario, Producteurs de grains du Québec, and SeCan Association.

The five-year program, which wrapped up in 2018, was led and administered by WGRF who has invested almost five million dollars annually into wheat breeding research on behalf of producers in Western Canada since 1995.

In total, the Wheat Cluster resulted in 50 research projects facilitated by 32 researchers across the country. Research activities were carried out at AAFC, University of Alberta, University of Manitoba, University of Saskatchewan, University of Guelph and Le Centre de recherche sur les grains (CÉROM) in Quebec. The work done at these institutions addressed regional needs and contributed to the development of enhanced germplasm and breeding tools that increased the efficiency of all breeding programs.

Ongoing and increased investment in research is needed for producers to continue to have access to the best performing wheat varieties – ones that offer higher yields, stronger disease and insect resistance, and the ability to better withstand environmental conditions – while meeting the strict quality standards required to address market needs.

The goal of this report is to showcase the many projects and people that helped make the Wheat Cluster so successful. The wheat varieties developed through the Wheat Cluster will contribute to the continued success of producers and have an important impact on Canadian and rural economies.

Wheat Cluster by the numbers

$25 million investment
(AAFC: $12.5; WGRF: $9.6 million;
AWC: $1.3 million; CFCRA: $1.7 million)

50 research projects

32 researchers across Canada

61 new varieties

5 YEARS
2013 – 2018

Wheat Cluster funders

Canada

Western Grains Research Foundation

Alberta Wheat Commission

CFCRA
CANADIAN FIELD CROP RESEARCH ALLIANCE

ARCCC
ALLIANCE DE RECHERCHE SUR LES CULTURES COMMERCIALES DU CANADA

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MEET THE RESEARCHERS

THIRTY-TWO RESEARCHERS PARTICIPATED IN WHEAT CLUSTER WORK. HERE'S A CLOSE-UP LOOK AT 13 OF THEM.

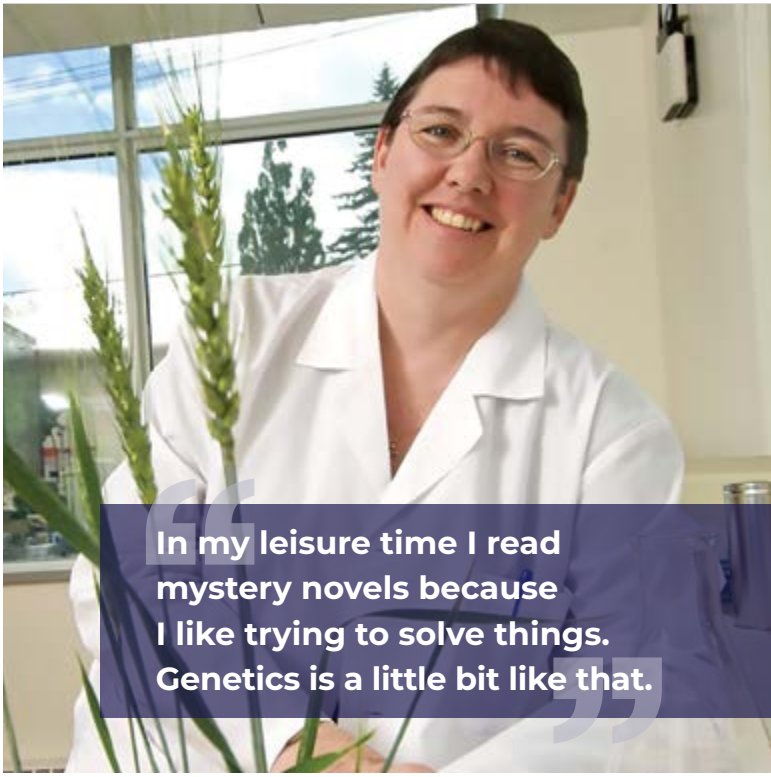
DR. ANITA BRÛLÉ-BABEL

Professor & Researcher
Wheat Breeding & Genetics
University of Manitoba

Even though Dr. Anita Brûlé-Babel grew up on the family farm near Prince Albert, Saskatchewan, university didn't seem like an option for her. "At that time, in the area I was in, the attitude was that girls didn't need to worry about education because they were going to get married and raise families," she says. But that didn't stop her.

Brûlé-Babel's interest in the research world was particularly peaked when her dad took her to annual field days in Melfort. "I always liked science in general, but I was absolutely fascinated with that," she says. "As a young child, I just thought it was really cool and interesting."

This fascination developed into a full-on career. Brûlé-Babel now specializes in wheat breeding and genetics, and has been a professor at the University of Manitoba for more than 30 years. And even though she's a little older now, she maintains her childhood fascination with science.



"In my leisure time I read mystery novels because I like trying to solve things. Genetics is a little bit like that – you've got a whole bunch of information and then you have to put it together and find the answer," she says. "We think we know how things are working, but until we actually do the experiment and the analysis, you don't know if what you thought is actually right."

DR. RICHARD CUTHBERT

Research Scientist, Wheat Breeder

Swift Current Research and Development Centre, AAFC

Dr. Richard Cuthbert grew up working in his dad's greenhouse operations. But after getting a student job in a canola breeding program at the University of Manitoba one summer, he decided he liked that better. "We got to use a lot of equipment in the field and that kinda flipped my switch – it was definitely more fun than washing pots," laughs Cuthbert.

His experience as a summer student also opened his eyes to the idea of agricultural research and breeding as a career. Previously, he thought he would study mechanical engineering because of his fascination with equipment, math and how things worked. "I was a curious kid. I liked to take stuff apart," he says. As a summer student he learned that plant breeding requires the same skills. "You're building better plants."

And so Cuthbert decided to follow in the footsteps of his older sisters, who were both studying plant breeding at the University of Manitoba. Shortly after completing his PhD, he got an incredible job opportunity working under plant breeder Ron DePauw at the AAFC Swift Current Research and Development Centre.

> **"If you're lucky, you get 30 years in a breeding career so I'm very lucky to get an early start."**

"I started in a commercial breeding program at age 29, which is typically unheard of. If you're lucky, you get 30 years in a breeding career so I'm very lucky to get an early start."

DR. ROBERT GRAF

Research Scientist
Winter Wheat Breeding
Lethbridge Research and Development Centre, AAFC

Dr. Robert Graf became aware of the importance of plant breeding when he was a teenager. Raised on a farm in central Saskatchewan, he watched both his dad and one of his uncles, a pedigreed seed grower, experiment with different varieties, and was struck by the vast differences in characteristics.

"I first became aware of the differences between varieties when my Dad moved from Neepawa to a variety called Sinton. It had higher yield, improved leaf rust resistance and it was an awned variety. At the time I thought that only barley was awned," says Graf. "The first fall we grew it I also noticed that it shattered quite a bit. It was also wet during harvest and it sprouted terribly."

So, after he finished his bachelor's degree at the University of Saskatchewan, inspired by people like Dr. Bryan Harvey, plant breeding seemed an obvious choice for graduate studies. Upon graduation, Graf spent nearly 12 years as a spring wheat breeder at the Saskatchewan Wheat Pool and then in 1999 moved to winter wheat breeding with AAFC in Lethbridge.

His breeding program now strives to make continual improvements to the milling and baking class of Canada Western Red Winter wheat by improving yield, winter hardiness and other agronomic characteristics, as well as disease resistance and end-use processing quality.

And he's had success so far. During the first wheat cluster, his breeding program released varieties Emerson and AAC Gateway, which were the two most popular winter wheat varieties on the Prairies in 2017.

DR. PIERRE HUCL

Professor & Researcher
Wheat Breeding & Genetics
University of Saskatchewan

For Dr. Pierre Hucl, plant breeding is a type of art. “It’s like having a huge painting and working on it for 10 years and watching it unfold as you go. You start with an idea of something you’re going to do and suddenly it’s there,” he says.

But it can be a painful process, too. “To be a wheat breeder in Canada you actually have to be a masochist,” laughs Hucl. “Canada is the most challenging jurisdiction to breed wheat in. You can work for 10 years, have something that looks really good, and in 10 minutes in a meeting it gets shot down.” That’s why he lists patience as a critical tool for people in his position. “If you’re looking for instant gratification you should not be a plant breeder,” he says.

Hucl became intrigued by the idea of breeding when, during his graduate student years, he read some research papers written by a University of Saskatchewan wheat breeder. Inspired, he moved to Saskatoon to pursue a PhD at the University of Saskatchewan and work for the Crop Development Centre, where he’s now been for nearly 30 years.

And despite the patience required for his type of work, Hucl says the payoff can make it all worth it. “Ninety-five percent of your ideas don’t work but the five percent that do, you go ‘oh, I had that plan and it actually worked!’ Sometimes it takes 10 years, but you get to see it.”

DR. GAVIN HUMPHREYS

Research Scientist, Wheat Breeder

Ottawa Research and Development Centre, AAFC

Dr. Gavin Humphreys' career in wheat has required him to not only shift major focuses, but also cities. He started working as a wheat researcher and breeder at the Winnipeg Research Centre in 1996. When the Centre was dissembled two decades later, Gavin and his wife (also a research scientist) were offered the chance to move to Ottawa. Since they are both originally from the East, they jumped on the opportunity. "It was a good time for us to reconsider our research paths," he says.

The move to Ottawa didn't just mean a change of scenery. It also meant a change of focus – having previously worked as a spring wheat breeder for 18 years, his focus shifted to Hard Red Winter wheat, as he took over the management of a program that aimed to breed winter wheat varieties adapted to Eastern Canada.

Humphreys was happy to take on a new challenge. "It was a new program when I got here, a new initiative. One of the reasons I was given the opportunity was because I was an experienced wheat breeder," he says. "We decided to focus on Hard Red so farmers could produce a wheat that could be blended with CWRS and delivered directly to local mills, creating new marketing opportunities."

"One of the reasons I was given the opportunity was because I was an experienced wheat breeder."

Credit: Linda Langille

DR. SANTOSH KUMAR

Research Scientist, Wheat Breeding

Brandon Research and Development Centre, AAFC

Dr. Santosh Kumar's life changed significantly and unexpectedly in 2003. After giving a presentation at an international conference in his native India, he was offered a position to do his PhD in Canada. "I was not even remotely expecting that to happen," he says. "I was very happy where I was and I had good scholarships. But when I looked at the potential Canadian supervisor's research achievements, it would have been foolish of me to say no."

Fifteen years later, Kumar is still living in Manitoba with his wife and two young kids. After completing a PhD, focused on barley, and gaining post-doctoral experience with flax, he has since joined the wheat breeding world, a new challenge for him. "Barley and flax are plants with smaller and simpler genomes. Wheat, on the other hand, is a beast," he says. "The wheat genome is much bigger and more complex than barley or flax, which makes it a challenge to understand and study."

But it's a challenge he loves. As a wheat breeder with a background in plant physiology, molecular biology and genomics, he feels that he has the right mix of knowledge and experience to develop better wheat varieties. He is also driven by doing work that has a tangible impact.

"The satisfaction of developing something farmers can use is the best part of the job for me. When a variety is released and the farmers find it useful, adapted, tolerant to adverse conditions, and they can make a profit from it, that satisfaction has no equal – it's really the driving force for me."

DR. CURT McCARTNEY

Research Scientist

Morden Research and Development Centre, AAFC

As a researcher for AAFC's wheat midge program in Morden, Manitoba, Dr. Curt McCartney strongly believes that wheat midge resistance is critical to the future of the industry.

"The wheat midge resistance gene has been recognized as one of the most important discoveries in Western Canada for wheat for quite a while. It has so much value in terms of wheat production and farmer profits," he says.

> **Before I retire I want to identify the DNA sequence of some important resistance genes that will have implications for breeding programs for Western Canada.**

Now, one of his major career goals is to carry on and further this work. "Before I retire I want to identify the DNA sequence of some important resistance genes that will have implications for breeding programs for Western Canada," says McCartney. "I also want to develop a good understanding of *Fusarium* head blight resistance, to enable breeders to be as efficient as possible in selecting for resistance. Breeders have made a lot of progress but it's still a big task!"

DR. MICHEL McELROY

Wheat Breeder

Le Centre de recherche sur les grains (CÉROM)

With a research background in smaller crops such as forages and hemp, Dr. Michel McElroy thought he was taking a big step up when he moved into the world of wheat breeding last year. But instead he found himself much more at home than expected.

“I found out when I arrived that winter wheat, which is what I’m in charge of here, is still something of an underdog crop in Quebec,” he laughs.

Breeding is in McElroy’s blood. His dad completed a full career as an AAFC breeder and then started his own plant breeding company, where McElroy worked as a teenager. After exploring the world of environmental and soil research, he decided to follow in his dad’s footsteps.

“There’s something about breeding and crop research that really drew me in. I find it interesting how there are so many different components to it, so many factors that go into what makes a particular cultivar successful in a particular place, but it’s also really applied,” he says. “It’s also nice to be able to see something you do have an impact more directly rather than abstractly.”

“There’s something about breeding and crop research that really drew me in. I find it interesting how there are so many different components to it.”

DR. HARPINDER RANDHAWA

Research Scientist
Spring Wheat & Triticale Breeding
Lethbridge Research and Development Centre, AAFC

Dr. Harpinder Randhawa was born in a wheat field in Northern India's Punjab state, right after his family finished seeding the crop. "My wheat plants were one week old when I was born. So I really grew up with wheat," he laughs.

His family grew several crops but he always had a close connection to wheat, having worked so closely with it from seeding, harvesting, thrashing and marketing. "We used to take our sack of grain to the local mill in the village where they'd mill it for you and then we'd bring it back home and use it for a month or however long," says Randhawa.

It's fitting that he has devoted his career to furthering this crop.

After studying agriculture and plant breeding in India, Randhawa moved to Canada in 1997 to complete a PhD at the University of Saskatchewan. He then spent some time in the United States working in genomics before taking a role with AAFC in 2007 as a wheat breeder.

Having worked on wheat from a variety of different perspectives, Randhawa has a greater appreciation of the breeding side of it. "Breeding gives you satisfaction of knowing you're making a difference in the lives of farmers," he says. "Being a farmer, I understand how difficult it is to have a good production system and to make a living on the farm. When we breed we look at the bigger picture – benefiting producers, maintaining sustainable production to feed the world, and making a difference in people's lives."

DR. SILVIA ROSA

Wheat Breeder

Le Centre de recherche sur les grains (CÉROM)

Dr. Silvia Rosa's family owns a wheat breeding company in Brazil, so after completing her PhD at the University of Manitoba in 2013, she moved back home and worked for the family business for three years.

But when an opportunity arose to work in wheat breeding at the University of Guelph, she was happy to move her young family to Canada, which she believes to be a safer country in which to raise young kids. "I love living here," she says.

Now she is working with a Quebec research program aiming to develop spring wheat varieties and germplasm for Eastern Canada, a job in which her international background has enriched her work. "There are similar challenges in wheat breeding between countries. Disease pressure in Brazil is much higher and it's pretty difficult to keep up resistance," says Rosa, adding that lots of current sources of disease resistance in Canada are actually derived from Brazil. She has even been able to collaborate with the research community there to source and share materials with breeders across Canada. "We had a collection sent from Brazil of more than fifty lines of material, which was tested for different diseases. Some of it is looking very good, so the idea is to use it in crosses this year."

"There are similar challenges in wheat breeding between countries. Disease pressure in Brazil is much higher and it's pretty difficult to keep up resistance."

Credit: Michael Shillinglaw

Credit: Anne Pratt

DR. DEAN SPANER

Professor & Breeder
University of Alberta

Dr. Dean Spaner became an agricultural researcher for reasons involving sibling rivalry. "Three of my siblings are doctors and I didn't want to compete," he laughs, adding that he also ended up fulfilling his mother's prophecy. "She always said, 'Dean's the farmer of the family.'"

Agriculture also appealed to him from a young age, having lived in Africa for a few years as a child. "I always thought growing food was important," he says. Inspired by this, Spaner's original intent was to work in international agriculture but instead he got a job working as a technician for a breeding program when he was 17 years old. That job ended up putting him through undergraduate studies. He then went on to study plant breeding and has been working as a breeder and academic at the University of Alberta ever since.

"Breeding is addictive. You walk out every springtime saying 'I'm going to have something better next year.' And then you walk around fields for a couple months and watch things grow and you can totally get lost in the work," says Spaner. "It's hard to explain what it feels like every spring – it's really exciting."

DR. LILY TAMBURIC-ILINCIC

Research Scientist
Wheat Pathology and Wheat Genetics
University of Guelph, Ridgetown Campus

For Dr. Lily Tamburic-Ilincic, cereal research offered her new opportunities not just for her career but also for her personal life.

She and her husband moved from their home in Serbia to Winnipeg in 1996 and there she began volunteering under a *Fusarium* head blight (FHB) specialist with Agriculture and Agri-Food Canada (AAFC).

Tamburic-Ilincic quickly found that her educational background came in handy. She had studied crop science and plant pathology in Serbia, and her Master's degree research had focused on *Fusarium* in corn.

"Because the *Fusarium graminearum* pathogen causes disease in corn and wheat, I was prepared for this work. The disease is predominant in both crops so that has helped me transfer my knowledge from corn to wheat," she says.

Her expertise in the disease also came in handy later that year when *Fusarium* was recognized as a growing and significant problem in Ontario. Tamburic-Ilincic was hired in 1997 to work as a Research Associate at the University of Guelph's Ridgetown Campus and help with Ontario's first FHB academic.

Twenty-one years later, she is still there. She completed her own PhD at the university, in plant breeding and genetics, and went on to lead a breeding program developing soft and hard winter wheats for Eastern Canada.

Now Tamburic-Ilincic lists many aspects she loves about her job, including being able to collaborate with other breeders in Canada, being able to develop and train new students for the job, and having an impact on the lives of Canadians.

"Wheat is so important. Growers and industry need it, but we also use it for so many different food products. It's a very nice feeling knowing that you can make a small difference by developing something that so many people will use in their daily routines," she says.

"Wheat is so important. Growers and industry need it, but we also use it for so many different food products. It's a very nice feeling knowing that you can make a small difference by developing something that so many people will use in their daily routines."

DR. YUEFENG RUAN

Research Scientist
Durum Wheat Breeder

Swift Current Research and Development Centre, AAFC

Dr. Yuefeng Ruan's background and educational training in agriculture spans the globe. Born and raised in a farming family in China, he visited his grandparents, who worked in the farm fields, every year as a child.

He also received education in agriculture, plant breeding and genetics at universities in China, Canada and Germany. This international experience has made him better equipped to do his current job – breeding Durum wheat for Western Canada.

"I like to see the different agriculture industries in different countries. International experience in agriculture gives me a better perspective on the work I'm doing," says Ruan.

When he travels the globe, Ruan is a proud ambassador of the Canadian wheat varieties that he has a hand in producing. "Canadian Durum is really special. I have travelled lots, and it doesn't matter which country I visit, every time people mention Canadian Durum they talk about its high quality and characteristics. Our Durum has a really good reputation in the world," he says.

Ruan has always been drawn to agriculture, which had great personal meaning to him, and he especially enjoys the rush of breeding. "Each time I release a variety it's like a new baby, I get so excited," he says.

> **"I have travelled lots, and it doesn't matter which country I visit, every time people mention Canadian Durum they talk about its high quality and characteristics."**

SUCCESS STORIES

THE WHEAT CLUSTER ENCOMPASSED 50 RESEARCH PROJECTS ACROSS THE COUNTRY. SOME HIGHLIGHTS ARE INCLUDED ON THE FOLLOWING PAGES.

See a complete list of new varieties from the Wheat Cluster beginning on page 44.

Early-maturing Canada Western Red Spring wheat varieties

Developing early-maturing Canada Western Red Spring (CWRS) wheat varieties is a tall order when you are the most northern breeding program in Canada, says breeder Dean Spaner.

Beyond early maturity, the varieties also need to be intermediately-resistant to resistant to bunt, leaf stem and stripe rust as well as *Fusarium* head blight (FHB). They must also meet quality characteristic standards for the class.

"You have to keep the quality as good or better than the checks. That's the reality of breeding CWRS wheat," says Spaner.

Five new CWRS varieties registered in 2018

The program registered five new varieties in 2018, all of which have varying levels of early maturity, elevated rust and FHB resistance, straw strength, high yields and all the quality characters necessary for the CWRS class. Four of the new varieties – PT782, PT783, PT784 and PT785 – have been accepted for registration and are currently being commercialized. Also released were Go Early (PT769), Zealand (BW986) and Parata (PT772), which was sold to SeCan in 2017.

Canada Western Red Spring wheat for the Eastern Prairies

As the leading market class of wheat in Canada, CWRS wheat is very important. Not only does it make up the majority of Canadian spring wheat production and exports, it maintains an international reputation for its high quality and versatility. However, CWRS is currently facing competition from other high-value crops such as canola and early-maturing corn and soybeans, especially in the Eastern Prairies.

Because of this, the program aimed to develop CWRS varieties adapted for Eastern Canada, with improved yields, FHB resistance, and midge- and pre-harvest sprouting tolerance, says breeder Santosh Kumar.

New varieties feature strong disease resistance

Three promising new varieties were developed from this program: AAC Warman, AAC Magnet and AAC LeRoy. According to Kumar, all have good resistance to leaf, stem and stripe rusts, and midge tolerance as well as varying levels of leaf spot resistance.

The varieties have also been very well received for *Fusarium* resistance. "We have made huge gains on the *Fusarium* resistance side while maintaining premium quality and better yields and protein, so we have been lucky," says Kumar.

AAC Cameron, which was registered in 2016 with a 5% higher yield than Unity, was also adopted by the famed United Kingdom bread company Warburtons, which has since started a program to buy from Canadian farmers who grow the variety.

Hard Red Winter wheat varieties and germplasm for Eastern Canada

Breeder Michel McElroy took over this Quebec-based breeding program late in the game, but he quickly learned the program's main focuses.

"While this is generally a spring wheat area right now, with earlier springs and hotter summers, it could be an area that is a little more favourable to winter wheat production as time goes on," says McElroy. "Because the band of winter wheat that predominates Ontario could be moving farther north, it's important that we have varieties that are well adapted to conditions here so we're ready for what's to come."

McElroy joined the program in its last year (2017), but was fortunate to have a several-month overlap with the previous breeder.

"Because I came in very late, I don't have the same feeling of ownership over the program but luckily there was some very good groundwork laid out that is going to be bearing fruit for me during my time here," he says.

Above-average yields and good FHB resistance

Although the program was not able to register any new varieties, one line that was put forward remains in registration trials. It features above-average yields compared to the feed-grade check as well as very good resistance to FHB, a big achievement for the program.

"The program was very much based around *Fusarium* resistance, so the germplasm we were working with was specifically trying to address the issue – really the holy grail of working with wheat – of getting something very *Fusarium* resistant," says McElroy.

A lot of the material that was sourced and developed over the last five years will fuel the next phase of breeding. "Breeding is an ongoing process and everything that we were able to generate during the last phase is in pipeline now," he says. "I'm very happy to see what's out in the field right now that I have to select from because I feel like this year there's going to be more lines in provincial trials and definitely more going forward."

Spring wheat varieties and germplasm for market competitiveness in Eastern Canada

This program aimed to improve the profitability and competitiveness of spring wheat in Eastern Canada by improving its productivity and milling characteristics. Another major focus was disease resistance.

"One of the priorities in breeding for spring wheat for Eastern Canada is resistance for *Fusarium* head blight. Environment conditions are very favourable to the disease development being more prevalent here than in the West," says breeder Silvia Rosa.

She adds that improving end-use quality is also a priority. "The wheat quality is not consistent from year to year, as the climate conditions are very variable."

New lines feature FHB resistance, high yields and good quality for bread industry

The program produced seven lines for Quebec farmers, six of which were supported for registration in Ontario. They are currently in different stages of the testing and registration process.

All seven lines present good adaptability in Eastern Canada, with acceptable FHB resistance, comparable or higher yields than the checks, and acceptable quality for the bread industry (except one line, which is specifically for feed). Going forward, the program will use newly discovered genetic materials to improve FHB resistance.

"It's very challenging to improve the wheat in Quebec but there is lots of potential to move forward, so we hope to be able to release new and better cultivars to farmers soon," Rosa says.

Wheat varieties for northern regions

This program aimed to develop varieties for northern growing regions, an area that is underserviced in many ways, says breeder Dr. Andrew Burt. "The northern growing regions are a unique area with unique challenges. They're not always able to take advantage of the newest full-season variety or material coming up out of the south."

Dr. Andrew Burt, wheat breeder
Credit: Sudhakar Pandurangan

According to Burt, it's particularly challenging to match yield gains to current standards while holding or gaining on early maturity. "Every fall is a risky time and any delay in harvest has high risk to the yield and profit of farmers. You add on the super long days in the summer in the North and not every variety responds well to that," he says.

Program lays groundwork for more modern agronomic varieties in the North

One line, PT485, was put forward for registration from this program. While the line did not test well for FHB resistance, it did show advances in other key areas. "PT485 was first line out of my program that maintained earliness and yielded very well but had a more modern short strong plant type that hasn't been available in the cultivars that have been targeted for the Northern Prairies," says Burt.

"Traditionally, a lot of northern varieties are very tall. The combination of early maturing, grade protection, high quality and high yield tended to be in tall germplasms only."

Three other lines were also put forward for registration from the program over the last five years: PT468, PT472, and PT474. PT474 did not fit the changes made to CWRS quality requirements over the course of the cluster work, and the other two lines were traditional northern types, which were too tall for significant market interest.

Another line, PT479, wasn't put forward for registration but had promising characteristics that will be retained for the program going forward.

The work done in the past five years has also allowed the program to streamline its goals going forward. "The program changed focus quite a bit, recognizing that farmers even in the Northern Region are willing to sacrifice extreme earliness in order to make yield gains, improve *Fusarium* resistance and gain shorter, stronger stature," says Burt. "I think this will bring more modern agronomic types to northern farmers going forward."

Winter wheat

Winter wheat is an important crop for Canada, says breeder Anita Brûlé-Babel. Not only does it provide farmers with diversity for crop rotations, which helps prevent buildup of weeds and diseases, it also has a 20 to 40 percent higher yield than spring wheat, better agronomic performance, and is beneficial for the environments in which it's grown.

"You still have to be able to plant it into standing stubble of the previous crop to trap snow, but that requirement is a good thing from the landscape point of view. It means fewer tillage operations," says Brûlé-Babel. "Groups like Ducks Unlimited like winter wheat because when you're growing these types of crops you're not disturbing nesting waterfowl and birds during their peak reproductive periods."

New varieties offer strong market potential

Five lines from Brûlé-Babel's program have been supported for registration and she is currently working on commercializing three of five of them.

W520 is a low protein, very high-yielding special purpose line with a yield that was 14 percent higher than the checks. "That represents a significant increase in yield compared to what has been currently available. It also looks really good agronomically and will be attractive to those wanting to grow winter wheat for feed or ethanol," she says.

W522 is a Hard Red Winter quality line that is attractive to both the export and milling markets. "Again, lots of farmers are looking for a short-strawed winter wheat, with high yield, good milling quality, and a good disease resistance package. W522 has all of these features and is very attractive to replace some other lines because of its shorter stature," says Brûlé-Babel, adding that the line will also give farmers the opportunity to sell into export market or domestic mills looking for that type of quality of grain.

Hard Red Winter wheat for Eastern Canada

Developing winter wheat varieties for Eastern Canada means focusing on breeding resistance to various diseases and optimal plant height. End-use quality is also a big focus.

"We decided to focus on Hard Red so farmers could produce a wheat that would provide them with alternative marketing opportunities," says breeder Gavin Humphreys. "There are mills in Quebec that would like to source their Hard Red milling wheats locally and market their products as 'made in Quebec,' which is something of value for Quebecois."

Double-haploid technology delivers new varieties to growers faster

Because it takes longer to develop winter wheat varieties than spring varieties, Gavin used double-haploid technology to increase efficiency and save precious breeding time. As a result, 127 new crosses and backcrosses were made, all focusing on increased yields and disease resistance, including FHB. From these, five winter wheat lines were advanced to eastern winter wheat registration tests and one is currently in its second year of testing.

Canada Western Red Spring varieties for the Western Prairies

Canada Western Red Spring (CWRS) is Canada's principal market class for wheat. It is in demand worldwide because of its consistent high quality and traits that make it ideal for producing premium breads and pastas or for blending with weaker wheats to improve their performance.

However, the CWRS class is currently facing several challenges, says breeder Richard Cuthbert. These challenges include constantly evolving pathogens causing diseases such as FHB and stripe rust, environmental conditions such as drought and heat stress, the high costs of farm inputs, and more. "We are always breeding for improved agronomic performance, disease resistance, and improved end-use quality traits," says Cuthbert.

Another major challenge to the Wheat Cluster work was that the Canadian Grain Commission made changes to the gluten strength parameters for CWRS, which came into effect in 2017. "That tightened the target that were shooting for," he says. "Being able to anticipate those kinds of changes is a major challenge because breeding is a 10-year cycle from cross to finished product. The crosses I'm making today won't be released to farmers until 2028 or 2029."

New CWRS varieties are game changers

Despite the challenges, Cuthbert's program was able to release 12 new varieties that met the outlined specs, several of which were noteworthy.

AAC Brandon and its sister variety, AAC Elie, both released in 2012, were very well adapted for Western Canada. "These two varieties have shown the largest impact for farmers," says Cuthbert. "AAC Brandon has been the number one variety grown on the Prairies the last two years and it seems to be growing."

AAC Viewfield is another up-and-comer with very high yields under drought conditions, excellent standability and intermediate FHB resistance.

BW5011 and BW5013, both supported for registration in 2018, appear to be exciting new varieties as well. "They appear to be game changers for midge tolerant wheat, with improved straw strength and significantly higher yields for what we have been seeing in the short strong straw type. BW5011 also has improved FHB resistance and desirably lower DON accumulation in the grain," says Cuthbert. Both varieties will be commercially available in the fall of 2020.

Field-ready Canada Western Soft White Spring varieties

The Canada Western Soft White Spring (SWS) class is unique for three main reasons, says breeder Dr. Harpinder Randhawa. It has a softer kernel than other wheat classes, which changes its milling properties. It also has a lower protein content, ranging closer to 10 percent rather than the 12 to 14 percent of other classes. Finally, it has a weaker gluten property. These attributes make it ideal for producing cakes, cookies, biscuits, noodles and breakfast cereals.

Historically, the class was grown mostly in Southern Alberta, but now it is expanding further into the northern parts of the province, Saskatchewan and even east. All these factors make breeding this class a challenge. "Since the class started being grown in new areas it has encountered new challenges in terms of production and diseases," says Harpinder.

For example, the germplasm for the class doesn't have built-in resistance to the diseases that are affecting these growing areas today, such as FHB and leaf and stem rust. It also isn't generally well adapted to different growing conditions. "These varieties tend to be on the later side so as we move further north and east we face new challenges for maturity as well as diseases," he says.

Three new Soft White wheat varieties offer high yields and good disease resistance

Randhawa's breeding program, part of the Wheat Cluster, was able to generate three new Soft White varieties.

AAC Indus, released in 2014, is high yielding and has good resistance to stripe and leaf rust and powdery mildew, although not to FHB and stem rust. The variety has since been adopted in Southern Alberta as an alternative to barley for feed purposes. "They are using AAC Indus because it has good standability, yield and quality for silage purpose," says Randhawa.

AAC Paramount, released in 2015, is also high yielding with good levels of resistance to stripe rust, loose smut, powdery mildew, leaf rust, stem rust and kernel black point. However, FHB resistance was still an issue. "We didn't have native resistance in soft wheat germplasm, like in other classes, and when we tried to bring it in from other classes, it changes the quality profile," he says.

Randhawa was able to make progress with FHB resistance with the final variety released from the program – AAC Awesome. Released in 2016, AAC Awesome is also high yielding with good general disease resistance. However, its protein content was slightly too high to qualify for the Soft White class.

Overall, the program made incremental gains in the important areas. "Now we have some new varieties in the pipeline that have intermediate-to-moderate levels of FHB resistance," says Randhawa. "Our next step is looking to improve yields along with disease so that we can generate some better options for producers in Western Canada.

Canada Western Red Winter wheat cultivars for Western Canada

Winter wheat offers lots of advantages for farmers, says breeder Robert Graf. Beyond its excellent milling performance, and perfect suitability in a wide range of bread and noodle applications, it's also significantly higher yielding than spring wheat and is able to break up weed cycles that would normally be a problem in spring-sown crops.

"In general, it tends to escape *Fusarium* head blight infection and it's also not synchronized with the life cycle of orange wheat blossom midge," he says.

According to Graf, the timing of its growing season is also a benefit. "During late, wet springs the crop is in the ground growing and using moisture that would otherwise be wasted. And during prolonged harvest seasons like we saw in 2016 and again in 2018, winter wheat will be in the bin with top grades while spring crops are still in the field losing quality," he says. However, there is a downside.

"Many producers feel that winter cereals are a nuisance because they take extra planning to have seed and equipment ready for the fall, and they may need to modify rotations to accommodate fall planting. It's also not as easy to market in some areas."

Strong new winter wheat offering

During the past five years, Graf's research program aimed to develop varieties for Western Canada with good winter survival, short to moderate height, strong straw, high test weight, and resistance to important diseases. The program also aimed for varieties with a yield increase of eight percent more than the long-term check, CDC Buteo. Several varieties Graf has developed have achieved these objectives.

AAC Elevate, released in 2014, is a high-yielding variety with good winter survival, medium height, very good straw strength and broad disease resistance. "What we were trying to do with Elevate was to develop a variety that was broadly adopted across Western Canada with all major disease resistance types covered in a package that had medium height, very good lodging resistance and good winter survival." For the most part they met these objectives, he says.

"We ticked off a lot of the boxes but unfortunately stripe rust ended up being one that eluded us. Initially it looked good for stripe rust resistance, but that resistance is no longer effective," says Graf.

AAC Wildfire, released in 2015, is particularly notable for its high yields, at about 15 to 18 percent higher than the check. It also has very good winter survival, good lodging resistance, and a good disease resistance package with the exception of stem rust resistance, making it best suited to Western Saskatchewan and Alberta. "This variety is ideal for areas where stem rust is not a threat," he says.

AAC Goldrush, released in 2016, also has very good winter survival, medium height, good lodging resistance and good disease resistance. It performs best in Saskatchewan and into Manitoba. "The genetic background works very well in Saskatchewan with yield that approaches that of Wildfire, but that isn't always the case in Alberta – it doesn't appear to have the same yield kick that we've seen moving east," says Graf.

Finally, the program released one Hard White Winter wheat, AAC Icefield, which offers special attributes for end-use markets. "Based on testing at both the Canadian Grain Commission and the Canadian International Grains Institute (CIGI), AAC Icefield appears to be ideally suited for noodles and Asian steamed breads," he says.

Winter wheat for Eastern Canada

There are several challenges involved with breeding winter wheat for Eastern Canada, says breeder Dr. Lily Tamburic-Ilincic. Top priorities at the moment include improving yields and developing resistance to *Fusarium* head blight (FHB). But it's also impossible to work on quality, stresses and other diseases such as stripe, stem and leaf rust. Septoria and mildew are also concern in Ontario.

"We are working on genetics and developing resistance sources for all these diseases. At the end of the day it has to be the whole package," says Tamburic-Ilincic.

Her program is also trying to expediate the breeding process using technologies such as doubled-haploid and molecular marker-assisted selection. "Usually, with conventional breeding, it takes up to ten years to develop and register new wheat, but in my experience we can do it in six to seven years," she says.

Four new varieties offer strong disease resistance and yield

Tamburic-Ilincic's program was able to successfully register four new winter wheat varieties, based largely on having good breeding materials developed in the previous cluster. Two of the released Canada Eastern Soft Red Winter (CESRW) wheat varieties are especially notable, she says.

Marker has a moderate resistance to FHB, which is the greatest level available in Ontario, and very good tolerance to deoxynivalenol accumulation. It also yields well, which is why it has quickly been adopted by Ontario growers since it was registered in 2013. "It has been very popular among growers already in Ontario for five years and is staying strong," she says.

UGRC Ring, registered in 2014, has also been widely adopted by growers in both Ontario and Quebec, as it is high yielding and has good other traits including winter survival.

Durum wheat for Western Canada

The biggest challenge to breed Durum wheat for Canada right now is managing Fusarium head blight (FHB), says breeder Dr. Yuefeng Ruan.

"Right now, there are no FHB-resistant cultivars available in the whole world, not just in Canada," he says.

And although breeders are currently busy working on sourcing and developing resistant germplasm – with efforts having really increased since 2014 – the best FHB resistance rating for a Canadian Durum variety is moderately susceptible. “Hopefully, we’ll see better resistant cultivars in the next few years,” says Ruan.

FHB isn’t the only challenge involved with his breeding program. New varieties also need to meet several more requirements involving yield, agronomic criteria, protein, yellow pigment, milling properties and more.

“Breeding is never specific to one trait. We have to put the whole package together – that’s really the big challenge,” he says.

First midge tolerant Durum variety

Ruan’s program was able to release ten varieties over the course of the last cluster, eight of which were registered and licensed. Several of these are noteworthy, he says.

AAC Succeed and AAC Marchwell are both midge tolerant varieties, while AAC Cabri, AAC Stronghold and DT878 have solid stems providing resistance to wheat stem sawfly.

AAC Marchwell is the first midge tolerant Durum variety registered in Canada. AAC Succeed, registered in 2017, combines high yielding and stronger straw. AAC Stronghold is noteworthy because it offers the strongest straw currently available in Canada, which has the potential to be popular with producers, says Ruan.

DT878, registered in 2018, could be considered as a new breeding standard for the solid-stemmed variety. “We reduced the plant height and increased straw strength because this makes it easier to grow in irrigated areas and it makes it easier for producers to harvest without losing quality and yield,” he says.

AAC Spitfire also offers shorter and stronger straw; in recent feedback, many producers remarked how short their harvest was with this variety, says Ruan.

ADVANCES IN PEST AND DISEASE RESISTANCE

Making strides in *Fusarium* head blight resistance

When it comes to wheat diseases, one in particular is top of mind for most farmers: *Fusarium* head blight (FHB). It poses a huge threat to the Canadian wheat industry as it reduces processing quality, causing significant losses to farmers' yields, grades and ultimately profits.

The toxin released by FHB can also affect animal and human health, posing larger concerns for the industry and potentially limiting future wheat production, which will be critical in feeding a rapidly growing world population.

For all of these reasons, one of the focuses of the Wheat Cluster work was breeding resistance into new wheat varieties. As the Cluster wraps up, the question is, how much advancement has been made?

Progress varies by wheat class

"There has been progress made across the board," says Dr. Anita Brûlé-Babel, who runs a FHB screening nursery at a University of Manitoba research farm in Morden, Manitoba.

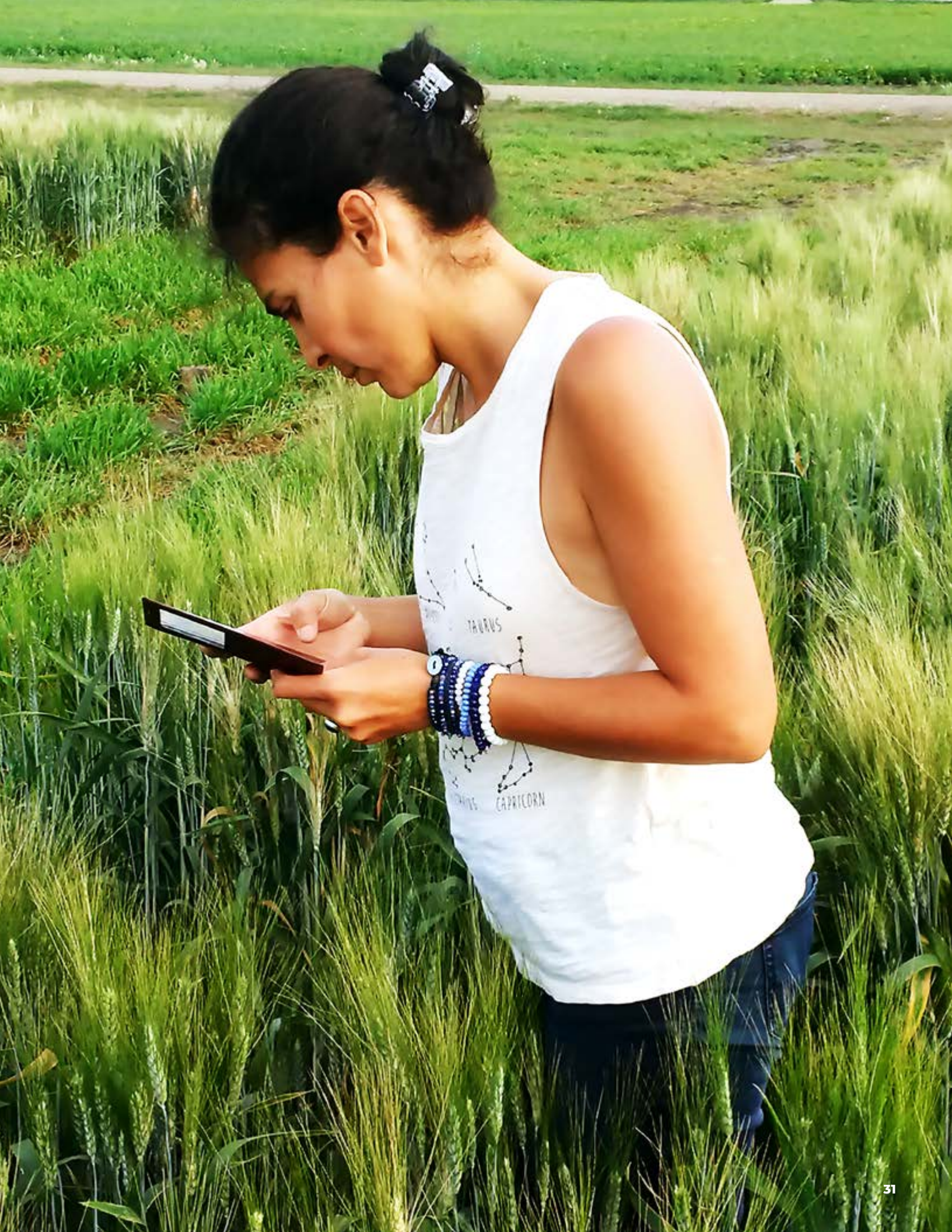
The progress is more advanced for some wheat classes compared to others. Leading the way is the Hard Red Spring class, where there has been the most investment.

"Breeders have been able to generate many cultivars with moderate-to-intermediate resistance in this class. They have much less disease and also do not have a yield penalty, so from a farmer's point of view, it's a win-win situation," says Brûlé-Babel.

Winter wheats have also done very well. "In this class, breeders have been very successful in getting materials that are moderate to intermediate in resistance, as well as one cultivar that is rated as resistant," she says.

In some of the other classes, such as Hard Whites and Durum, breeders are more limited in their resources. "There are not a lot of good sources of resistance in Durum wheat, so breeders have to use more exotic sources, which will take more time to develop," says Brûlé-Babel.

However, progress has still been made. Durum varieties have moved from mainly susceptible cultivars to moderately susceptible, and there are now Hard Whites available that have intermediate resistance, she says.


TAURUS
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Examining new *Fusarium* fungus strains

Another project within the Cluster, led by Dr. Dilantha Fernando, aimed to advance knowledge and management of FHB by examining *Fusarium* fungus that causes FHB disease in Canada, to learn whether or not new strains of the pathogen were harming wheat grains.

The research had some interesting findings. It identified a species of *Fusarium* that produces Nivalenol on wheat, a toxin more potent than DON. In another study, they identified that DON toxin can be converted to the less toxic DON-3-Glucoside (DON-3G), which is generally masked and not detected by regular toxin detecting methods. These results shows that more in-depth work is needed to test and develop FHB resistance.

"This research highlights the changes as well as the need to have proper detection tools and methods to identify these potential new risks at the elevator or where grain consignments are tested for potential toxin contamination," says Fernando whose work in this area is ongoing.

> **"There has been progress made across the board."**
>
> Anita Brûlé-Babel
> University of Manitoba

His team is currently using cutting-edge technology to closely examine resistance and toxin detoxification in wheat varieties, to determine the best ways to breed for resistance. They are also currently looking at new strains of the *Fusarium* fungus, found in some parts of the United States, to determine whether or not Canada is at risk of developing the same issues.

More varieties feature wheat midge tolerance

Another current insect pest of concern for Canadian farmers is wheat midge, which has been responsible for estimated losses of between $3 to $300 million annually. Luckily, breeders have better resources to work with for this issue. A wheat midge resistant gene was discovered in Canada in the 1980s and has subsequently been crossed into breeding programs.

Dr. Curt McCartney's work in the Wheat Cluster aimed to make sure that resistance is present in new wheat varieties across Canada. His research, done in conjunction with fellow researchers Dr. Alejandro Costamagna and Dr. Tyler Wist, evaluated breeding lines being put forward for registration to see if they contained the wheat midge resistant gene.

> **"This wheat midge work has been very successful and in terms of a genetics timeframe, it's been quite quick."**
>
> Curt McCartney
> Morden Research and Development Centre

To facilitate this, a technician in McCartney's lab would go through wheat samples from co-op sites across the country by hand, peeling the head off the chaff to examine the individual kernels for damage caused by wheat midge. "It's not glamourous work," he laughs, "but it's accurate and its very effective for identifying the breeding lines that have this gene."

Samples came from nine co-op sites across the country; McCartney estimates they examined more than 13,000 spikes in 2017.

The results were positive he says, indicating that there is more and more resistance being found in new varieties.

"When Unity came out, the first resistant variety, the gene was only present in one co-op. Now it is present in every co-op, and we're testing a lot more material than we did in the past," he says. "This wheat midge work has been very successful and in terms of a genetics timeframe, it's been quite quick."

Results from McCartney's work were sent back to breeders so that the information could be made available to farmers when choosing new varieties.

Keeping on top of tan spot

Although field crop diseases vary in their severity and impact from year to year, it's important to keep on top of as many as possible. Tan spot is one such example, says Dr. Randy Kutcher, a professor and researcher at the University of Saskatchewan.

"You don't hear as much about tan spot these days because *Fusarium* is so prevalent, but tan spot has always been here. Especially with going to zero-till in the last 20 to 30 years, tan spot is more of an issue," he says. "It is the main wheat leaf spotting disease on the Prairies." In fact, it can cause up to a 10 to 15 percent yield loss in some years.

"You don't hear as much about tan spot these days because *Fusarium* is so prevalent, but tan spot has always been here. Especially with going to zero-till in the last 20 to 30 years, tan spot is more of an issue."

Randy Kutcher
University of Saskatchewan

Kutcher's work within the Wheat Cluster, done in conjunction with fellow researchers Stephen Strelkov and Kelly Turkington, focused on gathering information about the disease to better understand it. The data they collected was used to determine whether the pathogen is changing in response to different varieties being grown.

"We did not find any new races of the pathogen, which if we had, would have suggested that the pathogen can overcome the resistance in current cultivars," he says.

The researchers also collected information related to the pathogen's resistance to fungicides. "We collected isolates and did fungicide resistance work to set a baseline so that if, in the future, farmers find that fungicides aren't controlling tan spot, we have some idea of the normal variability of the pathogen to the fungicide."

Fungicides are still going to be useful, Kutcher says. "If farmers are spraying for FHB anyways, they're going to get some control of tan spot." But if the pathogen becomes insensitive to the fungicide, that will be timely and valuable information to share with farmers. "They will have to choose a different fungicide or at least be aware that they're not controlling tan spot anymore."

Long-lasting leaf rust resistance

Sometimes combatting wheat disease means not only responding to current issues but being proactive against potential future issues. This is why Dr. Colin Hiebert, a wheat genetics research scientist with AAFC, led work in the Wheat Cluster to develop germplasm with combinations of genes with resistance to leaf and stem rust.

Why do we need to continue developing resistance to a disease when we already have sources of resistance? "Complacency can catch you unprepared," he says. "The fungi that cause leaf rust or stem rust or any of the major diseases of wheat these days will change, as the populations aren't static. If we want to stay ahead of it, we can't just rely on a single-resistance gene to provide long-lasting resistance."

The idea is to be proactive and stay ahead of pathogen by having a more genetically diverse basis of disease resistance. "If you become complacent that makes you vulnerable," he says.

Hiebert's program also aimed to discover DNA markers that will allow new resistant genes to be used in the development of future varieties.

> **"Complacency can catch you unprepared.**
>
> Colin Hiebert
> AAFC

SUMMARY

- Breeding for FHB resistance is advancing across all wheat classes with the Hard Red Spring class leading the way
- More and more new varieties have tolerance to wheat midge
- Researchers are gathering information to better understand tan spot, the main wheat leaf spotting disease on the Prairies
- Long-lasting leaf rust resistance will require combinations of genes with resistance versus a single-resistance gene

ADVANCES IN BREEDING TECHNOLOGY AND TOOLS

Plant breeding today looks a lot different than it did 20 years ago. That's because the technology used by breeders and researchers is constantly evolving to improve the efficiency of the process and the quality of the end results.

Breeding programs within the Wheat Cluster relied heavily on two newer technologies to be able to produce better results for Canadian farmers.

Marker-assisted selection

Researcher Dr. Pierre Hucl's work in the Wheat Cluster involved trying to improve the germplasm used in breeding. He did this using a technology called 'marker-assisted selection' (MAS).

MAS works by allowing breeders to select desirable traits (disease resistance, for example) by identifying markers for those traits rather than the traits themselves. The MAS process improves the overall efficiency of large wheat breeding programs by about 10 percent, Hucl estimates.

Although MAS is not a brand-new technology, it has only begun to be adopted and widely used within plant breeding programs in the last two decades. "In the last five years, we've been getting more effective markers that are also easier to use, what molecular geneticists call 'breeder-friendly markers,' meaning they are dumbed down for people like me," he laughs.

The use of MAS varies between breeding programs because it requires additional time and resources, such as its own lab, but at the University of Saskatchewan's Crop Development Centre (CDC), where Hucl works, it is widely used for most of the larger crop breeding programs. "We basically test all our advanced wheat breeder lines for a suite of markers and look at the agronomy, quality, disease data and then at marker data to see if it matches up with what we are seeing in the field."

MAS has been used in breeding programs across Canada to improve disease resistance, end-use quality and more. In Hucl's most recent work in the Wheat Cluster, his program was able to deploy some effective markers

for grain quality. One of these markers was for a sub-unit on the gluten protein that is associated with a desirable level of dough strength. "We took that marker and then selected for it when making complex crosses, which gave us an indication of a higher probability that we'd end up with stronger dough," he says.

Another program in the Wheat Cluster, led by AAFC research scientist Dr. Ron Knox, aimed to help breeders increase their use of MAS to help breed resistance to common wheat diseases such as FHB, loose smut and stripe and leaf rust into new wheat varieties. This work will not only help to strengthen disease resistance in new varieties but will also improve the efficiency of overall breeding programs, says Knox.

"When we use MAS at the very earliest stages, each marker eliminates half of the breeding material. If we didn't do it then all those lines that move through the breeding program would have to be evaluated in the field, so they're filling spaces with material that is not of value," he says.

Knox's work was able to identify DNA markers for resistance factors to the previously mentioned diseases. These markers are currently being adopted into Canadian breeding programs to help breeders select and stack genes for resistance, which makes for small but steady gains.

> **Markers is just one way we've improved that efficiency.**
>
> Ron Knox
> AAFC

"Breeders are working on the margins in terms of the increments they make but part of the reason we can keep making increases is because we are improving breeding efficiency," he says. "Markers is just one way we've improved that efficiency."

Double-haploid technology

When Dr. Gavin Humphreys took over a Wheat Cluster program to breed Hard Red Winter wheat for Eastern Canada, he realized there were unique challenges involved. "In spring wheat you can usually grow two generations a year, but with winter wheat you really are limited to one generation a year because the wheat has to undergo about nine weeks of cold temperatures before it will switch from the vegetative to the reproductive stage," he says.

To overcome this obstacle, Humphreys used something called double-haploid technology, which allows breeders to produce a breeding line that is genetically pure in about a year and a half. To do this, breeders remove the pollen from the plant they are working with and replace it with corn pollen, which stimulates the wheat embryo to grow. Breeders then transfer the embryo to artificial media that allows it to successfully grow into a small plant, which is then transferred into the soil.

"The plant is called a haploid," says Humphreys. "It's unique because it only has half the normal number of chromosomes." The chromosomes are then doubled, which makes the plant fertile and which makes it a 'doubled haploid.' "All the chromosomes came from the female so it's genetically pure, just like a variety that's been grown in the field for eight to 10 generations," he says.

> **All the chromosomes came from the female so it's genetically pure, just like a variety that's been grown in the field for eight to 10 generations.**
>
> Gavin Humphreys
> AAFC

Double-haploid technology was first used in breeding programs in the mid-1990s and is now quite widely used in Canada. Several wheat varieties have been developed using the technology, including Superb, Snowbird, Snowstar and Burnside. AC Transcend, the first Durum variety created using the technology, was released in 2011 and has reached 43 percent of the Durum acreage in Canada, which translates into half a billion dollars of income for Canadian farmers.

"We're seeing double-haploid technology being translated into cultivars," says Knox. "And we're seeing more and more new varieties that have been influenced by the use of the technology."

But despite the major benefits the technology has brought to Canadian farmers, it still has its limitations. For example, the embryos produced through the double-haploid process have a low germination rate in Durum because of an inherent resistance to germination and pathogen contamination. This makes the technology more expensive to use.

This is why Knox led another research program, partially funded by the Wheat Cluster, that aimed to address this limitation by improving the number of germinating embryos within double-haploid breeding lines. “We were looking for bioactive molecules and testing them to see if they would have an effect on the embryo germination, so it was basically a trial and error process,” he says.

The research was successful in finding a way to improve the germination rates. “We start with bioactive molecules such as silver nitrate, which also has the effect of limiting microbial growth in addition to a small effect on stimulating embryo development,” says Knox. However, he says there is more work to be done on improving the process. “The effect is not as great as we would want and we need to get germination to where the bread wheats are, but it does improve efficiency because we lose fewer embryos from contamination from microbial growth,” he says.

SUMMARY

- Wheat Cluster breeding programs relied on two newer technologies to be able to produce better results for Canadian farmers
- ‘Marker-assisted selection’ (MAS) allows breeders to select desirable traits (disease resistance, for example) by identifying markers for those traits rather than the traits themselves
- ‘Double-haploid technology’ allows breeders to produce a breeding line that is genetically pure in about a year and a half (versus waiting four to 10 years)

BUILDING THE NEXT GENERATION OF AG RESEARCHERS AND BREEDERS

The Wheat Cluster aimed to address the needs of wheat farmers across the country. But not all these needs were directly related to growing wheat. One focus was growing the pool of trained and experienced researchers and breeders to carry on the important work that is currently being done.

Training the next generation of high-quality personnel (HQP), as they're referred to in the academic world, is a major focus of all agricultural research, says Randy Kutcher, a professor and researcher at the University of Saskatchewan. "It's part of what we're paid to do here at the university – train the next generation," he says. Kutcher generally supervises about three or four graduate students at a time.

Training is built into a university's mandate, says Anita Brûlé-Babel, a professor and researcher at the University of Manitoba who has supervised 30 graduate students to date. "We don't just do breeding and research for the sake of breeding or research, there's always a training component to it. That's part of being a university as opposed to government or industry," she says.

Randy Kutcher says training the next generation is an important part of his job

For both Kutcher and Brûlé-Babel, this means not only giving students an academic background and designations but also real-life, hands-on experience. “The focus is really on how to do the research,” Kutcher says. “The students are the ones doing the actual hands-on work. The technicians are guiding them, helping with equipment and managing summer students, but it’s up to the students do the projects.”

Lab and field experience makes students versatile

The hands-on experience is often the most critical part of what makes a program successful, says Brûlé-Babel. “The thing I provide my students with, which makes them heavily in demand from industry, is both lab and field experience. There are a lot of people training in the sciences that have really good lab and molecular genetic experience, but not a lot of practical experience in growing plants in the field or the greenhouse. My students have that, which makes them very versatile.”

Richard Cuthbert, one of her former PhD students, can attest to this. “Dr. Brûlé-Babel was a phenomenal mentor – she bridges the gap between theoretical and applied genetics and focuses on how it works in the real world,” says Cuthbert, who now works as a research scientist and breeder for AAFC.

“That was one of my biggest advantages of working with her,” he says. “She’s a very good quantitative geneticist and being able to work with examples of things like FHB resistance in her nursery, is very unique and extremely beneficial.”

And sometimes supervising students means providing guidance in other areas, too. “I try to support them in all ways possible, not only academically,” says Kutcher. “A lot of our grad students are from other parts of the world, so sometimes it’s quite a change in culture, language and climate when they arrive in Canada.”

> **“We don’t just do breeding and research for the sake of breeding or research, there’s always a training component to it.”**
>
> Anita Brûlé-Babel
> University of Manitoba

Richard Cuthbert benefited from lab and field experience during his PhD study

Job opportunities abound for ag researchers

Because grad students are so well supported and trained, it can sometimes be a challenge to get them to finish their programs, Brûlé-Babel says. She estimates that more than half her students have job offers before they finish their degrees. “There have been lots of job opportunities for students and there will continue to be. We’re in a position right now where there are more jobs than there are well-trained people to fill those jobs,” she says.

Having good job opportunities is important to helping attract the next generation of HQP. Brûlé-Babel recruits many students from other disciplines when she hires undergraduate students for summer work. “Not all students necessarily come from agriculture backgrounds. Lots come from the sciences and when they get this training quite a number of them will change their area of focus because they see a lot of opportunities,” she says.

Dean Spaner has supervised approximately 35 Masters and PhD students during his 17 years at the University of Alberta and he sees his students take positions all over the country after they graduate. “There are a number of people now in prominent roles in agriculture that got degrees from our program,” he says. In fact, one of the students he oversaw throughout the Wheat Cluster has since took a position working for the AAFC Lacombe Research Centre and Development Centre.

Dean Spaner supervises Masters and PhD students at the University of Alberta

Continuing to develop HQP will be important for building the next generation of agricultural researchers, but a lot of progress has already been made in this area, Brûlé-Babel says. “I think we contributed quite significantly to the next generation. I have graduated quite a few students in the disciplines of breeding and genetics and provided them with really good training. Most of them are working in the industry now.”

SUMMARY

- Growing the pool of trained and experienced wheat researchers and breeders is another focus of the Wheat Cluster
- Real-life, hands-on experience is a critical success factor when training HQP
- There are more jobs than there are well-trained people to fill those jobs
- Continuing to develop HQP will be important for building the next generation of agricultural researchers

WHEAT CLUSTER NEW VARIETIES LISTING

61 **NEW VARIETIES WERE PRODUCED THROUGH THE WHEAT CLUSTER, PROVIDING CANADIAN PRODUCERS WITH VARIETIES THAT DELIVER HIGH QUALITY, HIGH YIELDS AND IMPROVED DISEASE RESISTANCE.**

YEAR OF REGISTRATION	NAME	OWNER	DESCRIPTION	LICENSEE
2013	**AAC Chiffon**	AAFC	• New high-yielding soft wheat (outyielding AC Andrew and AC Sadash on irrigation and dryland in Co-op Registration Trials) • Medium-tall stature with good straw strength • Good shattering resistance • High kernel weight	SeedNet Inc.
2013	**AAC Innova**	AAFC	• High-yielding wheat in CWSP class (107% of AC Andrew and 120% of AC Unity VB) • Short stature and good standability • Maturity equal to AC Andrew (110 days) • Resistant to leaf rust, moderate resistance to stem rust and general leaf spotting	Alliance Seed
2013	**AAC Brandon**	AAFC	• Awned, semi-dwarf CWRS • When compared to AC® Carberry, has more than 5% grain yield, 0.5 day earlier maturity, 1 cm shorter and similar lodging, tolerance and disease resistance	SeCan
2013	**AAC Elie**	AAFC	• Grain yield and time to maturity in line with the checks • Low lodging and strong straw • Resistance to races of leaf and stem rust, intermediate resistance to FHB, yellow rust, common bunt and loose smut • Consistent results in Manitoba, Alberta and Saskatchewan	Alliance Seed
2013	**AAC Ryley**	AAFC	• Awned semi-dwarf spring wheat • Yields significantly more than 5700PR, maturing 1.9 days earlier and growing 5 cm taller • Resistance to prevalent races of leaf rust, stem rust and common bunt • Intermediate resistance to loose smut and moderately susceptible to FHB	SeCan

YEAR OF REGISTRATION	NAME	OWNER	DESCRIPTION	LICENSEE
2013	**AAC Scotia**	AAFC	• Top-yielding wheat • Tall variety that requires management of nitrogen availability	Semican
2013	**AAC Whitefox**	AAFC	• Top yielding, with 5% better yield and 2% greater protein than AC Snowstar • Top quality, slightly taller and weaker straw than AC Snowstar	SeCan
2013	**AAC Marchwell**	AAFC	• First midge tolerant Durum • Agronomic and quality similar to AC Strongfield • Refuge variety will be AAC Raymore that could provide some sawfly protection because of a solid stem • Resistant to leaf rust, stem rust, stripe rust, common bunt, loose smut and common root rot	SeCan
2013	**CDC Whitewood**	CDC	• Intermediate FHB reaction • Yields 95% of AC® Carberry	
2014	**AAC Prevail**	AAFC	• Very high yielding, equal to AC Unity VB • Midge tolerant • Improved standability to AC Unity VB • Excellent stem and leaf rust resistance including Ug99 type • Improved FHB resistance	Alliance Seed
2014	**AAC Durafield**	AAFC	• One of the best disease packages in the CPS class	SeCan
2014	**AAC Penhold**	AAFC	• High yield potential • Exceptionally short, strong straw, which allows it to be grown under very high production conditions • MR rating to FHB • Straw strength will allow CPS Red to be grown in areas where CPS has not traditionally been grown	SeCan
2014	**AAC Spitfire**	AAFC	• Excellent grain yield potential • Good lodging tolerance • Good disease package • Shorter and stronger strawed than AC Strongfield • Lower protein than AC Strongfield and AC Avonlea	SeCan

AAC Penhold – 59% of CPS acres; more than 310,00 acres planted in Alberta alone in 2017.

WHEAT CLUSTER NEW VARIETIES LISTING CONTINUED

YEAR OF REGISTRATION	NAME	OWNER	DESCRIPTION	LICENSEE
2014	**AAC NRG097**	AAFC	• Early maturing (-2 d compared to Pasteur) • Very good overall disease resistance • Good lodging resistance • Heavy test weight and large seeds • Awned	Canterra
2014	**AAC Cabri**	AAFC	• Solid stem with excellent sawfly tolerance • Improved yield potential, high test weight, good pigment content, good gluten strength and low grain cadmium • Taller than AC Strongfield by 3 cm and similar straw strength	SeCan
2014	**AAC Foray**	AAFC	• Offers midge tolerance and very high yield • No. 1 yielding CPS wheat after three years in the Co-op trials • Intermediate rating to FHB, which gives it a bit of protection; the refuge variety is AAC Penhold, which gives it extra straw strength	SeCan
2014	**AAC Tenacious**	AAFC	• Offers wheat midge tolerance and unparalleled disease resistance including the only full R rating for FHB in the Canada Prairie Spring Red (CPSR) class	Alliance Seed
2014	**CDC Titanium**	CDC	• First midge tolerant CWRS variety from Proven Seed • Highest FHB resistance rating of all available midge tolerant varieties • Provides farmers an excellent and flexible choice that resists lodging, allowing for maximum yield potential • Delivers excellent resistance to stripe rust and FHB	Proven Seed
2014	**CDC Fortitude**	CDC	• The first solid stem and sawfly-resistant Durum variety, resulting in successful harvest results • Intermediate to moderate resistance rating for FHB plus strong standability makes it an excellent option for high fertility or irrigation acres in the Durum growing regions of the Prairies	Proven Seed
2014	**CDC Carbide**	CDC	• First midge tolerant Durum wheat variety from Proven Seed • Mid-maturity with improved yield and agronomics over the existing midge tolerant Durum • Notable for holding its colour and quality • Excellent disease package, including resistance to stem, leaf and stripe rust • Available only at Proven Seed	Proven Seed

CDC Plentiful – more than half a million acres planted in 2017.

YEAR OF REGISTRATION	NAME	OWNER	DESCRIPTION	LICENSEE
2014	**Coleman**	University of Alberta	• Awned, hollow-stemmed cultivar of high yield potential • Higher yielding than Katepwa (8.5%) (P≤0.05), AC Splendor (5.8%) (P≤0.05), CDC Teal (2.1%) and CDC Osler (2%) • Exhibited maturity, height and lodging resistance similar to, or in the range of, the checks • Higher test weights than the checks • Good resistance to leaf, stem and stripe rust • FHB resistance greater than check cultivars and DON contamination levels lower than check cultivars	Lefsrud Seed
2014	**Thorsby**	University of Alberta	• Early maturity without sacrificing yield potential • Broad geographic fit • R to stripe rust • Awnless	
2014	**Marker**	University of Guelph	• Excellent standability and bushel weight • Large plump kernels • Short straw • Good protein levels	Bramhill Seeds
2014	**UGRC Ring**	University of Guelph	• High grain yield • Good pastry qualities • Good winter survival	
2014	**CDC Plentiful**	CDC	• Market-leading disease package • Best-in-class resistance to FHB, rated MR • Early maturity • Competitive yields; up to 106% of the check • Superior grain quality • High protein and high gluten strength	FP Genetics
2015	**AAC Elevate**	AAFC	• CWRW variety with short strong straw • High grain yield potential • Medium maturity • Improved protein content	SeCan
2015	**AAC Indus**	AAFC	• Soft White wheat with improved yield and milling quality • Yield 105% of AC Andrew, with three days later maturity and 6 cm taller • Midge tolerant and is paired with AC Andrew as a refuge • Fits traditional Soft White milling markets • Works well for ethanol • Excellent straw strength makes it a great fit for silage production	SeCan

WHEAT CLUSTER NEW VARIETIES LISTING CONTINUED

YEAR OF REGISTRATION	NAME	OWNER	DESCRIPTION	LICENSEE
2015	**AAC Cameron**	AAFC	• Very high-yielding CWRS wheat with resistance to the orange blossom wheat midge • Medium maturity and very good lodging resistance • Rated MR to stem and leaf rust • Improved FHB resistance	Canterra
2015	**AAC Jatharia**	AAFC	• Awned midge tolerant variety with medium to tall straw and very high grain yield • Midge tolerant CWRS that is seen as a replacement for AC Unity VB • Stronger straw • Incorporates AC® Carberry as a refuge for additional straw strength • On average AAC Jatharia VB outyields AC® Carberry by 7% • Good sprouting resistance • Intermediate "Fair" rating to FHB	SeCan
2015	**AAC Connery**	AAFC	• Awnless, semi-dwarf variety that combines early maturity with the benefits of short, strong straw • Suitable for high-input farm management, as well as irrigation • Superior disease resistance package to rusts and FHB, making it broadly adaptable across the Prairies • Excellent milling and baking quality	Canterra
2015	**AAC Tradition**	AAFC	• CNHR wheat variety with good yield potential • Grain yield of 109% of AC® Carberry and maturity equal to AC® Carberry • AAC Tradition was selected for improved yield under organic production systems • Five cm taller than AC® Carberry, has good lodging resistance, and an intermediate rating for FHB	SeCan
2015	**AAC Congress**	AAFC	• Improved yield over the current varieties on the market • Superior end-use quality, such as high pigment concentration, as well as low semolina ash • Excellent resistance to stripe and stem rusts • Same level of FHB resistance as the current Durum varieties • Expresses a lower DON accumulation in grain	Canterra
2015	**AAC Wildfire**	AAFC	• Hard Red Winter wheat with short strong straw • Good winter survival • Excellent lodging resistance	SeCan
2015	**CDC Bradwell**	CDC	• New CWRS with strong straw and intermediate "Fair" rating to FHB • Reduced damage from wheat midge due to "egg laying deterrence"	

YEAR OF REGISTRATION	NAME	OWNER	DESCRIPTION	LICENSEE
2015	**CDC Alloy**	CDC	• Top-in-class yields; up to 114% of the checks • Comprehensive disease package • Shorter straw, improved standability	FP Genetics
2015	**CDC Precision**	CDC	• Sets the new standard for yield potential without sacrificing important agronomic characteristics	
2015	**CDC Dynamic**	CDC	• Solid stem, denoting improved resistance to wheat stem sawfly damage • Yielded 9% higher than AC Strongfield in pre-registration trials	
2015	**Go Early**	University of Alberta	• Bred from CDC Go with similar large kernel size, but 5% higher yield, better disease resistance and matures two days earlier	Mastin Seeds
2015	**Parata**	University of Alberta	• Very early, 4 days earlier than AC® Carberry, 2 days later than AC Splendor • Yield similar to AC® Carberry, 106% of AC Splendor • MR to stripe rust and leaf rust, R stem rust	
2015	**UGRC C2-5**	University of Guelph	• High grain yield, with good pastry quality (high flour yield, high falling number) and is moderately resistant to powdery mildew • UGRC Ring has good winter hardiness and is well adapted for the winter wheat growing areas of Ontario	
2016	**AAC Crossfield**	AAFC	• Desirable combination of short, strong straw well suited for high inputs and or under irrigation and early maturity	Canterra
2016	**AAC Entice**	AAFC	• Semi-dwarf in stature, excellent straw strength and high grain yield • Show excellent resistance to leaf, stem and stripe rust	CPS
2016	**AAC Paramount**	AAFC	• Soft White midge tolerant Spring wheat with high grain protein and excellent milling quality	SeCan
2016	**AAC Viewfield**	AAFC	• Top of class in standability • Semi-dwarf and shortest CWRS available • Very high yielding; up to 117% of the check • Intermediate resistance to FHB; a strong base for a *Fusarium* IPM system • Good sprouting resistance for high grain quality	FP Genetics

CDC Fortitude – one of the five most popular CWAD varieties planted in 2017.

WHEAT CLUSTER NEW VARIETIES LISTING CONTINUED

YEAR OF REGISTRATION	NAME	OWNER	DESCRIPTION	LICENSEE
2016	**AAC Concord**	AAFC	• 20% higher yielding than AC Lillian in the registration trials • FHB resistance stronger than AC Lillian • Resistance to leaf, stripe and stem rust • Resistant to wheat stem sawfly • High test weight and seed weight • Awnless	Canterra
2016	**AAC Redberry**	AAFC	• Very high grain yield • 15% higher than checks, 8% more than AC® Carberry, 4% higher than AC Unity VB including Parkland zones; unique for a semi dwarf • Good protein retention, 3 days earlier maturing • Strong disease package including resistance to stem and leaf rust, stripe rust • Similar FHB to AC® Carberry with lower DON	Alliance Seed
2016	**AAC Stronghold**	AAFC	• Solid stem Durum with short strong straw for ease of straw management and speed of harvest	SeCan
2016	**AAC Awesome**	AAFC	• Very high yielding Special Purpose Spring (with a Soft White kernel type) wheat with a strong agronomic package • Good straw strength and excellent disease package • *Sm1* gene for tolerance to the orange wheat blossom midge, maturity similar to AC Andrew, manage maturity by seeding early and increasing seeding rate to hasten maturity	SeCan
2016	**AAC Goldrush**	AAFC	• High yielding CWRW with excellent winter hardiness • Good standability and strong rust resistance, and is rated intermediate to FHB	FP Genetics
2016	**CDC Landmark**	CDC	• Top in class; up to 113% of the checks • Wheat midge tolerant • Leading standability in a varietal blend • Semi-dwarf and semi-solid stem • Intermediate to FHB; a strong base for a *Fusarium* IPM system	FP Genetics
2016	**CDC Kinley**	CDC	• Hard White Special Purpose variety suitable for baking and malting	
2016	**CDC Hughes**	CDC	• Shorter straw and partial solid stems provides a leading edge in standability along with excellent yield potential • High test weight and a sound disease package	
2016	**CDC Credence**	CDC	• High-yielding Durum variety with improved resistence to FHB • Shorter and stronger straw, lower DON accumulation, high pigment concentration	

YEAR OF REGISTRATION	NAME	OWNER	DESCRIPTION	LICENSEE
2016	**CDC Terrain**	CDC	• Very high yielding CPSR • Good disease package and sprouting tolerance	
2016	**Zealand**	University of Alberta	• An early-maturing, standard height (similar to Katepwa and AC Unity VB), high-yielding line • Improved lodging resistance compared to cultivars of similar height • Good yellow and leaf rust resistance	
2017	**AAC Succeed**	AAFC	• 14-16% yield above check varieties • Varietal blend for midge tolerance • Has some drought tolerance, good stand ability at medium height, good FHB rating for Durum varieties at MS • Good quality retention for a Durum variety • Available fall 2019 or 2020	FP Genetics
2017	**AAC Tisdale**	AAFC	• Medium height, awned, hollow stemmed CWRS wheat with high yields	
2017	**AAC Goodwin**	AAFC	• High-yielding CPS wheat with short, strong straw and medium to late maturity	
2017	**AAC Alida**	AAFC	• CWRS wheat with a great disease package, including an MR rating to FHB • Potential midge tolerance to be confirmed	
2017	**CDC Adamant**	CDC	• The first CWRS wheat that provides resistance to both wheat stem sawfly and orange blossom wheat midge • A significant step up in yield from its predecessor AC Lillian, with the same early maturity • A solid choice for comprehensive resistance to both wheat stem sawfly and wheat midge	
2017	**AAC Prevail**	AAFC	• Offers consistent high yields • Higher than average of all checks • Much improved standability to midge tolerant wheat	Alliance Seed

AAC Brandon – 24% of CWRS acres; more than 2 million acres planted in 2017.

Canada

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