DFCC
DIVERSE FIELD
CROPS CLUSTER

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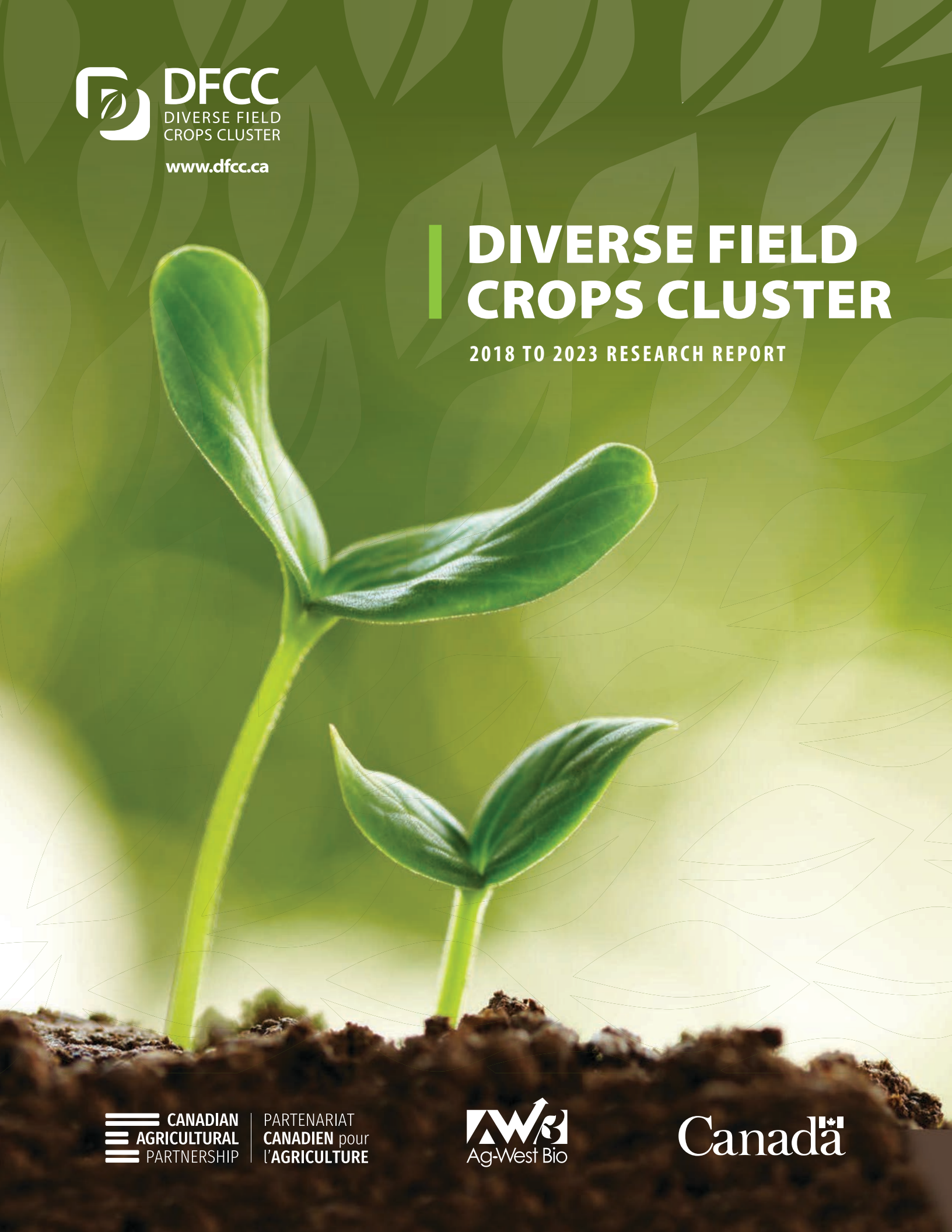
DIVERSE FIELD CROPS CLUSTER

2018 TO 2023 RESEARCH REPORT



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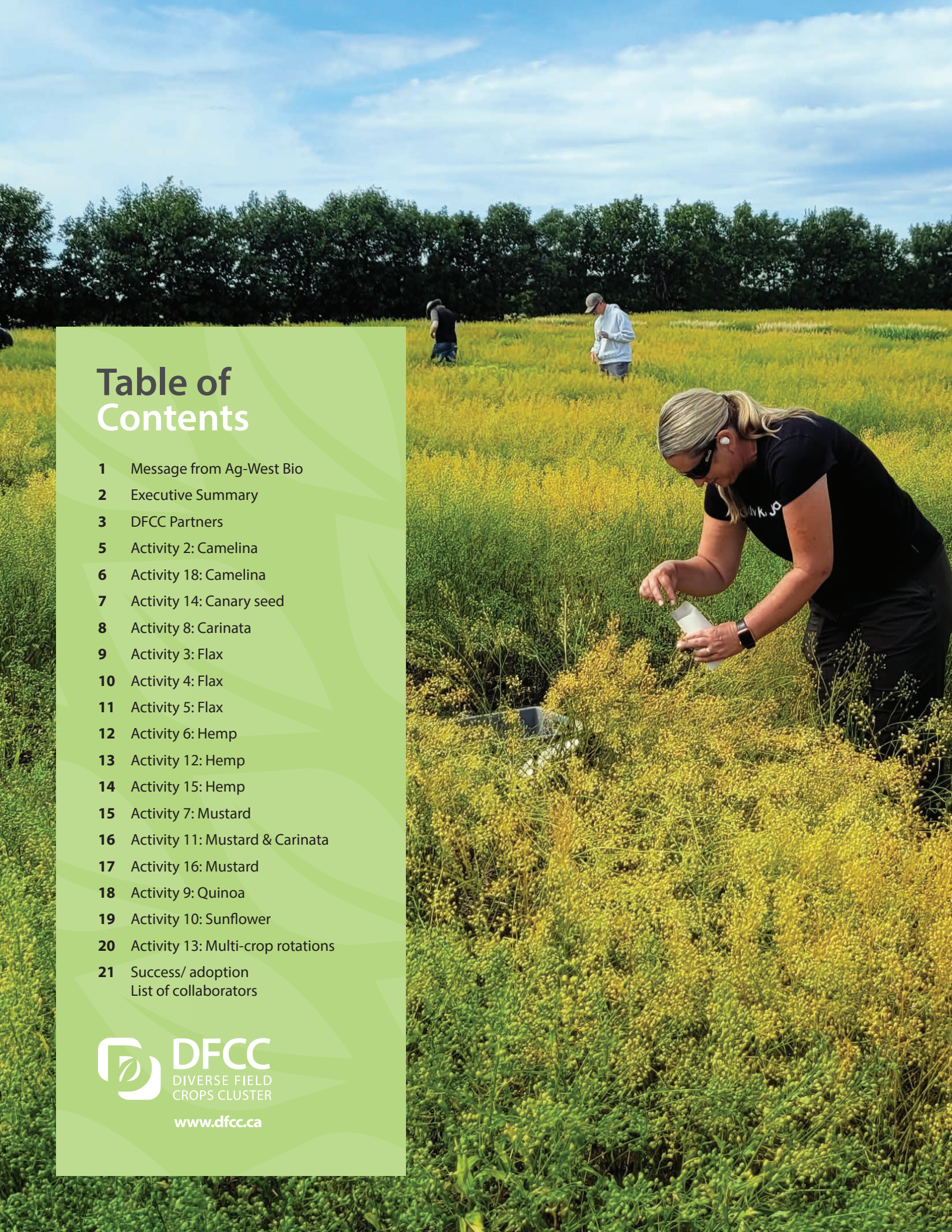

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Sustainability is at the root of the Diverse Field Crops Cluster

Ag-West Bio was pleased to have played an important role in the success of the Diverse Field Crops Cluster over the past five years, providing management and administrative support for the project. Crop development is a vital link in the agriculture industry's value chain, beginning on lab benches and greenhouses, moving to the fields, and finally, becoming value-added products on the shelves. Our strength, as an industry, begins with the research.

We believe diversification is essential for the agriculture sector to be sustainable. Canola, wheat and pulses are important, high-value crops and staples for this province. But as all producers know, including other crops in rotations is key to keeping the land healthy and productive.

The goal of DFCC is to increase the value of high-potential, special crops through research, to supply producers with more cropping options. This will break disease and pest cycles, help producers cope with changing weather patterns and volatile commodity prices and provide market opportunities.

We wish to thank the seven Crop Sector Members who participated in the DFCC project, along with the researchers involved in the 16 activities, the industry funders (all are listed at the back of this publication); and of course Agriculture and Agri-Food Canada for funding support through the AgriScience Clusters Program under the Canadian Agriculture Partnership.

Karen Churchill
President & CEO
Ag-West Bio Inc

Executive Summary

The Diverse Field Crops Cluster is an agri-science cluster whose purpose is to support the research and development of high-potential, special crops: flax, camelina, canary seed, sunflower, hemp, quinoa, mustard and carinata.

Led by Ag-West Bio, and with funding from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program and industry partners, DFCC aligns industry and research stakeholders to seize market opportunities and accelerate the acreage and market returns of these crops.

It was a pleasure to work with the Crop Sector Members and the scientists who undertook this important research to advance these special crops.

We are pleased to present the research results from the five-year DFCC project in the following articles.

Carol Ann Patterson
DFCC Project Manager

Crop Sector Members

Canary Seed Development Commission of Saskatchewan

SMART EARTH

MANITOBA CROP ALLIANCE

Mustard 21 Canada inc.

SaskFlax

NORQUIN CANADIAN GROWN QUINOA SINCE 1992

CHTA ACCC
Canadian Hemp Trade Alliance
Alliance Commerciale Canadienne du Chanvre

Other Industry Funders

InfraReady PRODUCTS (1998) LIMITED

RDAR Results Driven Agriculture Research

WGRF Advancing Agriculture through Research

nuSEED

SASK MUSTARD SASKATCHEWAN MUSTARD DEVELOPMENT COMMISSION

Saskatchewan

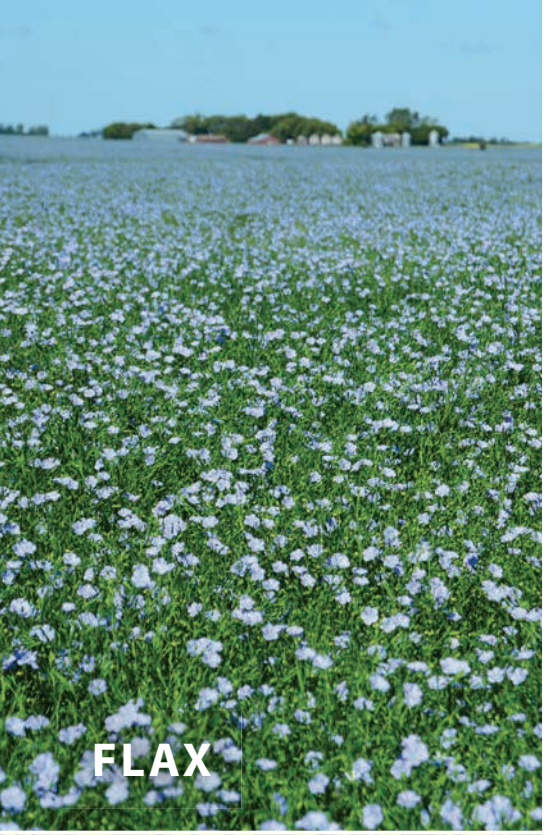
Manitoba

Alberta

CMA

DAIRY FARMERS EST. 1974 OF MANITOBA

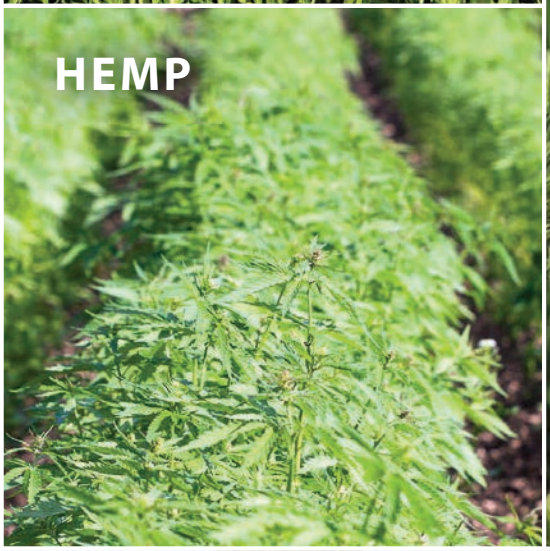
InnoTech ALBERTA A SUBSIDIARY OF ALBERTA INNOVATES


FLAX


CAMELINA


CANARY SEED


SUNFLOWER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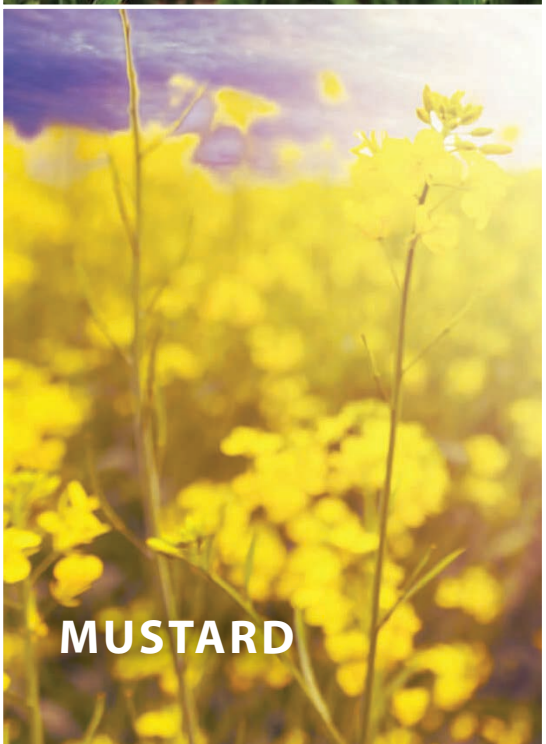

MUSTARD

Activity 2: Camelina

Camelina's unique oil profile offers exciting opportunities as a feed ingredient for livestock, companion animals and aquaculture, and in emerging markets.

New genetics support camelina's full potential on the Prairies

Camelina is an ancient oilseed native to Europe and southwestern Asia that has been associated with human civilization since prehistoric times. Now it is experiencing an awakening on the Canadian Prairies.

This is largely due to its unique oil profile, which offers exciting opportunities as a feed ingredient for livestock, companion animals and aquaculture, and in emerging markets like human health supplementation and biofuels.

Market interest is growing rapidly; however, seeded acres have not kept up with demand.

With DFCC funding support, Christina Eynck, Isobel Parkin and Mark Smith, a team of research scientists with Agriculture and Agri-Food Canada, are utilizing modern technologies adopted for breeding of major commodity crops to develop new camelina varieties that are more attractive to growers and processors.

Smart Earth Camelina led this DFCC activity. Debbie Puttick, Smart Earth's Oilseeds Research Team Leader, says "We think there is an important place for camelina in the market. Early studies show that camelina can outperform canola in areas that wouldn't produce high input and high-cost crops. In particular, it shines in Saskatchewan's brown soil zone. We see a lot of potential."

Eynck, primary researcher on the project, is using pedigree breeding to develop camelina lines with superior agronomic traits and seed quality. "The team is using traditional breeding methods to improve camelina's agronomic traits, like increased seed yield, disease resistance and larger seed size," she says. "This means looking at thousands of lines to achieve results, which is why combining this work with molecular breeding is so important."

Running parallel to Eynck's breeding program, Parkin is responsible for developing a molecular breeding platform for the crop.

"Molecular tools will speed up the breeding process by following traits within breeding populations," says Parkin. "We are applying the latest technologies used to breed the bigger crops. Ultimately, this means new and better varieties get to market faster."

The targeted and collaborative effort is paying off. Parkin's work has resulted in a comprehensive catalogue of the available variation in each of the parental lines of the world's first camelina multi-parent advanced generation (MAGIC) mapping population. This will facilitate efforts to develop markers for specific regions of interest in the genome and to target any trait in future breeding programs.

In fact, newer registered varieties now offer increased seed size of up to 50 per cent. Feedback from growers is that this has made a big difference with seed establishment and harvestability.

Smith's work has also offered extremely promising results.

"We've used mutant lines to screen for more desirable fatty acids," he says. "It's a strategy that has allowed us to reduce the unhealthy omega-9 oils to make room for the more desirable omega-3 fatty acids."

Perhaps one of the most exciting components is the development of a winter-type variety, the only true winter type oilseed available to growers on the Prairies. The team is currently incorporating the superior agronomic traits from spring varieties into winter types as well as herbicide resistance and resistance to downy mildew.

Eynck is extremely optimistic about camelina for the Prairies.

"The interest in camelina has been slow but it is gaining momentum steadily. There are more and more companies interested in utilizing camelina," she says. "Growers have the chance to grow something with value that won't sit in the bin."

This DFCC activity is led by Smart Earth Camelina Corporation with funding support from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program, and Smart Earth.

Summer students and technicians helped Christina Eynck's research team phenotype lines of a large camelina mapping population (in this photo they are collecting pods). The data will be used for genome-wide association studies (GWAS) in Isobel Parkin's lab, with the aim to develop molecular markers for agronomically important traits.

Phenotyping biologist, Hema Duddu (on the right) with one of his phenotyping tools, a drone, used for DFCC Activities 2 and 8. AAFC increasingly uses UAV imagery to characterise germplasm for traits of interest.

Winter camelina is seeded in the fall and overwinters in the form of a rosette. Its winter hardiness is comparable to that of fall rye. It is the only oilseed that can be grown as a winter crop on the Canadian Prairies.

Activity 18: Camelina

Results from this research have the potential to create lucrative opportunities for camelina in the pet food market.

Camelina: An ancient crop with exciting opportunities in the canine and equine feed market

Camelina has numerous benefits from an agronomic perspective that make it an attractive option for prairie growers' crop rotations. Camelina's unique fatty acid profile, enriched with omega-3 fatty acids, is making waves amongst companion animal scientists.

DFCC supports research to establish camelina as an oil of choice for the companion animal market. Results from this research have the potential to create lucrative opportunities for camelina in pet foods and as a supplement option for horse owners.

Kate Shoveller, Professor and Champion Petfoods Chair in Canine and Feline Nutrition, Physiology and Metabolism at the University of Guelph and principal investigator, says Canada is on track to be a major pet food exporter. "Canada-made and Canadian ingredients signal quality. There is a lot of interest in moving away from diets that contain more starch to diets containing more oils. Low-fat diets may not be optimal for all healthy mammals." Camelina checks a lot of the boxes.

Camelina oil has an optimal ratio of omega-6, omega-9, and omega-3 fatty acids, with linoleic acid (LA) identified as essential in canine diets because dogs are not able to produce this fatty acid in their body. However, the omega-3 fatty acid, α-linolenic acid (ALA) needs to be provided at a ratio of around 1:5 to 1:10 (omega-3: omega-6 fatty acid ratio) to help to balance inflammatory processes in healthy mammals. Different ratios may be appropriate for different life stages and health needs. The research conducted in Shoveller's laboratory explored camelina's unique oil composition and whether this may improve a dog's quality of life by supporting skin and coat health.

Shoveller's team examined camelina oil use for dogs over a five-month period, using both objective and subjective measures to test the safety and efficacy of camelina oil supplementation compared to flax and canola oil, two commonly used oils in canine and equine nutrition programs.

"Our data indicates that camelina oil is safe for inclusion in dog food," says Shoveller. "This research also confirmed our hypothesis that camelina offers the same skin and coat benefits as other high-quality, gold standard oils currently used in pet foods. This is an extremely exciting development for the pet food sector as it provides a new oil option, diversifying the ingredient supply chain."

Subsequent research by Wendy Pearson, Associate Professor at the University of Guelph, built on Shoveller's work to test camelina versus flax oil and canola oil in equine diets. In addition to comparative studies, Pearson investigated camelina's influence on the equine inflammatory response. "Previous work from our lab demonstrated that flax oil reduced inflammation in horses, and we wanted to determine if adding camelina oil yielded similar results," she says. Pearson's team is in the process of analyzing the results of the equine trials.

Camelina has several advantages that make it exceptionally attractive to companion animal feed and food industries.

MSc students Scarlett Burron (left) and Taylor Richards (right) with horses Big Mac and Samson.

Shoveller notes, "It is a non-GMO product, which automatically makes it a fit for pet food companies attempting to enter the European market. It is also a desirable ingredient in that the oil is remarkably shelf-stable at room temperatures." This means pet food manufacturers and owners can be less concerned with rancidity and storage issues compared to other types of oils.

All ingredients used in any pet food must be acceptable either via the AAFCO (Association of American Feed Control Officials) ingredients definition process, formal FDA-CVM review, or Self-Affirmed GRAS (Generally Recognized As Safe). Smart Earth Camelina Corp., the industry partner in this research, recently was able to complete an Independent GRAS Conclusion (Self-Affirmed GRAS) for camelina oil based on the research performed by Shoveller's team. This data further substantiates the inclusion of camelina oil as part of the AAFCO definition for Vegetable Fat, or Oil so that camelina oil can be used throughout the North American companion animal industries.

Canadian pet food brands are globally highly sought-after products. Jack Grushcow, president of Smart Earth, believes camelina's uniquely Canadian quality will further enhance the country's already respected reputation for innovative food production. "With these ratings," Grushcow says, "I anticipate the pet food industry will see camelina as a continuing point of differentiation in their products."

This DFCC activity is led by Smart Earth Camelina Corporation, with funding from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program and Smart Earth Camelina Corporation.

Activity 14: Canary seed

Canary seed for the food market presents value-added opportunities along with other benefits for growers.

Canary seed makes leaps and bounds towards human food market

In 2015, glabrous (hairless) Canary seed received approval for the human food market in both Canada and the U.S. Thanks to a Diverse Field Crops Cluster research project, the lab-scale dehulling process has now been optimized using several varieties and recent research into heat processing is providing valuable information on its storage stability, functional properties and taste attributes.

The research team of Nancy Ames and Lovemore Malunga at Agriculture and Agri-Food Canada worked with processor InfraReady Products (1998) Ltd. to investigate how heat processing can extend shelf life, prevent rancidity and control microbial activity.

They looked at the shelf life of heat-treated, dehulled, whole grain Canary seed (called groats) and whole grain flours versus non-heat-treated groats and flours when stored for up to 10 months at different temperatures. The project also investigated the effect of heat treatments on the flavour profile.

The researchers found that, similar to oat processing, a heat treatment to inactivate enzymes that cause rancidity is necessary to extend shelf life of Canary seed. They also conducted sensory studies to evaluate taste and developed a 'flavour profile lexicon' of Canary seed to inform food ingredient manufacturers of its potential appeal to consumers. This involved identifying and describing the attributes of Canary seed flour in, for example, porridge or muffins.

"The biggest question now," says Malunga "is how does the food industry take Canary seed and make it something that people want to eat? Unlike a product like oats, that people are familiar with, Canary seed is a new food source. How do the various compounds in Canary seed influence taste and smell?"

Canary seed for the food market presents value-added opportunities, along with other benefits, for growers.

"Canary seed has attracted the attention of the food ingredient market for its starch and protein composition, as well as its healthful fibre," states Ames. "It is very versatile and has potential for a wide variety of foods including gluten-free items."

"Saskatchewan has a history of developing niche market crops, of bringing different attributes to crop rotation, and making crop rotation more sustainable," says Kevin Hursh, executive director of the Canary Seed Development Commission of Saskatchewan (CSDCS). "Although Canary seed is not as high yielding as some crops, it's a relatively low input crop and requires fewer nutrients than others. It's also a high protein cereal, averaging 22 per cent as compared to 12 to 14 per cent for other cereals, and has an oil content similar to oats."

He adds, "We have a small dehulling operation in West Central Saskatchewan near Herschel. We also have InfraReady that is able to turn the seed into flour or flakes, both raw and pre-cooked."

The Commission is also promoting food use of Canary seed, branded as Alpiste. (Visit www.alpistecanada.ca to learn more.)

"Now that we have a good handle on heat treatments and other processing practices, we can provide InfraReady with information they need for processing and testing," says Malunga. "We've gone in-depth to figure out flavour profiles that contribute to taste, which will help breeders and growers in selecting varieties that appeal to processors and consumers."

What's next for Canary seed? Beyond including the whole groat or whole grain flour in food products, the industry will be looking at fractionation processes to create value-added ingredients, such as protein or starches.

Left: Research team member Babak Sobhi using the dehuller. Bottom Right: Lovemore Malunga doing volatile compound analysis of Canary seed using GC-MS system.

This DFCC activity is led by the Canary Seed Development Commission of Saskatchewan with funding support from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program, Western Grains Research Foundation, InfraReady Products (1998) Ltd. and CSDCS.

Activity 8: Carinata

The carinata variety Nujet 400 was a direct result of the hybrid development work. It features a 20 to 30 per cent higher yield than traditional varieties.

AAFC research technician Jill Hueller, working on the development of doubled haploid (DH) plants of *B. carinata*. Jill was working on the development of DH restorer lines, used in the development of carinata test hybrids.

Saskatoon-based R&D developing new industrial oilseed crop

Carinata is an oilseed in the Brassica family, closely related to mustard and canola. It is being developed as a dedicated industrial feedstock crop for biofuel production and its meal co-product for livestock feed. Researchers at AAFC's Saskatoon Research and Development Centre, in cooperation with Nuseed's Saskatoon research team, recognize the crop's global potential.

Canada's pledge to reduce greenhouse gas (GHG) emissions to 30 per cent of 2005 levels by 2030, and the increasing global demand for plant-based oil feedstocks is driving the development of low carbon intensity biofuels. Both the United States and Europe also have clean fuel policies supporting lower carbon fuels and the need for scalable renewable feedstocks. Carinata is recognized as a sustainable fuel feedstock crop that can reduce GHG emissions.

"There is huge opportunity in the renewable fuel markets today, particularly in Europe, with its large number of hydrogenated vegetable oil treatment facilities," says Rick Bennett, Senior Plant Breeder based at Nuseed research facilities in Saskatoon, Saskatchewan. "Carinata is a high-value biofuel feedstock crop as the oil composition works well in the biofuel conversion process."

Carinata, when crushed to extract the non-food oil, yields a high protein, non-GMO meal for animal feed. It has a higher protein and lower fibre content than canola meal. In North America, carinata meal has been approved as a feed source for the beef industry in the U.S. and its non-GMO status paves the way for access to European markets.

Top: The carinata nested association mapping (NAM) populations trials were conducted in 2017 and 2018. Christina Eynck's team, which included many summer students, phenotyped the carinata NAM population extensively.

Bottom: The harvest of the carinata NAM population in 2018, the AAFC combine is in the front and Nuseed's combine behind. The trial was so big (over 3,000 plots) that the two groups decided to harvest it jointly.

In this project, research focused on germplasm development using inter-specific hybridization, meaning that carinata was cross-pollinated with canola and condiment mustard to achieve desired traits. The goal was to develop varieties that will enhance the marketability of carinata by increasing erucic acid content and lowering glucosinolates. Erucic acid is valued by the oleochemical industry (chemical compounds derived from natural fats and oils) for its industrial applications and higher energy potential. Glucosinolates are antinutritional compounds found in Brassicas that limit a body's ability to absorb nutrients and therefore limits carinata's use in specific feeds to include only the meal after oil processing has adequately reduced levels.

Christina Eynck, a research scientist with AAFC and one of the researchers involved in the project, says the results have been extremely promising. Recent development of super high erucic acid carinata varieties boast an erucic acid content of about 58 per cent.

Hybrid variety development is also a key part of the work being conducted between AAFC and Nuseed in Saskatoon through the Diverse Field Crops Cluster.

Nuseed has commercial contract production of a new hybrid carinata variety in South America and the southern United States underway this year. Nujet 400, a direct result of the hybrid development work, features a 20 to 30 per cent higher yield than traditional carinata varieties.

Currently there are no carinata acres in Canada due to existing regulations. Its high heat and drought tolerance may make it an option in areas that may not be as productive for other crops, like canola, due to climate or soil conditions.

Combating climate change is a multi-faceted, multi-year, global endeavour, with temperatures rising on the Prairies and droughts like the 2021 event expected to increase in frequency. Saskatoon-based carinata research is helping grow the global renewable energy feedstock supply; adding a drought and heat tolerant oilseed crop makes carinata a worthwhile investment for global agriculture.

This DFCC research activity is led by Mustard 21 Canada Inc. with funding support from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program, Saskatchewan Mustard Development Commission, Canadian Mustard Association and Nuseed Canada Inc.

Activity 3: Flax

New flax varieties on the horizon

It's exciting news – not just for breeders and growers but the entire industry.

Research scientist Bunyamin Tar'an, flax breeder at the Crop Development Centre (CDC) at the University of Saskatchewan, in collaboration with Agriculture and Agri-Food Canada's Research and Development Centre at Morden, Manitoba, have successfully developed a new brown seed variety that was released to select seed growers in the spring of 2022. This is in large part due to strategic vision of the breeding program.

Research scientist Bunyamin Tar'an, flax breeder at the University of Saskatchewan Crop Development Centre in a research plot at Indian Head, SK.

A pedigree analysis revealed that Canadian flax cultivars shared an average of only 8.8 common ancestors and therefore have low genetic diversity. In other words, all current domestic flax cultivars basically shared the same genetic background. The Canadian flax breeding program is attempting to increase genetic diversity through the introduction of new germplasm.

Tar'an comments, "We need to continue to build on yield capacity of flax because compared to other commodities, yield capacity has plateaued. We needed a new strategy for the longer term."

Superior oil quality and higher oil content have long been the major features of Canadian flax seed. In fact, Canada is the world's leader in the production and export of flax. Flax was Canada's first oilseed and has a long history of breeding, initiated in the early 1900s. Since its inception in 1976, the Crop Development Centre Flax Breeding Program is currently the sole provider of new cultivars for the Prairies and is the only one of its kind in Canada.

To meet the objective of increasing seeded acres, growers placed a high priority on maintaining flax rust and Fusarium wilt resistance as well as improved resistance to powdery mildew and pasmo (a fungal disease). They also conducted extensive Adaptation Testing where experimental lines were grown in the varieties of ecozones that exist across the Canadian Prairies.

Tar'an and his team are now testing about 20 lines of seventh and eighth generation seed. These will go into registration trials in about 15 locations across Western Canada involving different regions and soil types. The parental germplasm for the project came from existing Canadian cultivars, the Plant Gene Resources Canada (PGRC) collection, as well from new sources not previously accessed by Canadian breeders.

"Our goal was to develop two new brown seed varieties and one new yellow seed variety with improved agronomy for growers," states Tar'an. "And we are getting close. Two breeding cycles per year – a summer nursey in Canada and a winter nursery in New Zealand – have allowed us to speed up the breeding process."

The breeding program will result in the creation of higher quality, higher yielding lines with more manageable fibre and better disease resistance, which also means reduced fungicide use. This translates into fewer input costs for farmers and is a good news story for the environment too.

"Having the best genetics for their farm puts growers at a competitive advantage for markets," says Wayne Thompson, former Executive Director of the Saskatchewan Flax Development Commission (SaskFlax). "We want to maintain oil quality and an acceptable oil profile that will appeal to both processors and consumers."

Seed was delivered to seed growers in 2022. It will take about three years for certification, so growers should be able to start accessing the new seed varieties in 2025.

This DFCC activity is led by Saskatchewan Flax Development Commission (SaskFlax) with funding support from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program and the Western Grains Research Foundation and SaskFlax.

Researchers have been able to identify the specific segment of the flax genome where pasmo resistance exists.

Activity 4: Flax

Collaborative research leads to better understanding of diseases in flax

With DFCC funding, Bunyamin Tar'an is leading the research on resistance to three fungal diseases in flax: pasmo, Fusarium wilt and powdery mildew. All three can reduce yield and quality and increase the cost of production due to higher use of fungicides.

The most practical method of controlling these diseases remains the development and use of resistant varieties combined with effective crop rotations. However, determining genes associated with disease resistance remains a significant challenge.

"We are looking at genetic resistance to disease to be able to develop varieties that will help reduce production risk," comments Tar'an. "Potentially we can also get higher yields because of less damage from disease and better seed quality."

Pasmo is the most prevalent disease in flax. Some estimates indicate that pasmo can cause up to 70 per cent yield loss, which makes the research incredibly important.

Tar'an and his team at the CDC have been working with Sylvie Cloutier and Frank You, scientists at the Agriculture and Agri-Food Canada's Ottawa Research and Development Centre, to determine how pasmo resistance is controlled in flax. From this research, they have been able to identify the specific segment of the genome where pasmo resistance exists.

Tar'an's team screened a large collection of germplasm from the Plant Gene Resources of Canada as well as their own breeding lines for pasmo resistance. They are looking at the correlation between this germplasm and what they now know about the genomic location of pasmo resistance.

"This genomic information will be critical in selecting new cultivars," says Tar'an. "Understanding how molecular markers are associated with disease resistance will greatly improve selection efficiency in the flax breeding program."

Because it is soil-borne, Fusarium wilt is a very difficult disease to control. Conditions that stress the plant, like the limited moisture that the Prairies has seen over the last couple of years, increases the risk of infection. Scientists from the CDC and AAFC in Ottawa, Ontario and Morden, Manitoba have been collaborating to identify the genetic components associated with Fusarium wilt resistance. They have come up with one genetic component that is resistant to Fusarium wilt which will help with genetic selection.

"What's very interesting is that, in looking at genetic components or mechanisms associated with disease resistance, we have identified the conserved genomic regions for resistance in both Fusarium wilt and powdery mildew," says Tar'an.

Thanks to previous breeding efforts, there is at least some genetic resistance to Fusarium wilt and powdery mildew in recent cultivars. However, even with these genetics, they can still cause up to 20 per cent and 50 per cent yield loss, respectively.

"Doing research is essential to flax crop development," says Wayne Thompson, former Executive Director of SaskFlax. "DFCC funding allows us to leverage growers' levy dollars to be able to work with Agriculture and Agri-Food Canada, so we can do more research than we can on our own."

"And, of course, it enables us to have access to other researchers, which is of significant benefit to the industry," he continues. "In that way we can all share in the work and generate results more quickly. Plant breeders can put it to use and create a product that is extremely useful for flax producers."

This DFCC activity is led by Saskatchewan Flax Development Commission (SaskFlax) with funding support from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program and SaskFlax.

Activity 5: Flax

Through this research we have gained substantial knowledge of genetics and what constitutes high accumulation of cadmium and low accumulation of cadmium.

Axel Diederichsen, research scientist with Agriculture and Agri-Food Canada's Plant Gene Resources of Canada, and Sylvie Cloutier, AAFC Ottawa Research and Development Centre, have been working on identifying genetic markers associated with cadmium accumulation.

Molecular markers key to identifying low and high cadmium flax germplasm

With the completion of a second set of field trials in 2021, a DFCC funded research project has made significant progress looking into cadmium accumulation in flax.

The research team has been working on identifying genetic markers associated with cadmium accumulation in flax. The team includes Axel Diederichsen, research scientist with Agriculture and Agri-Food Canada (AAFC) Plant Gene Resources of Canada (PGRC) in Saskatoon; Sylvie Cloutier, AAFC Ottawa Research and Development Centre; Megan House, a member of the flax breeding team led by Bunyamin Tar'an at University of Saskatchewan's Crop Development Centre (CDC); and Oscar Molina, Research Scientist at the AAFC Morden Research and Development Centre.

Flax has an affinity for uptake of cadmium, a heavy metal. At present, the biggest market for flax is industrial applications, so the presence of cadmium has not been an issue. However, given the growing market for flax for both food and feed, creating flax cultivars with minimal or no cadmium accumulation has become a new priority for breeding. The European Union (EU) has set a threshold value for cadmium concentration in the seed.

PGRC had a collection of over 3000 unique flax samples (or accessions). The first step for the team was to assess a 'mini-core collection' from these samples. They produced highly uniform varieties with less genetic variation through repeated self-fertilization (called 'pure-lining'), resulting in 166 pure lines that included 144 gene bank accessions, 20 recent Canadian flax cultivars and two check cultivars. This seed material was used for field trials at three locations in western Canada with four of the tests being assessed for cadmium concentration in the mature seed. Additional experiments were conducted at the CDC in greenhouse tests to better understand cadmium accumulation in various plant parts and during various growth stages; and at AAFC Ottawa, to study the gene expression in high and low cadmium lines grown in high and low cadmium soils.

The findings showed that the genotypic effects in cadmium accumulation were not restricted to the seeds. The cadmium concentration was higher in roots and leaves than in seeds. There were varietal differences in mechanisms that determine cadmium concentration and distribution in various plant tissues. In the field, some lines were consistently low in seed cadmium content and others were consistently high, indicating that there is a genetic component to cadmium accumulation in flax seeds.

All recent Canadian flax varieties included in this screening accumulated cadmium in the seed above the threshold level of 0.5 mg/kg set for cadmium in flax seed by the EU; in the PGRC collections only four lines had mean values lower than this threshold.

The complexity of the genetic mechanisms underlying the accumulation of cadmium in flax seeds was dissected. A total of 14 regions of DNA associated with cadmium concentration were identified. The location of three candidate genes and their single nucleotide polymorphism (SNP) was determined and can be used for marker-assisted selection in breeding programs to develop low-cadmium flax varieties. The researchers say using genomic selection could translate into rapid progress towards developing low-cadmium flax varieties.

The project demonstrated that resolving the problem of cadmium accumulation in flax seed using a breeding approach is a great challenge. The heritability of the characteristic of cadmium affinity is low and molecular markers had only a low association with this characteristic. Before this is resolved by breeding, researchers recommend that producers grow flax in low-cadmium content soils to avoid exceeding the threshold value for cadmium in the seeds.

With the flax food and feed market growing, creating flax cultivars with minimal or no cadmium accumulation has become a priority.

"The most important thing is that through this research we have gained substantial knowledge of genetics and what constitutes high accumulation of cadmium and low accumulation of cadmium," said Cloutier. "We are well on our way to translating that for breeders to achieve the objective of creating low-cadmium genotypes. This research will help ensure the long-term sustainability of flax production in Canada.

This DFCC activity is led by Saskatchewan Flax Development Commission (SaskFlax) with funding from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program and SaskFlax.

Activity 6: Hemp

Precise, unbiased information will help processors and growers select the hemp variety with the characteristics they are looking for and that best suit their needs.

Developing a better understanding of how hemp varieties perform across Canada

Hemp could be regarded as one of the most versatile crops grown in Canada. However, little is known about how individual varieties perform in growing regions across the country. A DFCC funded project seeks to develop a better understanding of hemp varieties and reduce risk associated with variety selection for the entire value chain.

"The Canadian Hemp Trade Alliance put out a request to industry, both Canadian and non-Canadian, to enter their varieties as cultivars to be grown at the research sites," comments James Frey, Diversification Specialist with Manitoba Agriculture and Resource Development and principal researcher on the project.

"From 2018 to 2022 we've had anywhere from 10 to 16 varieties entered into the program year by year at nine to 17 locations. We replicated trials to analyze information statistically at the end of each season to determine how a variety expresses its genetic traits in different locations with unique environmental conditions," says Frey.

James Frey, Principal Investigator, examines a hemp plant for seed maturity.

"What we've found is that some varieties do express themselves quite differently, especially based on day length," he adds. "This can affect plant height and development."

Frey and his team are establishing a framework to optimize and standardize measurement practices for both economic and agronomic traits. In grain type varieties, for example, that would include seed size, oil and protein composition. In fibre varieties, one trait that is being investigated is tensile strength.

Cannabinoids is a completely different story.

All hemp varieties grown in Canada must be approved by Health Canada. Varieties on the List of Approved Cultivars have been demonstrated to contain 0.3% or less THC (tetrahydracannabinol) in the flowering heads, branches and leaves. With regards to other, non-intoxicating cannabinoids, Frey states that, "These are present at low levels in industrial hemp and have health and wellness potential if extracted and concentrated, but there are many unknowns. How does the profile of the cannabinoids change in the plant over time? How do they react to stress, like drought or insect pressure? We don't know in a replicated, scientifically validated way."

And direct applications are just the tip of the iceberg for hemp.

"It's possible to develop fractionation processes to use oil and protein for other purposes," says Frey. "Hemp fibre has the potential for resins and plastics, as well as composites for industrial applications, like car panels, to replace plastics with a lightweight and durable alternative. This could have environmental and economic benefits. The hemp plant has enormous potential in the industry, and we will be able to tap into this database going forward."

The research will provide accurate and impartial third-party data to growers and industry about the environmental stability and agronomic traits of each variety.

The idea is not to increase performance of the hemp crop but to validate a database and create a baseline for the industry, explains Frey. "It's precise, unbiased information that will help processors and growers select the variety with the characteristics they are looking for and that best suit their needs. It will improve efficiency and reduce risk and costs for the entire industry."

Frey notes that over the four years of the project the team has generated 41 years of site data: "The more site years of data that you have, the more confidence you can have in the numbers," he says. They are steadily expanding this baseline of information, deepening and broadening their understanding of different varieties. "We are increasingly confident in the performance of varieties across the Canadian landscape. In turn, this will give growers and processors a greater sense of confidence."

This DFCC activity is led by the Canadian Hemp Trade Alliance with funding from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program, Government of Alberta and Canadian Hemp Trade Alliance.

Activity 12: Hemp

This research provides solid evidence to demonstrate to the international community that Canadian-produced hemp is safe from heavy metal contamination.

Jan Slaski (right), principal investigator, and Sharla Eldridge, senior technologist at InnoTech, inspect the National Hemp Variety Trial at InnoTech Alberta's research farm in Vegreville, AB.

Research demonstrates hemp cadmium levels negligible

Hemp, like other efficient nitrogen transporter crops (e.g. flax and durum wheat), tends to accumulate cadmium, a naturally occurring heavy metal that may have adverse effects on human health. Canadian soils in some regions may contain relatively high levels of cadmium and other heavy metals.

Recent DFCC funded research on hemp aimed to identify whether the industry should be concerned about cadmium levels in hemp in Canada.

Jan Slaski of InnoTech Alberta was principal researcher on the project. The objective of the research was to identify if there was the potential for hyper-accumulation of cadmium and other metals in hemp grain. Slaski says "This could be a safety issue or a non-tariff barrier for international trade if cadmium exceeds the proposed maximum acceptable limit of 0.1 µg/g of seeds. If cadmium uptake is a concern, farmers would have to be very careful about field selection and management practices to minimize cadmium uptake."

"Transporters on the membrane allow for the uptake of cadmium in hemp," explains Slaski. "However, what really matters is the translocation of cadmium to different organs of the plant, particularly the seeds, which is what is consumed."

Jan Slaski in a hemp crop. Research found that a combination of low soil pH and considerably elevated concentration of cadmium can contribute to higher cadmium uptake in hemp.

Phase 1 of the research involved controlled greenhouse studies to evaluate the potential of three hemp types (fibre, grain and dual (fibre/grain)) to accumulate cadmium and to identify soil conditions conducive to enhancing cadmium uptake. This research found that the combination of low soil pH and considerably elevated concentration of cadmium in soil contribute to higher cadmium uptake by the plants.

Researchers analyzed four distinct plant parts – roots, stems, leaves and grain (seeds) – and found that the majority (50-70%) of cadmium was found in the roots, regardless of the variety. This is good news, as it is the seeds of the plant that are used for food.

Phase 2 involved quantifying cadmium and other heavy metals in soil and corresponding grain samples of 13 Canadian hemp varieties grown at 11 test sites participating in the National Hemp Variety Trials. On average, cadmium was 0.4mg Cd/kg of soil; however, levels of cadmium in the grain did not exceed 0.1 µg/g of seeds, regardless of the variety.

Phase 3 during the summer of 2021 tested soil and grain from commercial hemp operations across the country. Soil was tested in the spring and grain samples submitted in the fall from 20 commercial field sites. In analyzing the data, Slaski and his team identified substantial differences in soil properties among locations in different regions, which could play a role in propensity for cadmium uptake. However, they did not find any grain sample that contained levels of cadmium greater than 0.1 µg/g of seeds, so are confident cadmium is not a problem in commercial fields.

It's a win-win-win scenario for everyone involved.

"Research like this," says Slaski, "will give consumers the confidence that hemp grain products contain negligible levels of cadmium and other heavy metals. It reassures farmers that they are at low risk – they don't have to be vigilant about cadmium levels, or continually test for cadmium. And, perhaps most importantly, it will provide solid evidence to demonstrate to the international community that Canadian-produced hemp is safe from heavy metal contamination."

This DFCC activity is led by Canadian Hemp Trade Alliance with funding from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program, InnoTech Alberta and the Canadian Hemp Trade Alliance.

Activity 15: Hemp

This research indicates that canola and hemp are comparable in terms of nutrition, and hemp meal is safe to feed to dairy cattle.

Hemp: A promising livestock feed alternative

Hemp is a crop commonly grown for food, fibre, and bioactive fractions. Now, Diverse Field Crops Cluster research is demonstrating how hempseed meal – a byproduct from hempseed oil processing – has tremendous potential as a livestock feed ingredient.

Jan Plaizier, a researcher at University of Manitoba, has been studying hemp feed in dairy cattle and the quality of hempseed meal in comparison to other feed alternatives, such as canola meal and soybean meal.

"The major regulatory concern with feeding hemp products is cannabinoids, including THC and CBD," says Plaizier, "but commercially grown hemp is very low in cannabinoids. Our research studied whether any cannabinoids are transferred to milk and meat products from hemp feed."

The first trial involved non-lactating cows that were fed rations containing hempseed meal, canola meal, or a combination of hempseed and canola meal. Feed intake, metabolism, nutritional status, as well as digestibility were compared. Cannabinoid levels in livestock tissues were also assessed.

"The results were that we found no cannabinoids in fat tissue, meat, urine and blood. We also concluded that, nutrition-wise, cows did equally well on hempseed and canola meal."

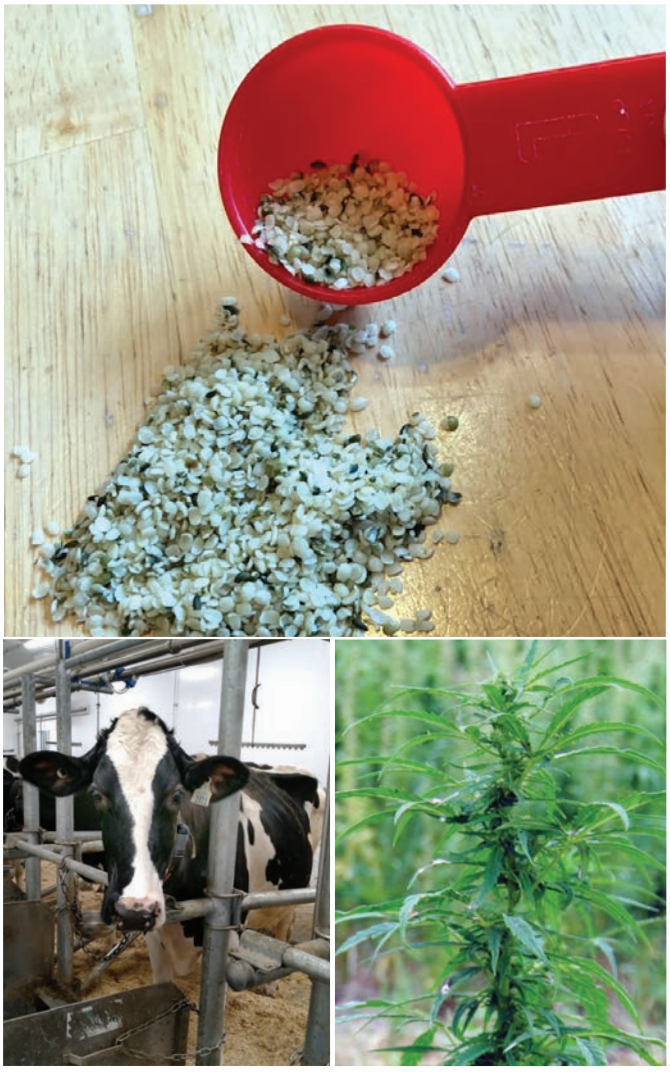
Similar trials were conducted with lactating dairy cows. Again, in analyzing the data, no cannabinoids were discovered in fat, meat, blood, milk, and urine. Cattle performed equally well on hempseed meal and canola meal. There were no differences in milk production, or fat and protein content in the milk.

"Our research indicates that canola and hemp are comparable in terms of nutrition, and that hemp meal is safe to feed to dairy cattle. This is exciting news for the dairy industry," says Plaizier. "The information gathered from this research will be part of the application to the Canadian Food Inspection Agency (CFIA) to allow dairy farmers to use hemp meal as feed."

The CFIA has not yet approved the use of hemp in livestock diets. As a result, hemp byproducts have no commercial value and are a net liability, as there is a cost for their disposal. This challenge affects the economic sustainability of the Canadian hemp industry and increases its environmental impact.

Plaizier adds, "The ability to use hempseed meal as an animal feed ingredient will provide more demand for hemp products. The hemp processing industry will benefit by getting more value for their byproducts and the livestock industry will benefit by having access to more local, high quality protein meals."

The amount and composition of fat in hemp is important for ruminants. Plaizier and his team found that replacing canola meal with hemp meal did not affect the concentration of synthesized de novo fatty acids, palmitic (C16) fatty acid, saturated fatty acids or mono-unsaturated fatty acids in the cows. However, feeding hempseed meal instead of canola meal did lead to a great increase in the concentration of total healthy polyunsaturated fatty acids in the milk.



Top: Hulled hemp seed. The ability to use hempseed meal as an animal feed ingredient will provide more demand for hemp products. Bottom Left: A hemp feeding study in dairy cattle compared the quality of hempseed meal to other feed alternatives. Bottom Right: Hemp plant.

When asked about what's next for hemp research related to livestock feed ingredients, Plaizier says that to expand the market, it will be necessary to look at other hemp byproducts, such as hempseed screenings and hempseed hulls for ruminant feed, or hemp feeds for other livestock species (e.g., swine and poultry), fish (aquaculture) and companion animals (horses, dogs and cats).

"There's so much conflicting information these days, particularly on the Internet. It's hard to know what is true and what is not, and too much information about conditions that don't apply to Canadian farmers," Plaizier says. "What works for hemp in Scandinavia will not necessarily work here. The information generated through our research is valuable and directly applicable to Canadian farmers, which is critical."

This DFCC activity is led by the Canadian Hemp Trade Alliance with funding support from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program, Government of Alberta, and Dairy Farmers of Manitoba.

Activity 7: Mustard

As an industry, our goal is to diversify the marketplace and increase demand for mustard, giving growers a profitable, sustainable oilseed crop for their rotations.

B. juncea **is commonly known as brown mustard. AAC Brown 18, released by AAFC in 2018, has a 21 per cent higher average yield than the check variety, Centennial Brown.**

Increasing mustard's yield will have big payoff for growers

Canadian farmers produce almost 40 per cent of the world's mustard crop and are the largest exporter of condiment mustards (brown, yellow and oriental varieties), much of which is grown on the Canadian Prairies. However, Canadian production faces competition from countries like Russia and Kazakhstan that are increasing their output.

Mustard 21 Canada Inc. (M21) is the organization that manages the commercialization of mustard seed. "Despite our impressive production statistics, the mustard crop has lagged behind in terms of crop development research," says CEO Rick Mitzel. "The Diverse Field Crops Cluster has helped us get significant funding for activities that will develop the crop in ways that really benefit farmers."

This round of funding served to enhance seed yield and promote more uniformity in plant height, seed size and maturity by expanding the genetic base in the elite parental lines. The team used the hybrid breeding strategy optimized in the development of AAC Brown 18 to improve brown and oriental mustard varieties.

Lead research investigator, Bifang Cheng, at AAFC - Saskatoon Research and Development Centre, notes that, "In brown and oriental mustard, we have successfully improved the Ogura cms [cytoplasmic male sterility] restorer line, which makes it possible to develop high yielding hybrids in this crop." This is an exciting development for the Canadian mustard industry.

With this approach, breeders use the cytoplasm from a radish plant to turn off male pollen production (A line) to make it sterile. The A line is multiplied by crossing with a maintainer (B) line. The fertile F1 hybrid seed that farmers grow was produced by crossing the A line with a restorer (R) line. Cheng says this strategy makes it possible to enhance seed yield by using germplasm with a broad genetic base.

She adds, "Our successful application of a hybrid strategy to enhance yield in brown mustard is the variety AAC Brown 18 that we released in 2018. It has seen 21 per cent higher average yield than the check variety Centennial Brown and, like Centennial Brown, it is well adapted to all mustard growing areas in Western Canada."

The latest variety released from the program is AAC Yellow 80 which was available for the 2021 growing season. It is a composite variety of yellow mustard, which is a combination of four component parental lines and naturally formed hybrids between those parents and has demonstrated an eight per cent higher yield (compared to the check variety Andante), easier harvesting and cleaner grain.

"Farmers are seeing the yield improvements that our research had indicated and are impressed with the harvestability of this new variety," says Mitzel. "An eight per cent increase makes a big difference in a year like this, with the high commodity prices we are seeing after the drought."

"We are continuing to move forward with new varieties and the hybrids give us an advantage in the global marketplace where we compete with other countries growing our open-pollinated varieties," he says. "In fact, AAFC-Saskatoon Research and Development Centre have several test varieties of each yellow, brown and oriental mustard going to the Mustard Adaptation Trials with excellent agronomic traits and higher yields in 2022."

"We are using Diverse Field Crops Cluster funding to explore and develop new market opportunities for mustard in the areas of protein, fibre and oil as well," says Mitzel. "As an industry, our goal is to diversify the marketplace and increase demand for mustard, giving growers a profitable, sustainable oilseed crop for their rotations."

This DFCC research activity is led by Agriculture and Agri-Food Canada-Saskatoon Research and Development Centre and Mustard 21 Canada Inc. with funding support from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program, Saskatchewan Mustard Development Commission, Canadian Mustard Association and Western Grains Research Foundation.

Activity 11: Mustard & Carinata

This research marks the first step in development of mustard and carinata varieties tolerant to Group 2 herbicides.

A single plant that survived an application of (Solo) imazamox. Rows of dead plants are visible in the background.

Non-GMO herbicide tolerant mustards and carinata offer more crop options and greater market access

Despite mustard's $120 to $140 million annual contribution to the Canadian economy, acres on the Prairies have remained steady for several years. One major challenge limiting producer uptake is the lack of registered herbicide options for managing hard-to-kill broadleaf weeds such as wild buckwheat, narrow-leaved hawk's beard, redroot pigweed and Russian thistle. These weeds affect yield and grain quality through weed seed contamination.

Carinata is a dedicated industrial oilseed being developed for the Canadian Prairies. Although it is currently not grown in Canada, the economic opportunity for carinata as feedstock for the emerging bioeconomy is substantial. To be a viable choice in their rotations, growers will need varieties that are suitable for current production methods.

Christina Eynck and Bifang Cheng, research scientists at AFFC-Saskatoon Research & Development Centre, along with industry partners Nuseed Canada and Mustard 21 Canada Inc., are bringing herbicide tolerant innovations to mustard and carinata breeding.

"The lack of herbicide options for small acreage crops like mustard and carinata is a gap. Most new technologies developed by multi-nationals are for larger crops," explains Eynck.

AAFC research technician Jill Hueller crossing *B. carinata* plants, attempting to combine two herbicide resistance genes in one breeding line.

An aggravating factor is that pulse and cereal production rely heavily on Group 2 herbicides to which mustard and carinata are highly susceptible. This limits the number of available acres suitable for carinata and yellow mustard production in the years following a pulse or cereal rotation.

This project, funded through DFCC, is focused on developing non-GMO, herbicide tolerant yellow mustard *(Sinapis alba)* and carinata *(Brassica carinata)* varieties that are tolerant to Group 2 herbicides.

Researchers are using seed mutagenesis to develop yellow mustard and carinata germplasm with Group 2 herbicide resistance. This will offer a much-needed alternative strategy for growers to manage weeds not controlled by currently registered herbicides.

"Our goal is to develop varieties that are resistant to Group 2 herbicides, which will provide growers some in-crop weed control and the option to re-crop mustard and carinata where soil residual Group 2 activity remains," says Eynck.

Acetolactate synthase (ALS) is an enzyme found in microorganisms and plants. Blocking ALS by Group 2 herbicides leads to stunting, malformation and/or death. Mutations in the ALS gene, occurring naturally or induced through mutagenesis, are known to prevent Group 2 herbicides (ALS inhibitors) from working and thus render plants herbicide tolerant. Through this work, Eynck and Cheng have been able to develop carinata and yellow mustard germplasm with increased tolerance to the Group 2 herbicide, Solo (an imidazolinone (imi)).

"This is a significant achievement for both crops as it represents the first step in the development of imi-tolerant varieties," states Eynck.

Chemical and physical mutagenesis of seed followed by selection under herbicide pressure was used in the study. This technique has been utilized to develop several herbicide tolerant crops and does not classify as genetic modification (non-GMO). Therefore, herbicide tolerant crops developed this way move through the regulatory process easier and have wider public acceptance. This will be important for developing Canadian acres as the European biofuel market is increasing its demand of non-GMO feedstocks.

"We are now working on pyramiding different herbicide tolerant genes, developed at AAFC and also Nuseed," says Eynck. "Our next step is to develop different combinations of herbicide tolerant ALS genes so we can test them against a range of Group 2 chemistries in the field."

This DFCC research activity is led by Agriculture and Agri-Food Canada-Saskatoon Research and Development Centre and Mustard 21 Canada Inc. with funding support from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program, Saskatchewan Mustard Development Commission, Canadian Mustard Association and Nuseed Canada Inc.

Activity 16: Mustard

Researchers identified ways to extract yellow mustard gums from the whole seeds and the separated seed coat, which increases processing opportunities.

Mustard seed components: untapped sources of tremendous potential

Canadian yellow mustard is a highly sought-after commodity that is marketed around the world. However, to remain competitive, the Canadian mustard industry needs to respond to growing competition from other crops and to changing consumer preferences. This involves positioning mustard beyond its traditional food uses as a condiment ingredient, flavour enhancer, and emulsifying and binding agent.

Yellow mustard *(Sinapis alba)* seed is a rich and inexpensive source of protein, polysaccharide gum and oil – all components that are valuable to the food industry.

A research project through the Diverse Field Crops Cluster investigated yellow mustard seed proteins, dietary fibres and gums, and explored their characteristics and functionalities for food applications. Janitha Wanasundara, with AAFC Saskatoon, was lead researcher on the project conducted by AAFC scientists.

The Saskatchewan Food Industry Development Centre created seasoned, extruded puffs made from yellow mustard powder, pea starch and pea fiber. Credit: Food Centre

"Ground yellow mustard is primarily used as a condiment but also in food processing because of its protein, and oil and mucilage content that make it a good binding agent," says Wanasundara. "Because of the high protein content and consumer's drive for plant-based proteins, we needed to characterize the types of protein available in the mustard seed and understand how to cleanly extract it and use it in food applications."

One noteworthy finding was that mustard protein has a great deal of potential as a supplementary protein source. Mustard proteins were compared to proteins found in peas, soybeans and milk. Wanasundara and collaborators found that mustard protein possess key functional properties required for oil emulsification, foam formation and fat holding capacity required for plant protein ingredient market options.

Additionally, mustard protein contains one of the essential (and often most limiting) sulfur containing amino acids that are needed to make up a complete dietary protein. This makes mustard protein a valuable additive to other plant protein blends that are deficient in this group of amino acids.

Steve Cui, a researcher at AAFC-Guelph, identified ways to extract yellow mustard gums from the whole seeds and the separated seed coat, which increases processing opportunities. Like xanthan gum, polysaccharide-rich, low protein yellow mustard gums have high viscosity, sheer-thinning properties, and high emulsifying and foaming properties with strong ability to stabilize the foods to which it is added. Applications include foods, such as salad dressings, mayonnaise-type products and other recipes that require a shelf stable formula, as well as industrial uses.

As most of their initial work was done at the lab level, a variety of fractionation methods were then tested to determine the best way to extract the different components on a larger scale. A key driver in this research was focusing on environmental sustainability and cost efficiency to remove barriers for processors looking to build mustard fractionation facilities.

"Being able to provide the ingredient processing industry with an efficient and sustainable blueprint for fractionating mustard into its components, based on their functions, will increase uptake and grow those markets faster," says Lamia L'Hocine with AAFC-Sainte-Hyacinthe, a project partner for the research.

Wanasundara supports L'Hocine's conclusions.

"Increasing the scientific and technological understanding of mustard components is the best way to extend the product value chain for the mustard industry," these researchers say. "Yellow mustard is an untapped source of nutritional material with tremendous potential."

This DFCC research activity is led by Mustard 21 Canada Inc. with funding support from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program, Saskatchewan Mustard Development Commission, Canadian Mustard Association and the Government of Saskatchewan.

This research has been able to identify an all-purpose class of quinoa with increased versatility and more market opportunities.

Activity 9: Quinoa

A greenhouse variety evaluation trial was part of the in-house NorQuin breeding program.

Research generates high-quality, multi-purpose quinoa varieties

With the support of the Diverse Field Crops Cluster, earlier maturing, higher quality and higher yielding varieties of quinoa have been developed. The research funding has also helped determine different market opportunities for quinoa and the varietals that best suit those markets.

Quinoa is a relative newcomer to the domesticated crops grown worldwide.

"This project is only one of four or five breeding programs in the world," says Marc Vincent, Vice President of Research and Development for Northern Quinoa Production Corporation (NorQuin), the industry partner leading the research. "There hasn't been a lot of work done on improving quality characteristics in quinoa until recently."

Vincent explains, "We started out by screening germplasm for earlier maturity and better-quality characteristics, then started a pedigree breeding program to start crossing the lines to make new populations that could be screened. We have been screening over the last three years to select lines for advancing to commercialization."

Top: Liam O'Halloran scouting for quinoa emergence in Central SK. Bottom: A potential new quinoa variety being field tested in Saskatoon.

One of the objectives was to determine markets for quinoa products—and the potential is huge. Quinoa has a wide range of applications, including being used as a whole grain, as an ingredient in baking and beverages, as well as in extrusions, like pet kibble. The research has been able to identify a class of quinoa that is all-purpose, as compared to the original varieties that were less versatile and could be used, for example, only as a whole grain or only in extrusions.

"The research has accomplished a lot in a short period of time," says Vincent. "We've been able to decrease maturity from 160 to 95 days, increase protein content to above 18 per cent (comparable to chickpeas and peas), as well as increase yields by 15 per cent. This helps enhance the nutritional standards of the product, resulting in better returns for growers and making it more marketable. Also, as a result of this research, quinoa has been reclassified as a cereal crop food which will increase the accessibility of pesticides for growers in the future."

NorQuin is now conducting pesticide tolerance trials. They have registered two insecticides and are working on registering a third, as well as two herbicides and a fungicide. They are also screening the top 25 varietals in 12 locations to ensure a good data set and increase breeder seed for all these varieties, with a goal to launch commercially in 2023.

According to Vincent, quinoa is a good fit for expanding most farms' rotations in Western Canada. It's high yielding and later maturing, which enables growers to manage their harvests with a later crop. It has similar input costs to wheat and canola, and uses the same seeding equipment, with similar settings.

In addition, quinoa is not susceptible to the main diseases seen in North America, giving growers a break from blackleg, clubroot and sclerotinia challenges (canola diseases) in rotations. It has better frost and drought tolerance than canola and most cereals. It can grow under higher moisture conditions but can also perform well in drier years.

When asked about the importance of DFCC research, Vincent says "A lot of research and money has been spent on major commodity crops, but research on minor crops seeded on smaller acres, like quinoa, is needed to bring them into the limelight because of the benefits they present to both growers and the industry."

This DFCC activity is led by Northern Quinoa Production Corp. (NorQuin) with funding support from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program and NorQuin.

Activity 10: Sunflower

This project has successfully worked with the processing industry to develop rounder seed varieties for the Canadian market as well as longer seeds for export.

DFCC research is helping to expand sunflower marketing opportunities by developing varieties with traits desired by food processors and consumers. Top right: Michael Hagen manages the year-round sunflower breeding program for Manitoba Crop Alliance. Bottom right: Planting at the nursery in Elm Creek, MB.

New approach to breeding reaps benefits for growers

The production of both oilseed and confection sunflowers in Canada has fallen off in the past few years largely due to the lack of innovation in sunflower genetics. The main sunflower hybrid grown in Manitoba is more than 30 years old, and there's not a wide selection of hybrids adapted to northern growing conditions. Nor do growers have access to modern hybrids with the agronomic traits they need to compete globally. This leaves growers with limited options.

Recent research on new sunflower varieties for confection – seeds primarily used for the food market – is changing that.

"There are two main markets for Canadian sunflowers," explains Darcelle Graham, Chief Operating Officer of Manitoba Crop Alliance. "The current variety we grow well in Canada (the round seed type) can only be sold in Canada. To be able to sell in the international marketplace, we must be able to produce a long seed type. However, these varieties are not adapted to Canadian growing conditions."

Graham is working with Mike Hagen, an independent researcher with CanSun LLC based out of Fargo, North Dakota. Hagen manages the year-round program that included a summer breeding nursery in Fargo, the sunflower breeding hub of North America; a contra-season nursery in Chile; and a Canadian Testing Program based in Manitoba. This program enabled the team to achieve second generations within a much shorter period.

They've also developed a unique breeding program that is achieving results.

"We've taken a new approach in the breeding process," says Hagen. "Instead of adapting the inbred parent lines to fit with Canadian growing conditions, we're looking at the performance of experimental lines to steer the program. It has been a much cleaner process than using parental lines as a guide. We're now testing hybrids in on-farm plots that we consider to be commercially viable."

Through these efforts, the project has successfully worked with the processing industry to develop rounder seed varieties for the Canadian market as well as longer seeds for export. These varieties contain seed traits desired by food processors and consumers and mean that growers now have expanded marketing opportunities.

Researchers also worked to adapt hybrids to the demanding growing conditions of the Canadian prairies – crops that are hardy, grow quickly and can compete against weeds and disease.

"We've incorporated herbicide and disease resistant traits into long-type seed hybrids," states Hagen. "Having varieties with herbicide tolerance and resistance to rust and downy mildew is crucial in these growing conditions."

The product of this research means that growers will have access to more Canadian varieties without having to rely on U.S. companies for their seed.

"The more control we can have over seed genetics and production in Canada, the less likely we will run into problems should American seed companies decide to pull varieties off the market, or are unable to deliver seed for any reason – drought, transportation issues, trade issues, etc.," says Hagen.

What's next for the sunflower research program?

Hagen emphasizes that variety development must go on. "We can't stop. We need to continue to evolve variety development with new traits for specific markets to advance the industry in Canada."

This DFCC activity is led by Manitoba Crop Alliance with funding support from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program, Western Grains Research Foundation, and the Government of Manitoba and Government of Canada through the CAP-Ag Action Manitoba program.

Activity 13: Multi-crop rotations

This research explored how adding special crops into rotations affects productivity, economics, and the environment.

Conventional crop rotations get a boost from adding special crops to the mix

AAFC Senior Technician Kelsey Brandt examines sunflowers in a test plot near Swift Current, SK. Credit: Mervin St. Luce

It's no secret that diversified cropping systems can help combat disease and improve yields. However, little research has been done on how special crops perform and contribute to carbon sequestration, and the productivity and cost-effectiveness of the rotational system on the Prairies.

That's where this research project, funded in part by the Diverse Field Crops Cluster, comes in.

"We wanted to explore how special crops can be added into rotations and the effect this would have on productivity, economics and the environment," explains lead researcher Mervin St. Luce of AAFC-Swift Current Research and Development Centre. "We looked at how we can integrate special crops that are typically grown on small acres – like mustard, camelina, flax, quinoa, Canary seed and sunflower – into crop rotations that are traditionally dominated by canola, wheat and pulses."

Manjula Bandara, another researcher on the project, says they were particularly interested in investigating the different species of mustard and carinata to see how the glucosinolate properties of each species affected the nitrogen fixing capabilities of the pulse crops that followed, specifically field peas and lentils.

The project included field studies that accounted for soil, weather and agronomic practices, as well as a controlled growth chamber study that assessed the direct net effect on carbon and nitrogen dynamics by growing one crop after another.

Lead researcher Mervin St. Luce examining yellow mustard. Credit: Kelsey Brandt

Initial findings from the project indicate that yellow mustard and camelina rotations showed the potential of producing a higher number of root nodules in subsequent pulse crops compared to other treatments. Biological nitrogen fixation (BNF) varied with the preceding Brassica oilseed crop species. In general, field pea rotations had higher total BNF than lentil rotations, and field pea following oriental mustard and Argentine canola had the highest total BNF.

The team analyzed glucosinolate levels in the seeds of Brassica species collected from the crop rotation study to demonstrate the effect of Brassica crops on BNF in subsequent field peas and lentils. The research demonstrated that there was no apparent relationship between Brassica seed glucosinolate contents and BNF capacities in subsequent pulse crops. Determination of glucosinolate levels in plant tissues was recently completed for a greenhouse study.

"These results tell us that you can grow any type of mustard and not affect the nitrogen fixation of the following pulse crop," commented St. Luce.

The research team is currently analyzing the economics of specific rotations by investigating the cost of production versus potential income.

"We know that for the producer, economics is the driver for all farm decisions," says St. Luce, "so we are conducting a cost benefit analysis by comparing rotations with these crops to the ones that don't include special crops."

The team hopes this information will lead to higher profits for Prairie farmers and a better understanding of the carbon credits available, based on each crop that makes up their rotation.

St. Luce says it's not only about economics. "This research will help producers make more informed decisions when it comes to managing nutrients, pests and environmental concerns related to current agriculture practices. It also contributes to our agronomic knowledge of rotational cropping systems and helps develop best management practices. This has the potential to generate payoff for farmers, the entire agriculture industry and the environment."

This DFCC research activity is led by Mustard 21 Canada Inc. with funding support from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership program, Saskatchewan Mustard Development Commission, Canadian Mustard Association, Government of Saskatchewan and Results Driven Agriculture Research.

Thank you to the Diverse Field Crops Cluster Crop Sector Members

- Canadian Hemp Trade Alliance
- Canary Seed Development Commission of Saskatchewan
- Manitoba Crop Alliance
- Mustard 21 Canada Inc
- Northern Quinoa Production Corporation
- Saskatchewan Flax Development Commission
- Smart Earth Camelina Corporation

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- Agriculture and Agri-Food Canada's Canadian Agricultural Partnership
- Canadian Mustard Association
- Dairy Farmers of Manitoba
- Government of Manitoba
- Government of Saskatchewan
- Government of Alberta
- InfraReady Products (1998) Ltd.
- InnoTech Alberta
- Nuseed Canada Inc.
- Results Driven Agriculture Research (RDAR)
- Saskatchewan Mustard Development Commission
- Western Grains Research Foundation

The research activity reports were written by The Magpie Group www.magpiegrp.ca

Photos were supplied by the researchers and crop sector members.

Successes & Adoption

DFCC's primary goal is to benefit producers and industry through research. This project truly illustrated the importance of public/private partnerships and collaborations.

Despite the pandemic interruptions, DFCC research has seen significant successes for special, small acreage crops grown across Canada: camelina, Canary seed, flax, hemp, yellow and brown mustards, carinata, quinoa and confection sunflower.

A few examples:

- A carinata hybrid, Nujet 400, was launched as the first international, commercial industrial biofuel feedstock, targeted towards the transportation industry.
- New yellow and brown flax oilseed varieties will become available for growers in 2025.
- Two new mustard varieties (the first Canadian hybrid brown mustard and composite yellow condiment mustard) were commercialized and adopted by producers. AAC Yellow 80 has shown a nine per cent increase in yield and AAC Brown 18 has shown a 20 per cent increase. For Western Canadian farmers, these are varieties with the first significant yield increases in three decades!
- Continued development of winter-type camelina varieties and successful development of spring varieties with increased seed size – a boon to producers for seed establishment and harvestability.
- The upcoming release of quinoa varieties adapted to Canadian conditions, with higher yields, earlier maturity, increased protein levels, and lower saponin content. Some varieties show unique functionalities for specific food applications.
- Camelina oil was proven to be a safe and efficacious ingredient in dog foods and as a horse supplement, and is now available throughout North America for the companion animal industry.
- Hempseed meal has proven potential as a livestock feed and is nutritionally comparable to canola meal.
- Successful development of long-type confection sunflowers will lead to increased access to the European confection market.
- Processes were developed to make shelf-stable Canary seed flours for the food industry.

And many more…

I encourage you to reach out to the DFCC partners and researchers to learn more about opportunities for these special crops. On behalf of Ag-West Bio and the DFCC Crop Sector Members, I extend our sincerest appreciation to the public and private funding partners who believed in and supported this diverse group of crops.

Carol Ann Patterson
DFCC Project Manager

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