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CANOLA DIGEST

Science Edition

Dozens of completed studies work to advance canola disease management including blackleg, clubroot, sclerotinia stem rot and verticillium stripe.

Inside

canola RESEARCH HUB
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Canola Research From Across Canada

Helping achieve an average yield of **52 bu./ac.** by **2025**

250+ pieces of research make the Hub the most thorough canola research database

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Find the Hub at CanolaResearch.org and on

Funded in part by the Government of Canada under the Canadian Agricultural Partnership's AgriScience Program, a federal, provincial, territorial initiative.

Provincial Bulletins

Completed Projects

Plant establishment

Nutrient management

Integrated pest management

22 **Advancing blackleg and verticillium stripe management**
Key result: Researchers worked on a rating system based on quantitative resistance to blackleg, specified the critical infection window for blackleg, and investigated connections between flea beetles and blackleg and verticillium stripe and blackleg.

24 **Hydrated lime treatments reduce clubroot infection**
Key result: A study of integrated management practices to manage clubroot show a benefit from hydrated lime treatments, particularly for clubroot-susceptible cultivars.

25 **Widespread triple resistance in kochia**
Key result: An integrated approach to stop kochia includes steps to deplete seedbanks, rapid crop canopy closure and herbicide tank mixes.

26 **Strategies to improve flea beetles control**
Key result: Landscape composition affected flea beetle abundance, as well as seeding rate, temperature, predator presence and the pest control option selected.

27 **Steps to reduce flea beetle risk**
Key result: This study based in the Peace River region of Alberta showed that later seeding, more plants and larger seeds can reduce flea beetle risk to canola yield.

28 **Trap to monitor canola flower midge**
Key result: This project developed a reliable, pheromone-trapping system to monitor *Contarinia brassicola*, canola flower midge.

29 **Biocontrol option for cabbage seedpod weevil**
Key result: Parasitoid wasp *T. perfectus* demonstrated high levels of parasitism of cabbage seedpod weevil in Ontario and Quebec.

30 **The effect of non-crop spaces**
Key result: Beneficial insect reservoirs near fields can contribute to sustainability with minimal (possibly positive) impact on profitability and productivity.

Genetics

33 **New clues to sclerotinia stem rot resistance**
Key result: Researchers discover Resistance: Avirulence protein interactions between the *S. sclerotiorum* pathogen and canola plants.

34 **Trait makes blackleg resistance more durable**
Key result: Researchers identified causative genes that provide adult plant resistance (APR) to blackleg.

35 **Gene editing turns off S genes to improve CR**
Key result: Researchers used CRISPR/Cas9 to confer clubroot resistance (CR) by introducing site-specific mutations to inactivate susceptibility (S) genes.

36 **RNAi spray for sclerotinia needs better formulation**
Key result: Field tests in 2022, hampered by heavy rain and dsRNA applications without a surfactant, did not show strong results for the treatments.

37 **Steps to boost NUE, canola yield**
Key result: Nitrogen at 130-147 lb./ac. in the Black soil zone and 76-89 lb./ac. in the Brown zone balances yield, nitrogen use efficiency and maximum returns.

38 **NUE improving more slowly than yield**
Key result: Total plant nitrogen uptake of old rapeseed and canola varieties was just as good as modern hybrids, they just don't have as much yield to pack nitrogen into.

39 **Quest to turn off secondary dormancy**
Key result: Canola has strong secondary dormancy, which is why volunteer canola can germinate years after harvest.

40 **Advances in genetic resources for breeding hairy canola**
Key result: This research on hairy canola (to deter flea beetle feeding) will provide canola breeders with *B. napus* lines that produce hairs.

Harvest management

31 **More plants equal more consistent yield**
Key result: In general, seeding rates of 120 and 180 seeds per square metre provided higher and more stable canola yield than rates of 60 seeds.

32 **Manual versus auto adjust to reduce combine loss**
Key result: Combines that auto-adjust settings to reduce harvest loss should still be calibrated and ground-truthed regularly.

New and ongoing studies

41 New projects launched in the past year will look into nitrogen-fixing bacteria, humic-acid-coated phosphorus, finding resistance to verticillium stripe, and capturing ancestral diversity for developing climate ready canola. Ongoing projects include research into biologicals for insect management, phenology-based weed control, and new techniques to breed for disease resistance and environmental stress tolerance.

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KATHRYN KNODEL

Alberta Canola
Research Coordinator

I started this May as the new research coordinator at Alberta Canola, freshly graduated from a Bachelor of Science in Biology. I hit the ground running, learning about and managing our research programs. I have big shoes to fill as I cover for our research director, Brittany, during her parental leave, but the challenge has been welcome. Working for Alberta Canola has opened my eyes to the complexities of canola research (and agricultural research in general).

I am impressed at Alberta Canola's commitment to funding research that benefits Alberta canola growers. Every year, we allocate funds to a diverse array of research projects, ranging from combatting diseases such as clubroot and blackleg, to developing varieties resilient to the challenges of climate change. However, our million-dollar budget only goes so far. Part of my role here is helping discern which projects are most relevant and beneficial for farmers.

It is exciting and rewarding to be involved in funding research projects that will have a positive impact on canola farmers, the canola industry and the environment. So far, I have enjoyed the process of reviewing research proposals and seeing so much potential for the future. I look forward to seeing which new projects we fund for the new year!

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DOUG HEATH

SaskCanola
Research Manager

This year SaskCanola funded new projects with a diverse range of themes, including drought tolerance and water use efficiency from ancestral brassicas, insect pest monitoring, disease resistance and monitoring, phosphate management practices, micronutrient advantages in Canadian canola meal and high value uses of canola meal for industrial fermentations. We anticipate results from other applied agronomy projects including evaluations of nitrogen-fixing foliar biologicals, phosphate solubilizers, and effects of seeding rates and dates on yield and resilience to flea beetles.

This year also marks the completion of the previous five-year Canola Cluster. This included foundational research on verticillium stripe in Canada, an important new challenge. These verticillium research results provide base knowledge to continue forward with new collaborative research efforts by teams across Canada.

We were also excited by the launch of our first year of on-farm field-scale research trials, and hope to build on this program with our partners and new cooperators next year!

We look forward to meeting with you at our winter extension events to discuss the results of our many research projects your levy dollars are funding, as well as our other programs including free disease testing for verticillium, blackleg and clubroot.

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AMY DELAQUIS

Manitoba Canola Growers
Research Manager

As the research manager with Manitoba Canola Growers Association, I'm responsible for prioritizing farmer-identified research needs, managing funding, exploring new research collaborations and growing our on-farm research program. I have been immersed in agriculture my entire life through farming, industry jobs and post-secondary education. My love for the agricultural community paired with curiosity has driven my research career and continues to push me to ensure that the MCGA research program is aligned with the priorities of Manitoba farmers. I also ensure that results produced from our program are available to farmers in a format they can use.

In 2023, we saw a ramp up of our on-farm research program, including an increased range of trials and greater collaboration across the industry. The goal of this program is to create and report farm-level data to support canola farmers across Manitoba to make meaningful on-farm decisions. The program is still in its infancy with only two field seasons currently completed, but planning is underway for 2024 field season. Working alongside the other commodity groups in Manitoba with established on-farm research programs, our hope is to provide a well-rounded set of farm-level research results to growers.

amy@canolagrowers.com

Alberta Canola commits $900,000 to 10 new projects

This past year, Alberta Canola committed close to $900,000 towards 10 research projects. For each grower dollar contributed by Alberta Canola, we were able to attract an additional $7 in investment from our collaborative research partners and programs, for a total of over $7 million in research funding.

Projects investigating diseases of canola took precedence in 2023. Clubroot remains a challenging disease for canola growers, and thus clubroot research is a priority in funded projects. At the University of Alberta, Stephen Strelkov continues his work on clubroot by examining clubroot resistance gene function and Habibur Rahman is evaluating the canola A-genome genes for *Plasmodiophora brassicae* resistance along with the C-genome. At the Université Laval, Edel Péréz-López is working to better understand how pathogen kinases in clubroot function in disease progression.

In addition to clubroot projects, funding has also been put into investigating other diseases. At Agriculture and Agri-Food Canada (AAFC) Saskatoon, Gary Peng is testing the use of susceptibility genes in canola to improve blackleg resistance, and at the University of Manitoba, Dilantha Fernando is searching for resistance against verticillium stripe in canola.

Thomas (Kelly) Turkington at AAFC Lacombe is further developing the Prairie Crop Disease Monitoring Network, a coordinated field crop disease monitoring program for the Prairies whose main focus is to highlight effective disease management approaches. The program is involved in developing standard recommended monitoring protocols focused on in-crop risk assessments and end-of-season final disease evaluations.

Gavin Chen at the University of Alberta is looking at ways to alter canola's cellular carbon partitioning in hopes of raising canola yield and the content of oil and protein.

Alberta Canola also keeps a continued focus on finding ways to improve yields and canola quality. Gavin Chen at the University of Alberta is working towards that by altering cellular carbon partitioning in hopes of raising canola yield and the content of oil and protein.

Charles Geddes, weed research scientist at Agriculture and Agri-Food Canada (AAFC) in Lethbridge, is working on a biovigilance strategy to manage and prevent herbicide-resistant weeds.

Charles Geddes at AAFC Lethbridge is building a strong biovigilance foundation through his work on The Prairie Weed Monitoring Network. This Prairie Weed Monitoring Network works with the Prairie Pest Monitoring Network and Prairie Crop Disease Monitoring Network under the overarching Prairie Biovigilance Network (weed biovigilance strategy). The main goal is to facilitate the adoption of a biovigilance-based approach to weed mitigation and management on the Prairies. Geddes will coordinate the herbicide resistance surveys and weed abundance surveys.

The need for building resiliency into cropping systems for our changing climate is critical for future growing success. At AAFC Saskatoon, Meghan Vankosky is conducting research to examine how insects in the Prairies respond to the changing climate and agricultural inputs. Concurrently, Isobel Parkin is dedicated to capturing ancestral diversity in canola progenitors, with the ultimate goal of developing a canola plant that is resilient to the challenges posed by climate change.

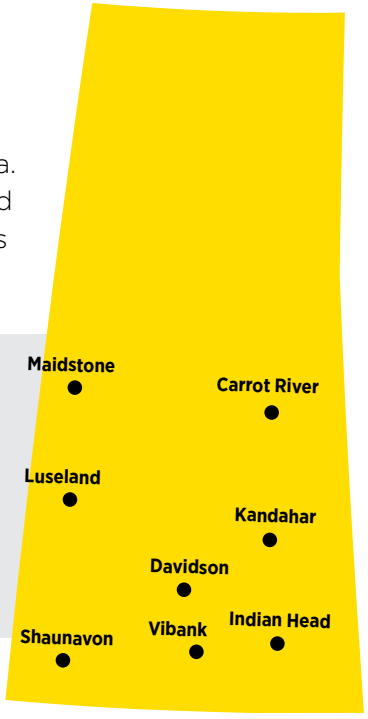
New Research Projects for 2023

Researcher	Project Title	Alberta Canola Funding	Total Project Cost	Funding Partners
Gary Peng AAFC Saskatoon	Exploiting susceptibility genes in canola to improve blackleg resistance	$50,000	$298,250	CCC, SaskCanola, MCGA
Dilantha Fernando University of Manitoba	Digging out the unknown: finding resistance against verticillium stripe in canola	$63,000	$346,610	CCC, SaskCanola, MCGA, WGRF
Isobel Parkin AAFC Saskatoon	Capturing ancestral diversity for developing climate ready Canola	$75,000	$350,000	CCC, SaskCanola
Meghan Vankosky AAFC Saskatoon	Insect response to climate change and agricultural inputs across the Prairies	$50,000	$1,425,000	Alberta Wheat, SaskCanola, SaskWheat, MCGA, WGRF, SPG, MCA
Habibur Rahman University of Alberta	Evaluation of the A-genome genes for resistance to *Plasmodiophora brassicae* pathotypes, and their combined effect with the C-genome resistance	$177,430	$377,430	RDAR
Thomas Turkington AAFC Lacombe	Prairie Crop Disease Monitoring Network: Fostering further network development	$10,000	$279,619	Alberta Innovates, Alberta Wheat, RDAR, SaskWheat, WGRF
Gavin Chen University of Alberta	Elevating canola yield and oil and protein content by altering cellular carbon partitioning	$29,500	$526,225	Alberta Innovates, RDAR
Edel Pérez- López Université Laval	Understanding the role of the clubroot pathogen kinases in disease progress and resistance	$194,998	$449,650	CCC, SaskCanola, MCGA
Stephen Strelkov University of Alberta	Clubroot resistance gene function based on whole genome sequences, genome editing and resistance phenotypes	$208,333	$1,250,000	SaskCanola, RDAR
Charles Geddes AAFC Lethbridge	The Prairie Weed Monitoring Network: Building a strong biovigilance foundation	$25,000	$1,779,050	WGRF, Alberta Wheat, SaskCanola, MCGA, Manitoba Pulse, MCA, POGA, SPG, SaskWheat
	2023 TOTAL	**$883,261**	**$7,081,834**	

CCC = Canola Council of Canada; **MCGA** = Manitoba Canola Growers Association; **MCA** = Manitoba Crop Alliance; **POGA** = Prairie Oat Growers Association; **RDAR** = Results Driven Agriculture Research; **SPG** = Saskatchewan Pulse Growers; **WGRF** = Western Grains Research Foundation

Introducing SaskCanola's NEW On-Farm Research Trials Program

The 2023 growing season marked the first year of SaskCanola's new on-farm, field scale research trials program. While there is merit to small plot trials, it is recognized that growers and agronomists have farm-specific questions that need to be answered and may work best when implemented over a large area. This program was designed to help answer these questions through replicated trials and data collection. The protocol for 2023 was employed on eight farms across Saskatchewan covering all regions and soil zones.



→ Why was this protocol chosen?

Some crops like wheat and canola generally require a large supply of nitrogen (N) to support high yields and quality, provided naturally from the soil as well as with applied fertilizer. New, commercially available biological products may have the ability to facilitate biological N fixation in non-legume crops, potentially reducing the N fertility requirements of these crops. However, there is little publicly available data regarding the performance of N-fixing biological products on canola.

2023 Trial: Foliar N-Fixing Biological Products

Objective: To determine if farms can see agronomic and economic benefits from applying a commercially available, foliar-applied nitrogen-fixing bacteria product in wheat or canola. Producer-cooperators will determine the value of utilizing this product under the typical management practices and environmental conditions of their operation.

Product: *Gluconacetobacter diazotrophicus* Envita, Syngenta

Treatment: The two main treatments compared crop growth and productivity with and without an application of a biological product under a normal operational rate of applied nitrogen (N) fertilizer. Two optional treatments further compared the performance of the product with a reduced rate of applied N fertilizer. The decision to include two or four treatments were dependent on each cooperator's objective for conducting this trial.

Protocols required that treatments were replicated and applied in randomized strips in the field. Option A was replicated a minimum of four times, for a total of eight strips. Option B was replicated a minimum of three times for a total of 12 strips. All strips were otherwise managed the same agronomically including seeding date, variety, seeding depth, seed treatment and pesticide application. The layout of Option B was dependent on the equipment width and capability of the operation for prescription-based application. Data collected by farmer cooperators included: spring soil sample, spring plant density, general observations throughout the season, weather data, yield and quality.

Results from this pilot year will be published in February – stay tuned!

Option A: Two treatments	Option B: Four treatments
1. No foliar N-fixing biological	1. Normal N rate + No foliar N-fixing biological
2. Envita at recommended rate and timing	2. Normal N rate + Envita
	3. Reduced N rate + No foliar N-fixing biological
	4. Reduced N rate + Envita

Seeking Saskatchewan farmers!

Reasons to join the program and become a cooperator in 2024:

- **EXCLUSIVE NETWORK** - opportunity to join a network of farmers and agronomists who are interested in on-farm research and learning from each other
- **ONE-ON-ONE EXPERTISE** – working with a research specialist or agronomist to mark out trial locations, create maps, and collect data
- **CUSTOMIZED LEARNING EXPERIENCE** – execute the trial using your own equipment, land and many of your existing practices while learning how to set up research trials
- **DATA ACCESS** – you'll be invited to partake in the public summer field tour and the private winter wrap-up meeting for primary access to the results of other on-farm, field scale trials in Saskatchewan

Farmers and/or agronomists interested in participating in the 2024 trials or who have ideas for future protocols are encouraged to contact SaskCanola.

Scan to access SaskCanola-funded research results:

www.saskcanola.com/research-results

Manitoba Canola Growers research overview

Research funding targets 2023-24

- Flea beetle management strategies
- Verticillium stripe management **[NEW]**
- Optimizing fertility management in canola
- Improving yield stability in environmental extremes
- Managing acres to improve soil health

The plant counts program encourages farmers to achieve five to eight plants per square foot, one way to improve yield stability. →

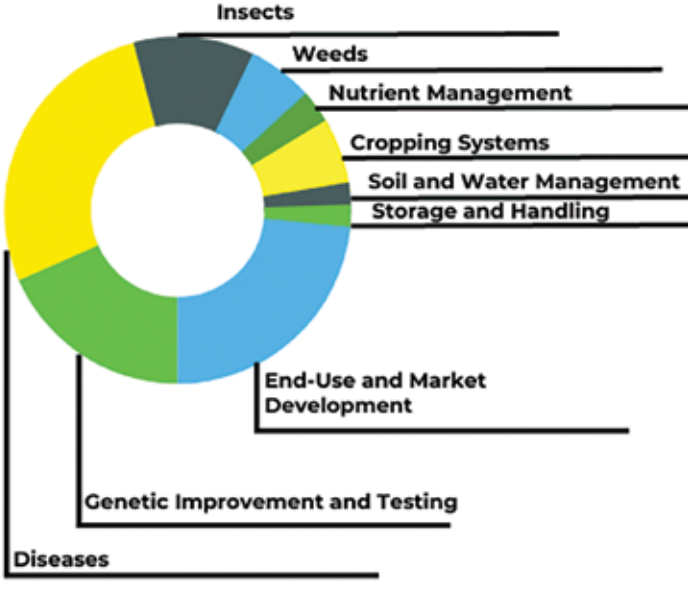
MCGA Research Priorities

The overall goal is to increase canola yield potential and stability in Manitoba conditions through genetic and agronomic solutions. Research priorities to help achieve this goal are:

- Protect canola yields from current and emerging pests
- Improve canola nutrient use efficiency through 4R management practices
- Reduce or improve the environmental impact of canola production
- Reduce harvest and storage losses through genetic and management solutions, as well as equipment optimization
- Ensure supply of high-quality canola to meet current and future end-use demands

Funding by Research Area

MCGA research funding is divided into research areas. The chart below shows the proportion of research projects funded in each area for 2022-23.



Sustainable Canadian Agricultural Partnership

2023 On-Farm Results

If you are interested in participating in MCGA's canola on-farm trials for the 2024 growing season, please contact amy@canolagrowers.com

The Manitoba Canola Growers' On-Farm Research Program was funded in part by the Governments of Canada and Manitoba under the Sustainable Canadian Agricultural Partnership, a federal-provincial territorial initiative.

Scan to find 2023 results

How to access the Research Database?

You can find current or completed research projects at Manitoba Canola Grower's Research Database (search at **canolagrowers.com/research**) or at the Canola Council of Canada's Research Hub (**canolaresearch.ca**)

Manitoba Canola Growers' on-farm research sites for 2023

Types of on-farm trials in 2023

Nitrogen rate trial (five site locations)

- **Research Objective:** Identify optimal nitrogen fertilizer rate based on return on investment and nitrogen use efficiency.
- **Treatments:** Farmer's standard nitrogen rate compared to reduced rate (75 per cent) and high rate (125 per cent).
- **Data Collected:** Plant counts, nitrogen tissue content at bolting, grain yield, nitrogen use efficiency, protein and oil percentages in harvest seed.

Seeding rate trial (seven site locations)

- **Research Objective:** Identify economic and agronomic optimal seeding rates for Manitoba canola production and the major factors influencing this relationship.
- **Treatments:** Farmer's standard seeding rate compared to reduced rate (75 per cent) and high rate (125 per cent).
- **Data Collected:** Spring and fall plant counts, emergence percentage, survival percentage, plant stand uniformity, grain yield.

Seed-placed fertilizer trial (20 site locations)

- **Research Objective:** Identify optimal seed-placed phosphorus fertilizer application rates based on investment and establishment.
- **Treatments:** Farmer's standard seed-placed fertilizer rate compared to no seed-placed (0 per cent) and higher rate (125 per cent)
- **Data Collected:** Spring plant count.

Faster ground cover can improve yields

KEY RESULT:

Canola crops that achieve vegetative ground cover more quickly tend to have higher yields. Seeding rate and row width contribute to faster ground cover.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"How does in-row seed spacing and spatial pattern affect canola yield?"
Steven Shirtliffe, University of Saskatchewan

FUNDING: SaskCanola

PUBLISHED ARTICLES:
Read the full report in the Research section at saskcanola.com.

When it comes to canola seeding rate and row width, think of your crop as a solar panel. The faster the ground cover, the more the solar panel can produce.

Researchers found that canola yields are maximized with seeding rates that result in early ground cover that is maintained throughout the growing season. Canola can compensate for lower seeding rates with increasing branching and podding, but if that reduction slows canopy closure, or if wide row spacings do not fill in, then yield will be reduced.

The overall hypothesis of this research is that optimal seeding rate and row spacing affect seed yield in canola by maximizing the ground cover through the growing season.

The study had three objectives: (1) to determine plant distribution, survival, branching, ground cover, and yield in response to row width and seeding density; (2) to develop and apply image analysis techniques to track space occupied by individual plants over time in different planting arrangements; and (3) to study and validate plant growth responses to planting arrangements through simulation modeling.

Researchers used a replicated, factorial field experiment that varied seeding rate and row spacing over a wide range. They grew canola in 2 x 6m plots using equipment similar to field scale equipment. Trials were repeated at Saskatoon, Saskatchewan (dark brown soil zone, semi-arid climate) and Carman, Manitoba (black soil zone, sub-humid climate) from 2019 to 2022. Researchers note that drought and heat stress during these field trials resulted in below optimal seed yield in canola and may have influenced the results. Despite these stresses and sub-optimal yields, researchers believe these results are still valid as plant population effects often have greater proportional effects in dry years.

Results

To maximize yield in canola, growers should seed at least 60 seeds per square metre (5.5 per square foot) and have row spacing of 30cm (12 inches) or less.

Canola was able to compensate for low seeding rates by increasing branching and number of pods, but this delayed flowering. The row spacing effect was minimal compared to seeding rate, however wider row spacings always trended to lower maximum yields than narrower row spacing.

Crop yield in canola is highly associated with the space that the crop canopy occupies over time. The highest yielding treatments were the ones that most rapidly achieved and maintained full canopy coverage. The practical agronomic message of this model is that canola yield is not able to compensate for reduced ground cover from poor stands. To manage canola for highest seed yield requires agronomic practices including seeding rates and row spacings, that result in rapid canopy closure.

Existing recommendations to establish five to eight seedlings per square foot with row spacings of 12 inches are adequate to achieve maximum yield.

This drone image, taken July 18, 2022, shows the row spacing by seeding rate trial at Saskatoon. Row spacing varied from 15cm to 90cm (5.9 - 35.4 inches) and seeding rate varied from five to 140 seeds per square metre.

Photo credit: Seungbum Ryu

Pathways to improve heat and drought tolerance

KEY RESULT:

Heat had a significant effect on yield by preventing seed set and had a more negative effect than drought on seed oil composition. Researchers found possible genetic solutions to enhance drought and heat stress.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Impact of drought and heat during flowering on canola yield." Raju Soolanayakanahally, Agriculture and Agri-Food Canada Saskatoon

FUNDING: SaskCanola, Saskatchewan's Agriculture Development Fund

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

Canola's resilience to heat and drought depends on when these stresses occur within the crop lifecycle. Plants may recover after stress during the vegetative stage, but stress during flowering and/or pod development usually has a negative effect on yield.

Objectives of the study were:

1. To evaluate spring canola nested association mapping (NAM) population founder lines for drought, heat and combined stresses in the greenhouse and later evaluate abiotic stress tolerance under field conditions.

2. To complete a comprehensive analysis of plant metabolites exhibiting enhanced stress-responsive roles, leading to the discovery of biomarkers and select stress-tolerant canola varieties based on the abscisic acid level.

3. To explore new rapid and non-destructive biomolecular imaging techniques to predict stress tolerance using mid-IR spectroscopy at the Canadian Light Source.

Results

Objective 1. Researchers used greenhouse and field experiments to compare 50 founder lines of the spring canola NAM population and a common parent (reference line). Results showed high variation in yield traits, especially pod weight, among the NAM lines. The most variable traits were stomatal conductance and transpiration rate. This suggests potential to breed canola with higher drought and heat tolerance.

Objective 2. Researchers compared plant growth under different temperatures (23°C versus 29°C daytime temperatures) and water amounts (30 and 90 per cent of soil water holding capacity) for N99-508, a reference NAM line.

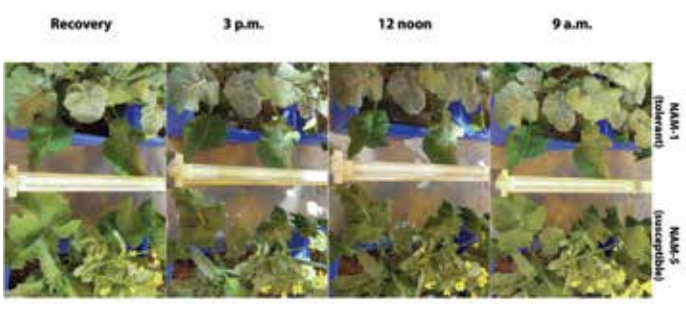
Results show that drought affected the carbon assimilation rate mainly through the limitation of CO2 diffusion through the stomata and seed yield components. Heat altered the reproductive organs and process, leading to a reduction in the number of siliques and yield. Heat had a larger effect over drought on seed composition, which resulted in higher levels of saturated fatty oils. While drought effects can be mitigated with irrigation and/or using genotypes with greater water use efficiency, heat requires the breeding of heat tolerant canola.

Objective 3. Researchers used two cultivars for this experiment: drought-resistant Czyzowska from Poland and drought-sensitive BN-1 from India. They measured growth with fluctuations in day/night temperatures and photoperiod, watering conditions and relative humidity to mimic drought conditions. They also measured photosynthetic activity, night gas exchanges, leaf waxes, cysteine and sucrose, and growth and yield.

Results confirmed previous studies demonstrating the involvement of sulphur in mitigating the effect of abiotic stressors on plants. The correlations between cysteine, abscisic acid and stomatal conductance suggest a role of cysteine and sulphur in modulating the stomata movement under water deficit conditions.

Also, the accumulation of significant levels of aspartic acid plays a crucial role during intermittent periods of drought. Aspartic acid mechanisms help prevent leaf death and preserve nitrogen and carbon resources. Canola benefits greatly when its leaves survive brief drought episodes. When favourable moisture conditions return, instead of waiting for new leaves to grow, the plant can promptly resume its photosynthetic activity.

The study also demonstrated the responsiveness of load and composition of epicuticular waxes to drought in Brassica napus and the importance of water losses through stomata during dark periods and early mornings.



↑ As the day progresses, the drought-sensitive canola line exhibits leaf wilting symptoms, whereas the drought-tolerant canola line maintains leaf turgor by foraging water from a larger soil volume. The sensitive line recovers from drought after being rewatered.

How to improve seed distribution with air drills

KEY RESULT:

Replace damaged or kinked air drill hoses immediately, and replace with the same length and diameter as the original. This is key to consistent air flow.

PROJECT TITLE, PRINCIPAL INVESTIGATORS:
"Understanding grain pneumatic conveying in seeding equipment," Hubert Landry, Ian Paulson, and Samuel Ferré, Prairie Agricultural Machinery Institute

FUNDING: SaskCanola, Government of Manitoba under the Canadian Agricultural Partnership Prairie Agricultural Machinery Institute

PUBLISHED ARTICLES: Read the full report in the Research section at saskcanola.com.

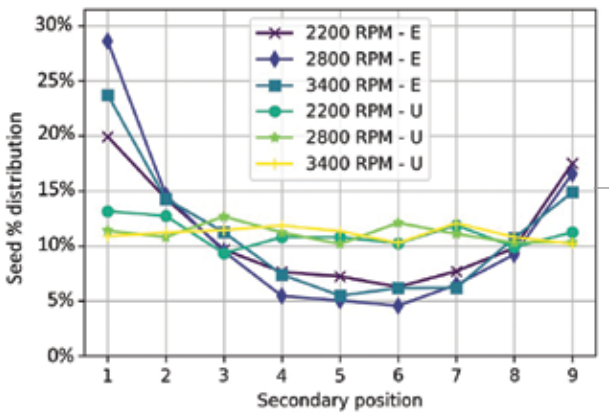
Air drills are common seeding tools on the Prairies, and growers need these pneumatic systems to distribute seed and fertilizer at a consistent and uniform rate to each opener. When replacing damaged hoses, use the same length and diameter as this is key to uniform distribution.

This three-year project measured air drill distribution performance, both in the laboratory and at field-scale, and simulated various configurations of pneumatic conveying systems.

The first objective was to determine the effect of air velocities, air hose lengths and routing geometries, and/or tool bar angles on the seed distribution coefficient of variance (CV) and germination of canola. Another objective was to develop and validate numerical models to track machine-seed interactions in the pneumatic conveying system.

Researchers tested a full-scale pneumatic seeding system to quantify seed damage, seed distribution consistency, and air flow behaviour. Air flow measurements were taken with and without seed being conveyed. Three different fan speed treatments were used, 2,200, 2,800, and 3,400 RPM. Seed germination was also measured after the experiments were completed to characterize possible germination effects from pneumatic conveying; samples were grouped by distributor and fan speed treatment.

Finally, numerical models were developed to predict both the airflow behaviour and the seed distribution performance of several configurations of pneumatic conveying systems.



Results

The project highlighted the importance of simple but careful maintenance of air drill pneumatic conveying components and systems. Recommendations include:

1. Replace secondary hoses with the same length to maintain consistency. This is important to system performance. If replaced with a longer hose, these secondary hoses tended to receive less seed in both measured and simulated datasets. Also maintain downward flow.
2. Follow the manufacturer suggested hose routings unless actual performance data suggests otherwise.
3. Severe bends should be minimized in both primary and secondary hoses wherever possible, and avoid introducing sharp bends close to the entry of a J-tube elbow when replacing primary hoses.
4. Replace damaged or kinked hoses immediately and use the hose fastening/restraint schemes suggested by manufacturers.

Results also showed that using the manufacturer-suggested fan speed provided the most consistent distribution of seed across the air drill. Increased fan speed reduced distribution consistency. The coefficient of variation across the whole drill increased from 11.0 per cent at the lowest fan speed tested to 12.5 per cent at the highest fan speed. Interestingly, air and speed distribution patterns differed from each other (i.e. more air through a given secondary hose did not guarantee more seed).

Full-scale testing of pneumatic conveying of canola seed through the air drill did not result in a reduction in germination from the control sample (seed that didn't go through the drill), and no variations in samples taken across the air drill were evident.

← When secondary hoses from manifolds to openers are even lengths (E), flow tended to favour certain runs over others. This had to do with where these hoses exited the manifold. When hoses have specific unequal (U) lengths, this can manipulate air flow and make seed distribution more uniform. Manufacturers usually have this figured out, which is why length of replacement hoses should match the originals.

Soil characteristics important to carbon storage potential

KEY RESULT:

Previous work showed that crop yields are higher in the diverse rotations, but when it comes to increasing soil organic matter and carbon storage, this study showed no consistent crop rotation effect.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Understanding the effects of crop rotation on soil organic carbon stabilization," Bobbi L. Helgason, University of Saskatchewan

FUNDING: SaskCanola

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

Soil organic matter (SOM) is a cornerstone of soil health and sustained soil productivity. However, not all SOM is created equal when it comes to carbon storage.

Particulate organic matter is one of the two major types of SOM. This is basically pieces of partially decomposed plant material, which are more easily destabilized through microbial decay. Carbon stored in particulate matter is more susceptible to turnover and future loss through biological processes like nitrogen transformations, unless it gets protected by stable soil aggregates.

Mineral-associated organic matter, the other major form of SOM, is more stable. To increase long-term carbon storage in soil, we need to move more plant material into this mineral-associated pool.

With this study, researchers hoped to provide evidence-based guidance – especially with regard to crop rotation – for improvements to soil organic carbon (SOC) stabilization. They examined archived soils from three different long-term cropping trials to assess the impact of crop rotations on soil carbon. Archived data were from canola and wheat rotation studies at Lacombe, Alberta, Scott, Saskatchewan and Swift Current, Saskatchewan.

Not surprising, the clay loam soils at Lacombe had more SOM and SOC than the loamy textured soils at Scott and Swift Current. However, results did not point to any specific recommendations on rotation to increase stored carbon in the soil.

The lack of consistent differences in carbon pools observed under different canola cropping frequencies indicates that the interplay between quantity and quality of crop root and residue inputs – canola, wheat, barley and field peas – did not lead to differences in carbon stabilization in these systems.

↑ Meagan Reed, Master of Sciences student at the University of Saskatchewan, performed the labwork for the project.

Canola, wheat, barley and field peas have different above- and below-ground biomass both in quantity and quality. Previous studies proposed that the proportionally higher below-ground carbon deposition by canola can contribute to increasing soil organic carbon stocks. However, this project demonstrated that mineral-associated organic matter and particulate organic matter pools were not affected by long-term continuous mono-cropping versus diverse crop rotations in the wheat and canola systems studied.

Previous work showed that crop yields are higher in the diverse rotations, but when it comes to increasing soil organic matter and carbon storage, this study showed no consistent crop rotation effect on the size of the two carbon pools.

Researchers concluded that long-term quantity or partitioning of mineral-associated organic matter and particulate organic matter pools in the Prairie annual cropping systems studied here may be determined more strongly by intrinsic soil properties. Quantity and quality of organic matter inputs, as driven by crop rotation decisions, seem to play a secondary role.

The benefit of crop rotation – "organic matter inputs" – on the Prairies could be more accurately measured with a change in methodology, the researchers conclude. For this study, they sampled at peak flowering in the canola systems which may not be ideal for detecting the long-term interactions of microbial abundance and carbon pools. It is recommended that future studies studying these relationships sample in fall after harvest or in early spring before the crop is planted.

New nutrient uptake and removal guidelines

KEY RESULT:

The nutrient uptake and removal guidelines for crops in Western Canada are updated. Researchers discovered considerable variability in uptake and removal due, in part, to known differences in weather and management. Thus these estimates are to be used as guidelines only, not prescriptions.

PROJECT NAME, PRINCIPAL INVESTIGATOR:
"Revising the crop nutrient uptake and removal guidelines for Western Canada," Fran Walley, University of Saskatchewan

FUNDING: SaskCanola, Alberta Wheat Commission, Prairie Oat Growers Association, SaskFlax, SaskWheat, Western Grains Research Foundation

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

In revising the nutrient uptake and removal chart for crops grown in Western Canada, researchers discovered considerable variability in uptake and removal due, in part, to known differences in weather and management. Thus these estimates are to be used as guidelines and should not be viewed as prescriptive.

The nutrient uptake and removal guidelines for crops in Western Canada were last revised in 2001 by the Canadian Fertilizer Institute (CFI). This project aimed to develop new nutrient uptake and removal guidelines for 14 annual crops grown in Western Canada, based on measurements taken from straw and seed samples. The new measured estimates were also compared to published and unpublished literature from Western Canada.

The study was conducted from 2020-22, analyzing grain and biomass samples for nutrient content. Biomass collection occurred in 2021 and 2022 only because of COVID-19 restrictions in 2020. Limited samples for both seed and biomass were collected in 2021 because of the prairie-wide drought. However, this gave researchers the opportunity to assess how nutrient uptake and removal were affected by drought. By comparing grain samples collected in 2021 with those collected in 2020 and 2022, it was determined that although drought impacted crop yields, the removal and uptake (on a pounds per bushel basis) remained relatively unaffected by drought conditions beyond the variability that was associated with "normal" years.

The 14 crops studied included barley, corn, durum, oats, spring wheat, winter wheat, canola, flax, soybean, mustard, chickpea, dry bean, lentil and field pea. Faba bean was added because samples were available and seeded acres had increased.

The new guidelines include removal and uptake estimates for macronutrients (N, P_2O_5, K_2O, S) and micronutrients (Cu, Zn, B). The purpose of these estimates is not to replace soil testing, but to assist in developing fertilizer management plans, or to help interpret soil test reports. These estimates should always be used in conjunction with soil testing.

Updated nutrient removal guidelines for Western Canada

Crop	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)	Sulphur (S)	Boron (B)	Copper (Cu)	Zinc (Zn)
	Pounds of nutrient per bushel of grain produced				Pounds of nutrient per 100 bushels of grain produced		
Canola (43) (31-55)	1.68 (±0.32)	0.67 (±0.15)	0.35 (±0.07)	0.19 (±0.06)	0.048 (±0.017)	0.020 (±0.010)	0.162 (±0.033)
Wheat (62) (41-83)	1.38 (±0.28)	0.49 (±0.09)	0.31 (±0.22)	0.10 (±0.01)	0.006 (±0.003)	0.029 (±0.011)	0.171 (±0.039)
Barley (79) (49-105)	0.86 (±0.28)	0.36 (±0.07)	0.26 (±0.07)	0.07 (±0.01)	0.009 (±0.008)	0.025 (±0.010)	0.129 (±0.032)
Pea (50) (29-73)	1.75 (±0.39)	0.47 (±0.10)	0.55 (±0.17)	0.10 (±0.01)	0.044 (±0.015)	0.037 (±0.009)	0.177 (±0.040)

← These are the updated numbers for four common crops. The full list includes 14 crops. Bolded values beside crop type are the average grain yields in bushels per acre (across the Prairies in 2020, 2021 and 2022). Macronutrients show removal as pounds of nutrient per bushel of grain produced ± standard deviation. Micronutrients show removal as pounds per 100 bushels of grain. Numbers in parentheses reflect possible range.

Try the Prairie Nutrient Removal Calculator. The online calculator estimates nutrient uptake and removal based on results from this latest study. The calculator uses the 75th percentile of the survey data as the nutrient coefficient, with the goal of limiting the risk of underestimating nutrient removal. The 75th percentile represents that point at which 75 per cent of the survey values were below the coefficient value and 25 per cent of the values were above the coefficient value.

Deep banding and EEFs reduce N loss in light soils

KEY RESULT:

On light-textured soils, farmers can greatly reduce nitrous oxide emissions (and ammonia losses) from soil by deep-banding urea or using enhanced efficiency fertilizer (EEF) products.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Optimal source, placement and application timing for yield and reduction of greenhouse gas footprint for canola production on light texture soils," Mario Tenuta, University of Manitoba

FUNDING: SaskCanola, Manitoba Canola Growers

PUBLISHED ARTICLES: Tenuta, M., Gao, X., Tiessen, K. H. D., Baron, K., & Sparling, B. (2023). Placement and nitrogen source effects on N2O emissions for canola production in Manitoba. *Agronomy Journal,* 115, 2369–2383.

Nitrous oxide is a major contributor to greenhouse gas emissions from agriculture in Canada (accounting for 54 per cent of agriculture emissions, according to Environment Canada 2017). Mario Tenuta, in an earlier study, showed that adoption of 4R Nutrient Stewardship practices can reduce nitrous oxide emissions from Manitoba soils by 50 per cent. These practices also reduce ammonia losses and other nitrogen losses which, though not greenhouse gases, represent a major reduction in nitrogen use efficiency.

This study showed how farmers with light-textured soils can reduce nitrous oxide (N2O) and ammonia (NH3) emissions through better management of fall-applied nitrogen fertilizer, use of newly available enhanced efficiency fertilizer products, management of depth of nitrogen fertilizer placement and utilization of in-season nitrogen application.

Treatments included application timing (fall, spring, and split with spring and in-season), source (urea, SuperU, UAN with Agrotain, urea with eNtrench, urea with DMPSA, and ESN and urea in a 70-30 blend), placement (surface, shallow and deep band), and combinations of all three. Rate for all treatments was 100 per cent of soil test recommendation. A zero nitrogen control was included.

Researchers established the trials on commercial fields in southern Manitoba, targeting light textured soils such as sandy loam. A total of six trial sites were conducted with two sites each for 2019, 2020 and 2021. Trials were not sited on the same location between years to avoid growing canola on canola stubble. InVigor L140P was grown at all sites. All three years of the study were drier than normal.

Results

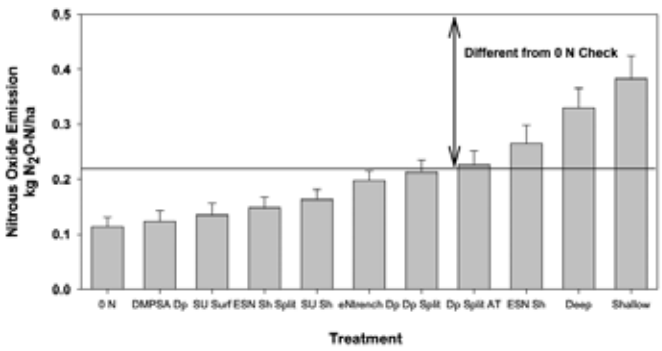
Enhanced efficiency fertilizers. Urea, whether shallow or deep banded, had the highest cumulative emissions of nitrous oxide. Enhanced efficiency fertilizer products greatly reduced emissions. Treatments SuperU surface applied, SuperU shallow banded, ESN shallow banded and urea plus DMPSA deep banded all had low emissions. Emissions for DMPSA-treated urea and Super U-treated urea specifically were similar to the control treatment with zero added nitrogen.

Deep banding. Researchers applied band treatments with a Bourgault disk-style mid-row bander at 2-2.5cm (1") or 7.5-10cm (3-4") depth. For straight urea, the deep band treatment reduced emissions compared to shallow banding. Adding an inhibitor reduced losses even further.

Split applications. Split application of urea, with both time-of-seeding and in-crop treatments applied as deep bands, had lower emissions than the single deep application of urea at seeding. Split application where UAN was streamed in-season at rosette stage reduced emissions compared to shallow urea and deep urea at the time of seeding.

Results from this study confirm conclusions from the previous Red River Valley study that nitrification-inhibited urea (single or dual) should be used when shallow banding. Results also confirm that urea with the single nitrification inhibitor treatment can reduce emissions as effectively as dual-inhibited (urease and nitrification) urea.

EEFs and deep banding reduce emissions from urea



← Cumulative nitrous oxide emissions during the growing season by treatment across all sites. Treatment averages above the horizontal line are significantly different (P<0.05) from the 0 N control by the Tukey test. Shown are treatment means (n=4) and +1 of the standard error of the mean. Treatments: DMPSA Dp is urea plus nitrification inhibitor DMPSA banded deep; SU Surf is SuperU on the surface; ESN Sh Split is ESN shallow banded and split applied; SU Sh is SuperU shallow banded; eNtrench Dp is urea plus eNtrench deep banded; Dp Split is regular urea deep banded and split applied; Dp Split AT is urea with Agrotain deep banded and split; ESN Sh is ESN in a shallow band; Deep is regular urea deep banded; Shallow is regular urea shallow banded.

Aim to synchronize nitrogen supply with crop demand

KEY RESULT:

Primary targets for emissions reductions in Western Canada should be the controls on emissions occurring at spring thaw and enhanced synchronization of nitrogen supply with crop nitrogen demand.

PROJECT TITLE, PRINCIPAL INVESTIGATORS:
"Balancing agronomic and environmental outcomes using enhanced efficiency nitrogen fertilizers," Richard Farrell and Kate Congreves, University of Saskatchewan.

FUNDING: SaskCanola, Saskatchewan Agriculture Development Fund

PUBLISHED ARTICLES: Read the full report in the Research section at saskcanola.com.

With the cost of synthetic nitrogen fertilizer increasing and the emergence of lower cost enhanced efficiency fertilizer (EEF) technologies, producers are increasingly looking towards technologies that can protect their fertilizer investment while improving both their agronomic and environmental performance. Previous research has shown that substantial reductions in N_2O emissions are achievable by combining EEFs with more advanced, 4R-based nitrogen management practices. (Practices that involve applying N fertilizer using the Right source at the Right rate, Right time, and with the Right placement.)

This three-year study over two field seasons evaluated and compared the performance of SuperU (urea treated with dual urease and nitrification inhibitors) and eNtrench (urea treated with a nitrification inhibitor) with that of conventional granular urea in both fall and spring applications. Researchers quantified and compared crop nitrogen uptake, nitrogen use efficiency, canola yield and N_2O emissions for all treatments. Yield-scaled N_2O emission factors were also calculated for each fertilizer type and application timing to determine the combination that optimized the balance between agronomic and environmental outcomes.

Field trials were conducted at the University of Saskatchewan on plots that had been previously cropped to barley. The fertilizer treatments were applied in the fall or spring and at 70 per cent and 100 per cent of soil test recommendation. The study included a non-fertilized check plot to quantify background emissions and calculate fertilizer-induced emissions. Researchers broadcast each treatment by hand in the late fall after soil temperatures had fallen below 7°C for five consecutive days, or at planting the following spring. They incorporated fertilizer to a depth of about 10 cm immediately after surface application. They seeded plots to hybrid canola in the spring.

Urea →
This study compared nitrous oxide emissions for urea (shown) and urea with EEFs eNtrench and SuperU. Drought conditions during the two growing seasons significantly impacted results of this study. Under these conditions the EEFs had no effect on either yield or nitrogen use efficiency.

Results

Drought conditions during the two growing seasons significantly impacted results of this study, with yields about 30 per cent and 90 per cent lower than target yields in 2020 and 2021, respectively. Overall, the study showed that under these conditions the EEFs had no effect on either yield or nitrogen use efficiency. Generally, the fertilizer rate effects were not significant.

Results of the daily N_2O emissions showed that major emission events coincided with snowmelt and spring thaw and the spring seeding and fertilizer operations. For fall nitrogen application, the magnitude of emissions during the spring thaw was determined by environmental and soil conditions both during the overwinter period and at spring thaw. Cumulative spring thaw emissions, which were much greater in 2020 than in 2021, were generally greater with fall nitrogen applications than those associated with the spring nitrogen applications. This reflects the differences in both soil and environmental conditions and available nitrogen supply.

Although severely impacted by moisture deficiencies in both years, the study provided new data on the performance of two common EEF products. However, the results are not reflective of what producers might expect in a "normal" year. Overall, the results provided strong evidence that the primary targets for emissions reductions in Western Canada should be the controls on emissions occurring at spring thaw and enhanced synchronization of nitrogen supply with crop nitrogen demand. Future research should also target nitrogen management strategies that improve synchronization of nitrogen supply with crop demand. This could include detailed studies of N uptake and N losses (including N_2O emissions) performed under varying soil and environmental conditions.

Nitrogen-fixing bacteria need more work

KEY RESULT:

Evaluation of a commercial nitrogen-fixing bacteria product showed that the bacteria did colonize many of the root and shoot tissues, but most did not show strong evidence of nitrogen fixation. In many cases, the percentage of nitrogen in the plants that were colonized was lower than the control (not inoculated) plants.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Advanced N management for canola, wheat and soybean: Evaluation of a new biological for N-fixation in non-legume." Diane Knight and Richard Farrell, University of Saskatchewan

FUNDING: SaskCanola, Western Grains Research Foundation

PUBLISHED ARTICLES: Read the full report in the Research section at saskcanola.com.

Cost effective practices and products that help synchronize the supply of nitrogen with a crop's demand for nitrogen will reduce losses and thereby reduce the amount of nitrogen fertilizer needed to produce the crop. Nitrogen-fixing organisms could, in theory, be one of those products. More work is required.

Many species of microorganisms are capable of nitrogen fixation, including *Gluconacetobacter diazotrophicus* (now marketed as Envita). Unlike the rhizobia that colonize the roots of legume plants, *G. diazotrophicus* is a free-living organism that does not require the presence of a host plant. However, it often lives inside of plant tissues and evidence exists that it can fix atmospheric nitrogen for the associated plant and improve yield. The product has had success in crops like corn in the United States, but very little data exists on how it performs in Western Canada.

In this project, researchers tested Envita for its ability to fix nitrogen in canola, wheat and soybean in a controlled environment. They inoculated the crops with Envita then evaluated if the inoculated crops were acquiring nitrogen fixed by the *G. diazotrophicus*. To trace the path of nitrogen into the plant, they supplied $^{15}N_2$ gas (labelled nitrogen for tracing in plant tissue) into the sealed chamber surrounding the plants, then analyzed plants for ^{15}N content.

They introduced *G. diazotrophicus* to the plant through (1) direct seed inoculation, (2) inoculation at germination and (3) foliar application.

Results

Envita was able to deliver *G.diazotrophicus* bacteria to roots and shoots of wheat, canola and soybeans, and the bacteria could colonize the tissues in most, but not all cases. However, the presence of *G.diazotrophicus* in the plant tissues did not always translate into $^{15}N_2$ being fixed into the plant tissues.

In terms of getting *G.diazotrophicus* into the plant tissues, the inoculation at germination method had the most positive result followed by foliar application and direct seed inoculation. Unfortunately, application at germination is the least practical method for farmers to use, even with changes for field scale use.

Results for canola were the most inconsistent among the three crop types. All of the plants inoculated at germination showed some slight ^{15}N enrichment in the roots and shoots, but not all tested positive for *G.diazotrophicus* colonization. Even though ^{15}N enrichment indicates the transfer of ^{15}N fixed by some means to the canola plants, there were not consistently higher percentages of nitrogen in the tissues, nor did the plants produce more biomass.

The presence of the introduced *G. diazotrophicus* organism in some of the tissues tested is encouraging, but further work is needed to improve colonization efficacy and to determine how to trigger the organism to fix nitrogen after it has colonized.

Spore threshold for sclerotinia stem rot risk

KEY RESULT:

Frequent occurrence during the flowering period of a minimum of 0.0001 nanograms of *S. sclerotiorum* DNA per petal or per cubic metre per hour combined with relative humidity over 80 per cent and cooler temperatures are expected to result in a disease incidence greater than 10 to 15 per cent. In this situation, fungicide is recommended, depending on commodity price and expected yield.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Improving the management of sclerotinia stem rot of canola using fungicides and better risk assessment tools," Kelly Turkington, Agriculture and Agri-Food Canada Lacombe

FUNDING: AgriScience Program (Canola Cluster) under the Canadian Agricultural Partnership

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

Results from this study emphasize that without a minimum threshold of spores and constant high relative humidity, risk from sclerotinia is low and fungicide is not economical.

Researchers aimed to (1) refine the use of qPCR analysis and investigate the potential of utilizing spore traps instead of canola petals; (2) understand the role and impact of relative humidity (RH), rainfall, and temperature on inoculum production and disease development; (3) evaluate the efficacy of very early applications alone or in conjunction with later applications of fungicide for management of stem rot; (4) develop a better understanding of factors (e.g. seeding rate) that influence crop development and variability in flowering and how this influences fungicide response at various crop growth stages; and (5) develop a better understanding of how inoculum availability and environmental conditions prior to and during the flowering period influence stem rot risk and the efficacy of fungicide application.

Results

Given weather conditions and relatively low inoculum levels, most sites showed limited disease development and no effects of fungicide timing and their interaction on yield. Trial sites at Outlook, Saskatchewan and Brooks, Alberta were irrigated yet inoculum loads and weather conditions were not overly favourable for stem rot development. Perhaps for these locations where warmer dry conditions normally prevail, the addition of irrigation wasn't sufficient enough to substantially increase the risk of stem rot of canola.

Inoculum load. This study indicated that spore tests that quantify spore load, not just the presence of spores, will more accurately identify the risk. Frequent occurrence during the flowering period of a minimum of 0.0001 nanograms of *S. sclerotiorum* DNA (from spores) per petal or per cubic metre of air per hour combined with favourable moisture conditions (see relative humidity below) and cooler temperatures are expected to result in a disease incidence greater than 10 to 15 per cent. In this situation, fungicide is recommended depending on commodity price and expected yield. Overall, no to low inoculum levels were associated with limited stem rot risk.

Rotorod testers are accurate tools that collect spores per cubic metre of air per hour. They could be deployed as regional monitoring tools, providing a pre-flowering indication of risk, but are not practical for on-farm use. Petal tests provide quantitative DNA and turn around time is fairly quick, but these tests have to be done right around the time fields need to be sprayed. The Spornado also provides an earlier warning. Refinements to Spornado's "detected" category to provide more quantitative results will improve its ability to assess stem rot risk and potential need for fungicide application.

Relative humidity. Results from this study supported previous work showing that relative humidity (RH) greater than 80 per cent was associated with increased stem rot incidence, while RH below 80 per cent was associated with lower disease incidence that would typically not require a fungicide application. RH of 80 per cent or higher is required for at least 21 hours per day to elevate disease risk. A few hours per day with lower RH seems to be enough to disrupt infection.

Timing trials for this study (objectives 3 and 4) did not come to any conclusions because disease levels were too low.

Overall results in 2022 and 2021, and from some sites in 2019, indicate that when the risk of stem rot is low based on weather and inoculum conditions, fungicide application is not needed and provides no crop productivity or economic benefit in terms of yield.

Sclerotinia spore sensor gets a patent

KEY RESULT:

InnoTech researchers have patented an automatic field unit that can count *Sclerotinia sclerotiorum* spores over a set period of time. They deployed six units in 2022 and are troubleshooting mechanical issues, mostly to do with the system's internal clock and power supply.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Development of a biosensor for sclerotinia stem rot disease forecasting in canola," Xiujie Li, InnoTech Alberta

FUNDING: AgriScience Program (Canola Cluster) under the Canadian Agricultural Partnership

PUBLISHED ARTICLES: Pedro A. Duarte, Lukas Menze, Gaser N. Abdelrasoul, Shari Yosinski, Zak Kobos, Riley Stuermer, Mark Reed, Jian Yang, Xiujie S. Li and Jie Chen. 2020. Single Ascospore Detection for the Forecasting of Sclerotinia Stem Rot of Canola. Lab on a Chip 20: 3644-3652

Lian C. T. Shoute, A. Anwar, S. MacKay, G. N. Abdelrasoul, D. Lin, Z. Yan, A. H. Nguyen, M. T. McDermott, M. A Shah, J. Yang, J. Chen, and X. S. Li*. 2018 Immuno-impedimetric biosensor for onsite monitoring of ascospores and forecasting of Sclerotinia stem rot of canola. Scientific Reports 8 (12396).

In this project to develop a sclerotinia spore detection tool, researchers redesigned their spore collection unit then deployed six of them to Alberta fields for evaluation.

Each unit gathers airborne *Sclerotinia sclerotiorum* spores in a liquid trap. In the liquid are microbeads coated with an antibody that specifically binds to *S. sclerotiorum* spores. This separates the target spores from other spores that land on the sensor. Once per hour, the system turns on to agitate the sample tray so the antibodies can bind with the spores. A second pump moves the mixed sample into a holding chamber for analysis.

One of six spore count units deployed to Alberta fields in 2022.

The system performs an analysis sequence once per day. Units use both a nano-scale impedance sensor and vision-based optics to detect spores. The spore-carrying liquid runs through the flow cell, a very narrow chamber where impedance sensors use electrical charges to measure how each spore impedes the charge. *Sclerotinia sclerotiorum* spores have their own impedance fingerprint. Vision-based detection uses a camera and magnification lens clamped to the flow cell assembly. It can see the spore-coated microbeads. A computer and coded software analyze the images. The same computer runs all functions of the automated unit. Units include a modem to send daily reports and a 12-volt battery.

Results

In the summer of 2022, researchers deployed six biosensor units to canola fields in Leduc, Devon, Viking, Lavoy and Vegreville. (Vegreville got two.)

Units passed the initial tests for assembly and wireless communication. Each got a test run before deployment.

One unit collected data for 25 days of the 30 days deployed and other units only collected data periodically or stopped collecting after a short duration after installation.

A field issue occurred with the real time clock board (RTC). Troubleshooting indicated that the RTC would randomly change its internal clock and randomly reschedule the start times. On some of the deployed systems, the battery was found to prematurely run low and the field analysis would stop.

The battery was changed to a power supply, which permitted long term tests without the need to maintain a battery on a charger. The RTC issue is presently under review and evaluation with the ongoing testing. Transitioning to full power down and RTC wakeup is required prior to changing back to battery.

Researchers obtained a U.S. patent for their biosensors. They also confirmed that their anti-*S. sclertotiorum* antibodies are very specific with high affinity to *S. sclerotiorum*. They have no affinity to *Botrytis cinerea*, *Leptosphaeria maculans*, and *Fusarium graminearum* – the other common spores in the air around farm fields.

Daily spore counts for unit 486 at Vegreville

Date	Spore count
July 7, 22	
July 8, 22	3
July 9, 22	14
July 10, 22	16
July 11, 22	18
July 12, 22	31
July 13 2022	
July 14, 22	
July 15, 22	78
July 16, 22	
July 17, 22	
July 18, 22	62
July 19, 22	83
July 20, 22	78
July 21, 22	113
July 22, 22	96
July 23, 22	127
July 24, 22	
July 25, 22	119
July 26, 22	117
July 27, 22	125
July 28, 22	169
July 29, 22	142
July 30, 22	149
July 31, 22	53
August 1, 22	175
August 2, 22	87
August 3, 22	124
August 4, 22	94
August 5, 22	110
August 6, 22	114

These spore counts (except for the "3" on July 8) are enough to develop sclerotinia stem rot disease in canola.

Seed treatments protect susceptible cultivars from blackleg

KEY RESULT:

Fluopyram, Saltro and Bion seed treatments look promising against early blackleg infection, however none of these seed treatments has shown significant additional efficacy on any of the resistant canola cultivars tested under field conditions.

PROJECT TITLE, PRINCIPAL INVESTIGATOR: "Exploring novel seed-treatment options to mitigate the impact of blackleg on canola," Gary Peng, AAFC Saskatoon

FUNDING: SaskCanola

PUBLISHED ARTICLES: Peng G, Liu X, McLaren D, McGregor L, Yu F. 2020. "Fungicide seed treatment for effective control of blackleg of canola in Canada." Can J. Plant Path. 42: 480-492.

The fungus *Leptosphaeria maculans* is the primary cause of blackleg, and *L. maculans inoculum* over 10,000 (>10^5) spores per gram of soil can also result in severe blackleg via root infection, especially if roots are wounded (by root maggots, for example). Fluopyram, Saltro and Bion seed treatments show promise to protect susceptible cultivars against the early blackleg infection, either through roots or from cotyledon and leaf wounds.

Study objectives were to 1) understand the soil inoculum level of blackleg pathogen required to cause root infection, which would lead to severe blackleg, 2) evaluate new commercial products for potential seed treatment against the early blackleg infection, 3) assess the rate effect of top candidates for maximum efficacy, and 4) validate the efficacy in multiple field trials.

Researchers used greenhouse studies for the first three objectives. Blackleg pathogen inoculum was applied as a soil drench at zero to 10^8 spores per gram of soil to cause infection via roots. Roots of certain plants were wounded by cutting to simulate soil insect damage. About a dozen of new seed-treatment candidates were evaluated for restricting infection on cotyledons, and promising candidates were assessed further for control of root infection. Top candidates were also tested in field trials (objective 4) by targeted inoculation either on different leaves or via roots (soil drench inoculation).

The drought of 2021 and early dry conditions in Saskatoon in 2022 hampered field trials. Many inoculated leaves had dropped before the pathogen was able to spread into the stem, so the disease levels were much lower than other years, despite the inoculation applied.

Result showed that *L. maculans inoculum* at 1,000 to 10,000 (10^4 to 10^5) pycnidiospores per gram of soil can cause root infection which ultimately results in severe blackleg. While current seed treatments Helix and Prosper are ineffective against blackleg infection from lower leaves or roots, new products Fluopyram, Saltro and Bion appear promising against early blackleg infection. However, more field work is required for robust data. The Fluopyram treatment at 75g/100kg seed (registered rate) showed stability in efficacy with delayed emergence under controlled environment, but failed to control blackleg significantly in these field trials, a circumstance partially attributable to the weather conditions experience. Increasing the product rate to 300g achieved significant efficacy against root infection. The Bion seed treatment reduced the blackleg severity via the cotyledon (but not first-leaf inoculation) on the susceptible cultivar Westar only. Efficacy of seed treatment may be improved by increasing the rate of treatment, which warrants further investigation.

None of the seed treatments evaluated showed efficacy against blackleg on resistant canola cultivars, on which the disease severity index was generally very low (<10 per cent) already in all these trials. However, due to the relatively low cost, a seed treatment may still be a good insurance policy in case of resistance erosion.

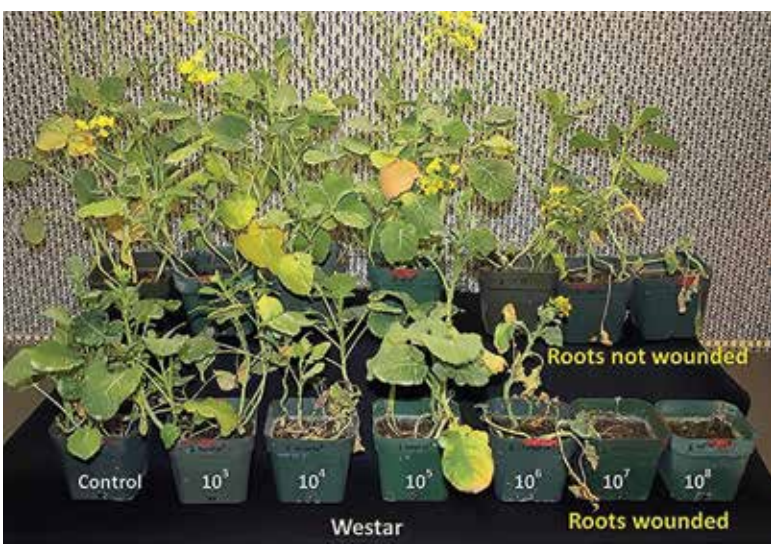


Figure 1. Effect of root wounding at six days after plant emergence and soil inoculum concentration (# spores/g soil) on blackleg infection via canola roots in greenhouse trials. Note that plants at >10^5/g soil inoculum levels showed severe disease at the early flower stage, and many of them died shortly after that.

Monitoring blackleg races to inform R gene development

KEY RESULT:

The avirulence profile of *L. maculans* population on the Prairies remained relatively stable from 2017 to 2021; only AvrLep1 increased noticeably. Even so, the current pathogen population is still highly diverse. Researchers should continue monitoring the pathogen population for early detection of resistance erosion to specific R genes, especially when new R genes are being used in canola cultivars.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Monitoring the race dynamics of *Leptosphaeria maculans* for effective deployment and rotation of resistance genes for sustainable management of blackleg of canola in western Canada," Gary Peng, Agriculture and Agri-Food Canada, Saskatoon

FUNDING: Alberta Canola, SaskCanola, Manitoba Canola Growers

PUBLISHED ARTICLES: Soomro W, Kutcher HR, Yu F, Hwang SF, Strelkov SE, Fernando WGD, McLaren D, Peng G. 2021. Race structure of Leptosphaeria maculans in western Canada between 2012 and 2014 and its influence on blackleg of canola. Can J Plant Path. 43: 480-493.

Liu F, Zou Z, Peng G, Fernando WGD. 2021. Leptosphaeria maculans isolates reveal their allele frequency in western Canada. Plant Disease 105: 1440–1447.

For canola cultivars with qualitative, or major-gene, blackleg resistance, the plant may have a gene that recognizes one of the common *Leptosphaeria maculans* races present in a field. When that happens, the race is considered to be carrying an avirulence gene, which triggers a resistant response in the plant that prevents the pathogen from causing blackleg. If the plant doesn't carry an R gene corresponding to any of the common pathogen races present in a field, these races are considered virulent, and the plant is likely somewhat susceptible to infection. (All current canola cultivars carry a level of quantitative resistance to blackleg.)

Analysis of avirulence-gene frequency in the *L. maculans* population provides important guidance to the selection of effective R genes in blackleg resistance breeding, as well as to the recommendation of canola cultivars carrying effective *R* genes.

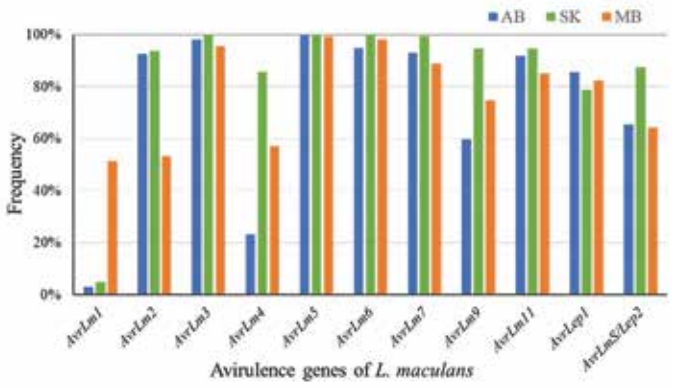


Figure 1. Avirulence *(Avr)* gene frequencies in the population of *Leptosphaeria maculans* on the Canadian Prairies in 2021. The higher an Avr-gene frequency, the greater chances for the corresponding R genes to be effective in a region. For example, the figure shows that the avirulence gene *AvrLm1* was moderately high (>50%) in Manitoba, while extremely low in Alberta and Saskatchewan. This means that cultivars carrying the R gene *Rlm1* or *LepR3* alone can be fairly effective in Manitoba, but not so much in the other two provinces.

This study identified the pattern of avirulence dynamics in the *L. maculans* population in Western Canada between 2017 and 2021. This prompted the deployment of new R genes in canola cultivars.

Key objectives were to (1) monitor and analyze the pathogen population to gain insights into race dynamics and population virulence; (2) provide industry and producers with up-to-date pictures on *L. maculans* population virulence in the prairie provinces to guide the selection and recommendation of effective *R* genes for blackleg resistance breeding and disease management; (3) understand the diversity of *L. maculans* population and identify pathogen races capable of overcoming common *R* genes in canola cultivars before widespread breakdown of the resistance; and (4) evaluate, develop and adopt markers for efficient *L. maculans* race monitoring.

Each year, provincial disease survey teams collected canola stubble with blackleg symptoms, and researchers tested these samples for the presence or absence of known avirulence (*Avr)* genes.

The study showed that canola cultivars carrying any of the resistance genes *Rlm5*, *Rlm6*, *Rlm7*, *Rlm10*, *Rlm11* and *LepR1* are likely resistant to blackleg in Western Canada due to common presence of corresponding *Avr* genes in the pathogen population. The resistance genes *Rlm3* or *Rlm9* may be ineffective due to the masking effect of *AvrLm7* on the *AvrLm3* or *AvrLm9*, and *Rlm4* may be less effective in Alberta due to low levels of the avirulence gene *AvrLm4*.

A total of 83 races were identified in the *L. maculans* population, with top-10 races accounting for 72.3 per cent of the population in Alberta, 93.7 per cent in Saskatchewan and 57.1 per cent in Manitoba. The diversity in pathogen shows the potential for resistance erosion as virulent races had already been present for all known R genes, except *Rlm10*. To manage selection pressure that can lead to resistance breakdown, judicious uses of R genes will be important.

Advancing blackleg and verticillium stripe management

Researchers laid the ground work for a rating system based on quantitative resistance to blackleg, specified the critical infection window for blackleg, and investigated connections between flea beetles and blackleg and verticillium stripe and blackleg.

The following nine summaries are for projects specific to blackleg and verticillium. The Government of Canada provided $3.3 million through the AgriScience Program (Canola Cluster) under the Canadian Agricultural Partnership, and growers contributed $1.8 million through SaskCanola and Alberta Canola. For full final reports for these nine projects, go to the Research section at saskcanola.com and look on the Canola Research Hub at canolaresearch.ca.

Toward a rating system for quantitative resistance to blackleg

Project title and principal investigators: "Developing a robust system for efficient assessment of quantitative resistance (QR) in commercial canola varieties for blackleg management," Gary Peng, Agriculture and Agri-Food Canada (AAFC) Saskatoon, and Debra McLaren, AAFC Brandon

Purpose: To develop and validate a system to rate quantitative resistance (QR) against blackleg under both controlled environment and field conditions. QR or adult plant resistance is important to sustainable blackleg management in Canada. Blackleg resistance labelling is readily applicable for major-gene resistance but not yet possible for QR.

Results: DNA analysis using droplet digital PCR (ddPCR) can identify strong QR in breeding lines for development of canola hybrids with good QR background against blackleg. It could be a new tool for blackleg resistance breeding, and a new standard for labelling the QR trait of canola cultivars against blackleg.

Project title and principal investigators: "Developing tools for the rapid screening of canola germplasm for quantitative resistance to disease," Hossein Borhan, AAFC Saskatoon, and Ralph Lange, InnoTech Alberta

Purpose: To optimize a protocol for identifying quantitative resistance (QR) to blackleg disease under controlled conditions (growth chamber) and validate the result under field conditions. A rapid screening method using a genome-wide association mapping approach will provide the canola industry with a valuable tool for developing new varieties.

Results: Researchers developed a protocol for growth chamber and greenhouse-based QR assay. It can be used for high-throughput screening to identify canola varieties with quantitative resistance to blackleg disease.

The critical infection window for blackleg

Project title and principal investigator: "Understanding the critical infection window that causes blackleg of canola in Western Canada," Gary Peng, AAFC Saskatoon

Purpose: To determine the relative importance of cotyledon versus lower true-leaf infection as they relate to blackleg severity on canola varieties with different levels of resistance. Results of the critical infection window will determine the optimal timing of fungicide applications, either as seed treatment or as a foliar spray at later stages.

Results: The fungus Leptosphaeria maculans can cause blackleg more successfully via wounds on cotyledons than on lower true leaves. Cotyledon infection results in higher disease incidence and severity at canola maturity. Researchers also found that QR, without the direct involvement of major R genes, can reduce infection spread from inoculated cotyledons and lower true leaves to the stem, with substantially reduced levels of blackleg relative to susceptible canola. This demonstrates the value of using QR for the management of blackleg in Western Canada.

The importance of cotyledon infection suggests an opportunity to use seed treatment to manage blackleg. Fluopyram and pydiflumetofen are promising seed treatments.

Project title and principal investigator: "Fine-tuning of the blackleg yield loss model in canola," Sheau-Fang Hwang, University of Alberta

Purpose: To build on the earlier work on Westar by modeling yield losses from blackleg in modern canola hybrids, making the model more accurate and more relevant to producers and agronomists.

Results: Researchers developed the blackleg yield loss calculator. Find it at canolacalculator.ca.

Flea beetles and blackleg

Project title and principal investigator: "Improving management of blackleg on canola via better flea beetle control and effective fungicide seed treatment in Western Canada," Gary Peng, AAFC Saskatoon
Purpose: To understand the relevance of flea beetle feeding to blackleg.
Results: This study provided strong evidence that wounds on cotyledons or lower leaves allow blackleg pathogen infection without the presence of leaf surface wetness. However, data from field trials failed to prove that controlling flea beetles with a foliar insecticide may help reduce blackleg infection. It appears that when inoculum is abundant, like in continuous canola used in this study, differences in wounding severity would have no significant effect on the success of blackleg infection. Results strongly indicate that applying foliar insecticide targeting flea beetles will unlikely help reduce blackleg infection in Western Canada.

Hossein Borhan

Blackleg R-gene rotation

Project title and principal investigator: "Improving blackleg resistance durability through R-gene rotation in commercial fields on the Canadian Prairies," Dilantha Fernando, University of Manitoba
Purpose: To help fine-tune the sequence of blackleg R genes to be deployed in rotation for maximum resistance durability.
Results: Canola cultivars rotated with new R genes showed good performance in reducing the disease incidence and severity. Rlm4 only or Rlm4 in combination with other R-genes showed lower disease severity and incidence.

Project title and principal investigators: "Genetic dissection of the Rlm3-4-7-9 blackleg R-gene cluster and KASP marker improvement," Hossein Borhan, AAFC Saskatoon
Purpose: To provide an in-depth understanding of R genes in the Rlm3-4-7-9 cluster, which is very important for the genetic improvement of canola against blackleg. This project will improve the efficiency of molecular markers so that growers can detect the blackleg races in their fields and make informed varietal selections.
Results: Cloning and knowledge of the sequence of these genes has facilitated the design of gene-specific allele markers for genotyping and breeding. It has advanced the understanding of their function and interaction with the corresponding *L. maculans* Avr genes.

Verticillium and blackleg

Project title and principal investigator: "Verticillium disease etiology and nursery," Dilantha Fernando, University of Manitoba
Purpose: To address the major research priorities needed to understand and manage verticillium stripe in Western Canada. Questions to answer include: How to improve the identification of this disease? Can the pathogen be rapidly quantified in the soil? How does the pathogen behave in Western Canada? What is the genetic diversity of the pathogen? What is the relationship and interaction between *V. longisporum*, the pathogen that causes verticillium stripe, and *L. maculans*, the pathogen that causes blackleg?
Results: Researchers identified three different *V. longisporum* lineages in Saskatchewan, and lineage A1/D1 is considered the most virulent. Researchers found a significant interaction between *V. longisporum* and *L. maculans* on blackleg scores, but not verticillium stripe scores. When researchers looked at seed yield, the main effect of both pathogens individually reduced seed yield, but they noted no significant interaction between *V. longisporum* and *L. maculans* – so there was not a significant additive effect on decreased seed yield.

Project title and principal investigator: "Genetics and genomics of brassica-verticillium interaction," Hossein Borhan, AAFC Saskatoon
Purpose: To develop tools for genotyping and monitoring changes in *Verticillium longisporum*. This research will provide an understanding of verticillium stripe resistance with output of genetic markers for resistance as well as insight into the infection process.
Results: Researchers identified two *B. napus* disease resistance QTLs on chromosomes A07 and C02 that are effective against *V. longisporum*. They developed three markers that can distinguish *V. longisporum* from other verticillium species. They also identified *B. napus* lines with resistant, intermediate, and susceptible responses to *V. Longisporum*. These could serve as checks in *V. longisporum* nurseries. Researchers potentially found a microorganism that can protect against *V. longisporum*.

Hydrated lime treatments reduce clubroot infection

KEY RESULT:

A study of integrated management practices to manage clubroot show a benefit from hydrated lime treatments, particularly for clubroot-susceptible cultivars.

PROJECT TITLE, PRINCIPAL INVESTIGATORS:
"Canadian Canola Clubroot Cluster (C1) Pillar 1: Integrated Disease Management," Sheau-Fang Hwang and Stephen Strelkov, University of Alberta

FUNDING: AgriScience Program (Canola Cluster) under the Canadian Agricultural Partnership

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

The utility of genetic resistance as a clubroot management tool is at risk. The entire zone infested by clubroot is susceptible to resistance breakdown and every commercially available clubroot-resistant genotype of canola is potentially susceptible to novel clubroot strains. Deployment of resistant canola varieties must be combined with other clubroot management strategies. This project explored various strategies, including lime, canola cultivar rotation and perennial grasses.

Hydrated lime (not limestone) can work

Researchers conducted field and greenhouse trials to study the effects of lime amendments to soil. For the field trials (at the Crop Diversification Centre North, Edmonton), researchers spread three rates of hydrated lime and seeded a susceptible canola cultivar. Rates were low (1.9 tonnes per acre), medium (3.2 t/ac.) and high (4.6 t/ac.).

At the first field site, untreated control blocks had a pH of 5.6. The highest lime treatment increased pH to 7.8 at the time of seeding. This high rate reduced the clubroot disease severity index by 91 per cent at eight weeks after planting and by 71 per cent at harvest time. The high rate increased yield by 13 per cent. At the second field site, untreated control blocks had a pH of 5.5. The highest lime rate increased soil to a pH of 7.7 at the time of seeding. The high rate reduced the clubroot disease severity index by 45 per cent at eight weeks after planting and 50 per cent at harvest time. Yield increased 343 per cent.

For greenhouse trials, researchers inoculated potting soil with four different populations of *P. brassicae* spores, then treated the soil with "zero grind" limestone or hydrated lime at rates equivalent to 4.7, 8.1, 11.4 and 14.8 tonnes per hectare of lime. These rates adjusted the pH to 6.0, 6.5, 7.0 and 7.5, respectively. Eight weeks after inoculation, disease severity indices were 92-100 per cent and nine-13 per cent, respectively, in the susceptible and resistant controls (no lime) treatments. The index of disease decreased to zero per cent in both the susceptible and resistant cultivars following treatment with any of four tested rates of hydrated lime. In contrast, the application of limestone resulted in a modest decrease in clubroot severity and only at the two lowest inoculum levels evaluated.

Researchers also note that when clubroot resistance worked on the clubroot pathotypes present in a field, lime didn't help yield.

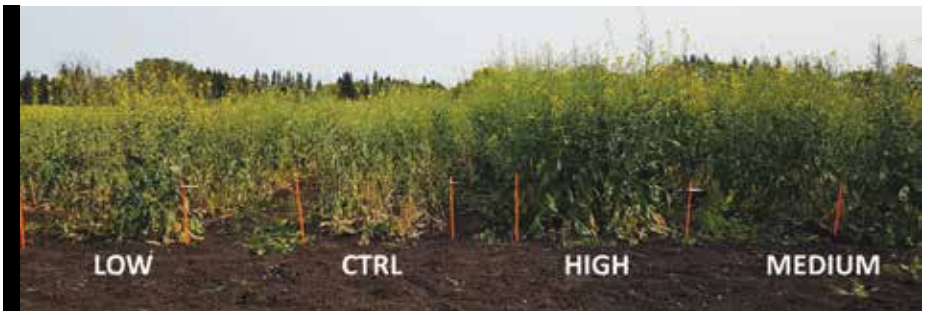
Cultivar rotation

Researchers used a greenhouse study to compare continuous cropping of three treatments: the same susceptible canola cultivar, the same resistant canola cultivar and alternating resistant canola cultivars.

At the end of the first cycle of each rotation, the susceptible cultivar had a disease severity index of highest 91.5 per cent, the resistant cultivar had an index of 78.0 and the resistant rotation had an index of 69.1. Back to back canola increases the risk of clubroot, and CR only helps marginally and for only a short time. After subsequent rotation cycles, disease levels were not significantly different.

Wheat a good rotation crop

Researchers conducted growth room studies to assess the effect of dense seedlings of perennial grasses and conventional rotation crops (wheat, barley, pea and soybean) on resting spores of *P. brassicae.* They showed that resting spore concentration declined more quickly in the presence of grass and wheat seedlings than in bare soil. Wheat was as good at reducing spores in soil as perennial ryegrass, but the effect of barley was less consistent, and soybean did not result in any measurable reduction relative to bare soil.



← Field results show the benefits of lime. Base pH at untreated plots were around 5.5. At site one, the highest rates of lime, 4.6 tonnes per acre, increased soil pH to 7.8 and yields by 13 per cent. At site two, the same rate of lime increased soil pH to 7.7 and yield by 343 per cent.

Widespread triple resistance in kochia

KEY RESULT:

Farmers need an integrated approach to stop kochia. Take steps to deplete seedbanks, use cultural methods to rapidly achieve crop canopy closure, and apply a tank mix of pre-seed herbicides.

PROJECT TITLE, PRINCIPAL INVESTIGATOR: "Glyphosate- or auxinic-resistant kochia and Russian thistle Prairie surveys," Shaun Sharpe, Agriculture and Agri-Food Canada Saskatoon

FUNDING: SaskCanola, Alberta Wheat, Manitoba Pulse & Soybean Growers, Manitoba Crops Alliance, SaskPulse, SaskWheat, Western Grains Research Foundation

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

Kochia infests agricultural and disturbed areas on the Prairies, spreading thousands of seeds per mature plant as it tumbles across the landscape. The weed has become harder to kill with herbicides.

Kochia has evolved resistance to several modes of action, including ALS-inhibiting herbicides (Group 2), glyphosate (Group 9), and synthetic auxins (Group 4). The study objective was to survey glyphosate-resistant and dicamba-resistant kochia distributions in Manitoba, Saskatchewan and Alberta.

Researchers conducted randomized surveys post-harvest, starting in early October. They surveyed Manitoba in 2018, Saskatchewan in 2019 and Alberta in 2021. Researchers planted seeds from each sample and applied discriminating doses of glyphosate (900 grams of acid equivalent per hectare) or dicamba (280 grams of acid equivalent per hectare) to test for resistance.

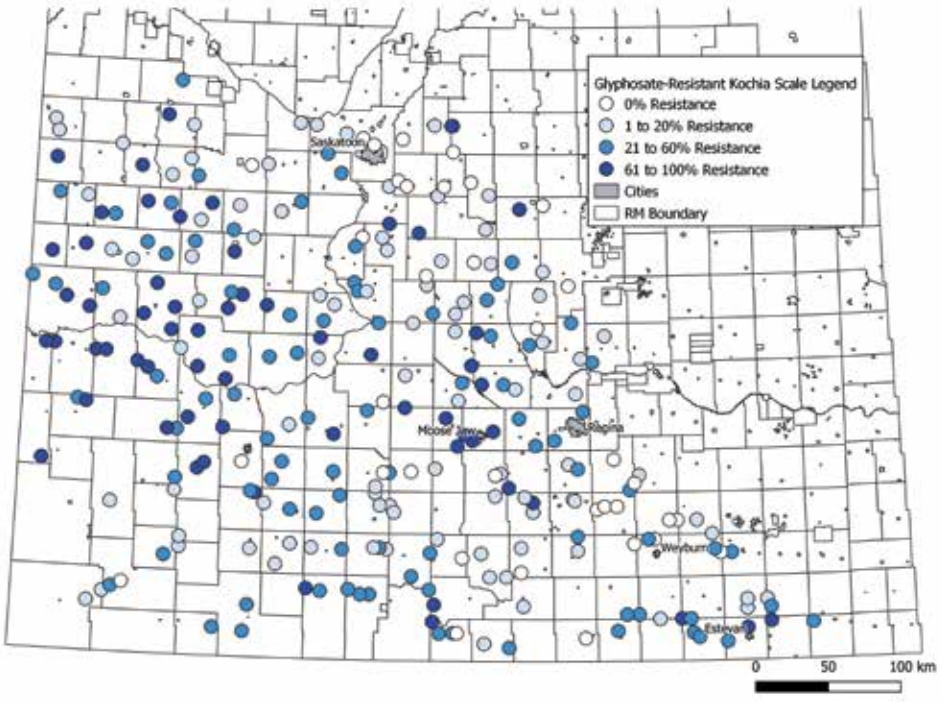
Results

The incidence of glyphosate-resistant kochia increased substantially from previous surveys. Researchers found glyphosate resistance in 58 per cent of Manitoba samples, 87 per cent of Saskatchewan samples and 78 per cent of Alberta samples. They found dicamba resistance in on per cent of Manitoba sites, 45 per cent of Saskatchewan sites and 28 per cent of Alberta sites. This documents the first instance of dicamba-resistant kochia in Manitoba.

Assuming all kochia is resistant to ALS-inhibitors, triple-resistant kochia was present in 40 per cent of Saskatchewan samples (n=255), less than one per cent of Manitoba samples (n=300), and 10 per cent (n=314) of Alberta samples. Additional screening showed 44 per cent of Alberta samples were fluroxypyr-resistant and 25 per cent were triple-resistant.

Herbicide-resistant kochia has become more prevalent on the Prairies. Seedbanks should be depleted to reduce selection pressure on herbicides. Cultural methods to rapidly achieve canopy closure should be integrated with pre-emergence herbicides to prevent escapes after herbicide efficacy wanes. Kochia is present in many environments outside of cropped land so mitigation procedures for tumbleweeds are advised.

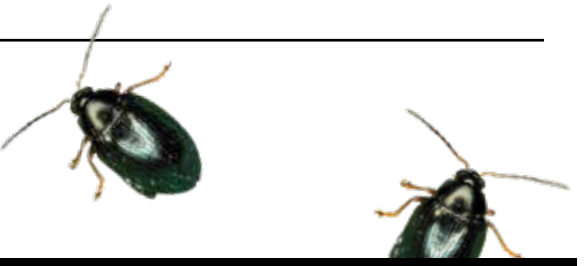
For practical tips to reduce the seedbank, read *"Integrated weed management: Best practices"* in the Weeds section at canolawatch.org/fundamentals.



↑ GR kochia Saskatchewan map

Glyphosate-resistant kochia within Saskatchewan in 2019. Resistance is expressed as low (one to 20 per cent), moderate (21 to 60 per cent), and high (61 to 100 per cent) which corresponds to the percentage of resistant plants within each population.

Strategies to improve flea beetle control



KEY RESULT:

Landscape composition affected flea beetle abundance, as well as seeding rate, temperature, predator presence and the type of pest control option selected.

PROJECT TITLE, PRINCIPAL INVESTIGATOR: "Integrated approaches for flea beetle control II: Incorporating the impacts of plant density, ground predators, and landscape-scale predictive models in the management of flea beetles in the Canadian Prairies," Alejandro Costamagna, University of Manitoba, and collaborators

FUNDING: AgriScience Program (Canola Cluster) under the Canadian Agricultural Partnership

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub.

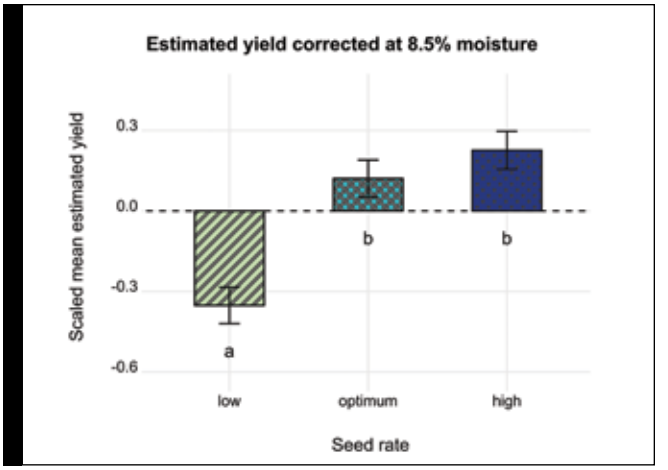
Flea beetles are a major pest insect in canola every year, yet management has many knowledge gaps. This research addressed the gaps that potentially prevent efficient flea beetle management, including: the effects of plant density, the effects of stem feeding damage and the role of natural enemies in flea beetle management, as well as regional predictive models for flea beetle abundance and damage.

Between 2018 and 2022, researchers conducted 16 trials in Manitoba, Saskatchewan, Alberta-Peace River and Alberta-Lethbridge. Treatments were a combination of different seeding rates and flea beetle control methods. Seeding rates were low (3.5 kg/ha or 3 plants per square foot), optimum (7 kg/ha or 6 plants per square foot) and high (14 kg/ha or 12 plants per square foot).

Flea beetle control methods included fungicide-only treated seeds (i.e. control), insecticide and fungicide-treated seeds (i.e. seed), foliar insecticide spray at 25 per cent defoliation with fungicide-only treated seeds (i.e. foliar) and a weekly foliar insecticide spray with fungicide-only treated seeds (i.e. FB-free).

Results

- The seed treatments were more effective in reducing flea beetle defoliation than the foliar spray, which provided intermediate control compared to untreated plots.
- The FB-free treatment indicated that foliar and seed treatments did not completely prevent damage in Manitoba and Saskatchewan.
- Seeding rate had no effects on defoliation of the control, foliar and FB-free treatments, whereas increasing the seeding rate decreased canola defoliation for treated seeds.
- For all treatments, low-seeded plots were less attractive to flea beetles than high-seeded plots. The optimum-seeded plots had an intermediate effect in the control and foliar treatments.
- Higher seeding rates resulted in a lower number of flea beetles per plant (as the total number of beetles can disperse onto fewer numbers per plant when more plants are available). The optimum seeding rate had intermediate levels of flea beetles per plant in Manitoba and Peace River, while Lethbridge had higher and Saskatchewan had lower levels.
- Though no economic analysis was incorporated, higher seeding rates resulted in better yield, regardless of flea beetle control methods and across all regions.
- Less whole-plant damage occurred when ground beetles and spiders were present. In addition to eating flea beetles, the reduction in stem damage without a reduction in cotyledon damage prevalence may suggest a behavioral change of flea beetles moving up the plant to avoid predation.
- Both striped and crucifer flea beetles increased damaging activity with warmer temperatures, causing the most cotyledon damage at 28°C. Both species also damaged the underside of the cotyledon more than the upper side. There was no difference in amounts of damage between species.
- Large canola crops favoured flea beetle abundances at the field scale, but fields located in landscapes with higher proportion of non-canola crops showed lower infestation levels. Grass borders at large scales appeared to favour flea beetle abundances potentially by providing overwintering/dispersing sites, however, the opposite effect was observed at smaller scales. Higher edge density (indicating smaller fields and habitats in the landscape) and more woody habitats helped against flea beetle infestations most likely by acting as physical barriers against flea beetle movement and dispersal to canola.



↑ Scaled effects of seed rate treatments on mean canola yield (standardized to 8.5% moisture).

Steps to reduce flea beetle risk

KEY RESULT:

This study based in the Peace River region of Alberta showed that later seeding, higher plant counts and larger seeds reduce flea beetle risk to canola yield.

PROJECT TITLE, PRINCIPAL INVESTIGATOR: "Evaluating the effect of canola seeding rate and seed size seeded into wheat stubble on flea beetle damage and population," María Angélica Ouellette, North Peace Applied Research Association

FUNDING: Alberta Canola

PUBLISHED ARTICLES: Read the full report in the Research Database at AlbertaCanola.com.

This study aimed to evaluate the impact of seeding rate, seed size and seeding date on flea beetle damage to canola foliage. It measured the impacts on the three major flea beetle species: crucifer (*Phyllotetra cruciferae* Goeze), striped (*Phyllotetra striolata* Fabricius) and hop (*Psylliodes punctulate* Melscheimer).

Researchers ran trials in 2020, 2021 and 2022 at three northern Alberta sites: the North Peace Applied Research Association facility in North Star, the Mackenzie Applied Research Association in Fort Vermillion and the Smoky Applied Research and Demonstration Association in Fahler.

The experiment was a four replicate, split plot analysis with three treatments:

- **Seeding rate.** Three rates were control (target of 10.4 plants per square foot), half rate (target of 5.2 plants per square foot) and 1.5x rate (target of 15.6 plants per square foot)
- **Seed size**. Sizes were classified as small (<2.2mm diameter), large (>2.2mm) as well as an unsorted control with both sizes. Researchers ran the same seed lot over a sieve to separate the sizes. Note that seed was treated with fungicide only. Researchers did not want insecticide seed treatment to deter actual numbers of flea beetles and limit the results.
- **Seeding date.** The goal was to use an early treatment seeded between late April and early May and a normal treatment seeded the second to third week of May. Weather conditions, such as frequent precipitation events, did not allow researchers to hit these targets. Hence early seeding was the second to third week of May and late dates were the fourth week of May and first week of June.

Researchers conducted flea beetle counts and leaf damage assessments every three days until canola stands reached the four-leaf stage.

↑ Flea Beetle - one crucifer and one striped.

Results

At later seeding dates, canola stand counts, canola yield and total number of flea beetles were greater. Overall flea beetle numbers may have increased in plots seeded later because more canola plants are available for feeding. Despite the higher flea beetle numbers and damage, higher yield for late-seeded plots is likely due to warmer temperatures that facilitate faster growth and plant development. These plants therefore had more tolerance to flea beetle feeding.

Control seeding rates produced more yield than both higher and lower seeding rates.

Seeds greater than 2.2mm and unsorted seed had higher yields despite having more striped flea beetles than plots with smaller seeds.

With the findings from their experiment, researchers demonstrate that stand count, leaf damage and total flea beetle number of individuals are impacted mostly by seeding date and rate, and to a certain length, seed size. On the other hand, seeding rate, date and seed size impacted canola yield and to some extent some flea beetle species in comparison to others.

The general conclusion is that later seeding, normal recommended plant counts and larger seeds reduce flea beetle risk to canola yield.

Table 1.
Yield results from Peace Region flea beetle trial
Canola yield from stands subjected to flea beetle herbivory, sown at two different dates in 2020, 2021 and 2022, at three seeding rates and two different seed sizes plus an unsorted control in Falher, Fort Vermilion and North Star, Alberta

	bu./ac. $^{-1}$	
Seeding dates[a]		
Early	34.12[b]	B[d]
Late	36.28	A
Seeding rate (target plants per square foot)		
5.2	32.9	C
10.4	37.33	A
15.6	35.67	B
Seed size (mm)		
<2.2mm	33.23	B
Unsorted	35.81	A
>2.2mm	36.56	A
Standard error	7.5[c]	

a Early dates were May 12, 2020, May 21, 2021 and May 26, 2020 in Fort Vermillion, May 21, 2019, May 18,2021 and May 24, 2022 in North Star, and May 18, 2019, May 15,2021 and May 18, 2022 in Falher. Late dates were May 18, 2019 and June 2, 2020 and 2021 in Fort Vermillion, May 28, 2019 and June 3, 2020 and 2021 in North Star and June 3, 2019 May 16, 2020 and June 7, 2021 in Falher.
b N=1080 α=0.05
c Standard error
d Different letters mean significant differences between values of the same column

Trap to monitor canola flower midge

KEY RESULT:

This project developed a reliable, pheromone-trapping system to monitor *Contarinia brassicola*, canola flower midge.

PROJECT NAME, PRINCIPAL INVESTIGATOR:
"Monitoring the canola flower midge within pheromone-baited traps," Boyd Mori and Kyle Van Camp, University of Alberta

FUNDING: SaskCanola, Alberta Canola, Manitoba Canola Growers, Western Grains Research Foundation

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

Canola flower midge, *Contarinia brassicola*, is a newly discovered insect pest of canola with relatively unknown pest potential. Larvae feed on developing flower buds, which prevents the flowers from opening and forming pods. Though widespread across the Prairies, canola flower midge population density is variable across the species range and damage is discreet and can be easily overlooked, except under outbreak conditions.

Previous work identified the female-produced canola flower midge pheromone and optimized the pheromone blend and dose to create a potent male attractant. This project refined the pheromone trapping system and evaluated the relationship between adult midges captured in pheromone-baited traps and damage in the field. It also explored weather conditions that might influence populations, midges' ability to infest canola at different growth stages, and alternative hosts.

Researchers carried out field studies in commercial canola production fields in central Alberta in 2021 and 2022. Experiments took place over the growing season. Of note, 2021 was an extreme drought and many fields had poor yields.

In the lab, researchers monitored midge to determine if males and females emerge in equal numbers and their lifespan.

Results

Researchers identified the pheromone-baited Jackson trap, deployed 50 cm above the soil surface along the crop edge, as the optimal combination of trap type and position to effectively monitor the canola flower midge. Male midge activity peaked twice during the day – morning and late-afternoon – which could be used to increase the precision of monitoring strategies or potential treatment applications.

Over the two years of this study, the number of male midges captured on pheromone-baited traps was not predictive of damage in the field. Average air temperature and weekly cumulative rainfall, at the scale measured in this study, did not have an impact on the number of midges captured in either year.

Midge larvae were identified from pods in commercial canola fields and experiments also confirmed canola flower midge larvae can develop in pods, but no alternative host plants were identified.

Although individual midge are short-lived, the midge emergence is prolonged over the summer when canola plants are susceptible to infestations. Researchers urge continued monitoring and vigilance for this species as its full pest potential is yet to be determined.

↑ Researchers used pheromone-baited Jackson traps to monitor canola flower midge.

Photo credit: Boyd Mori

↑ Canola flower midge damage to canola flowers. Midge larvae are also present.

Photo credit: Shelley Barkley

Biocontrol option for cabbage seedpod weevil

KEY RESULT:

Parasitoid wasp *T. perfectus* demonstrated high levels of parasitism of cabbage seedpod weevil in Ontario and Quebec with minimum spill over into non-cultivated habitats. The insect did not appear to pose a major risk in the Prairies, suggesting it could work as a biological control option in Western Canada.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Feasibility of using *Trichomalus perfectus* for biological control of cabbage seedpod weevil in the Prairies," Héctor Cárcamo, Agriculture and Agri-Food Canada Lethbridge

FUNDING: AgriScience Program (Canola Cluster) under the Canadian Agricultural Partnership

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

Cabbage seedpod weevil
Photo credit: Dan Johnson

Cabbage seedpod weevil (CSPW) is a serious pest of canola and related brassicaceous crops in North America and Europe. Since being found in southern Alberta, the weevil continues to spread north and east into the canola growing regions of Western Canada (including Manitoba), with no practical alternatives to insecticides.

However, a parasitoid wasp, *Trichomalus perfectus*, which parasitizes CSPW in Europe and exists in Eastern Canada, has potential to provide a biological control solution. Where it occurs at high populations in Quebec, the parasitoid wasp appears to be managing CSPW to levels that no longer require insecticide spraying.

Since non-target weevils could also act as hosts for this parasitoid, this comprehensive environmental and economic study was required before potential relocation into Western Canada. Surveys of the pest in Quebec showed that the parasitoid is keeping the weevil at low numbers so extensive surveys and ecological studies in Western Canada were conducted. Key outcomes pointing to one overall conclusion were generated through this collaborative project.

Results

The field assessment of the environmental impact of *T. perfectus* on non-target weevils in Quebec determined that *T. perfectus* is the dominant parasitoid in canola attacking CSPW and that it does not "spill" in a major way onto non-cultivated habitats.

Data (2018-22) from monitoring the spread of *T. perfectus* in southwestern Ontario showed that *T. perfectus* has become the dominant parasitoid of another weevil (*C. obstrictus)* in southwestern Ontario in canola, having displaced but not eradicated several native parasitoid species that previously used CSPW as a host.

Results from surveys of canola and other Brassicaceae plants in Ontario (2018-22) monitoring non-target effects of *T. perfectus* confirmed that the parasitoid established in the Ottawa area and is using the native *C. neglectus* seed-feeding weevil as hosts.

The identification and initial risk assessment of potential non-target weevils and parasitoids in the Prairies concluded that the only native weevil species identified in the Prairies is *C. neglectus*, which is abundant in the west and has been considered a potential pest of canola. Also, based on the study in Quebec and Ontario, this species is rarely attacked by the parasitoid *T. perfectus*.

CLIMEX models are being updated for CSPW and will be developed and validated for canola. Once these models are published, they can be used to create CSPW parasitoids models to help predict the impact of climate change on this community.

Evaluating the landscape influence on the CSPW infestation and abundance and the parasitism of *T. perfectus* in Quebec showed key habitat features that can facilitate establishment of the parasitoid (such as landscape diversity, crop edge density, hay/pastures and soybean crops). Preliminary analysis from a similar study conducted in southern Alberta suggested that landscape features may not have a major influence on the distribution of the CSPW or the parasitoids in the region.

Therefore, it appears that *T. perfectus* does not pose a major risk to the diversity of weevils in Western Canada and is unlikely to have major negative effects on native parasitoids. Plus, optimal landscape composition learnings can be used to enhance the success of this biological control option.

Researchers measure the effect of non-crop spaces

KEY RESULT:

Keeping non-crop beneficial insect reservoirs – such as grass margins, treed areas, wetlands, and shelterbelts – near fields can help canola producers contribute to sustainability objectives while having a minimal (and possibly positive) impact on profitability and productivity.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Surveillance Networks for Beneficial Insects II: quantifying the canola yield effect of wetlands, shelterbelts and other insect reservoir habitats," Paul Galpern, University of Calgary

FUNDING: Alberta Canola, Manitoba Canola Growers

PUBLISHED ARTICLES: Nguyen L et al.. 2022. "Medium-resolution multispectral satellite imagery in precision agriculture: mapping precision canola (Brassica napus L.) yield using Sentinel-2 time series." Precision Agriculture 23:1051–71.

Nguyen LH et al.. 2022. "Effects of landscape complexity on crop productivity: an assessment from space." Agriculture Ecosystems & Environment 328:107849.

Robinson S et al.. 2022. "Livin' on the edge: precision yield data shows evidence of ecosystem services from field boundaries." Agriculture Ecosystems & Environment 333:107956.

The second phase of the Beneficial Insects Surveillance Network (2019 to 2023) demonstrates that existing non-crop spaces near fields, such as field margins, treed areas, wetlands, and shelterbelts provide measurable benefits to canola producers in Western Canada.

Researchers collected and analyzed yield data from 1,075 field-years in central Alberta. This included field sampling in 20 unique canola fields, precision maps for 94 field-years of canola yield data (298 from all crops) and satellite images for 757 field-years of canola.

Study 1:
Can beneficial insects move into canola fields?

This study investigated whether natural enemies and the services they provide (i.e., pest regulation) were spilling over from non-crop spaces into canola fields. To test this, researchers placed pitfall traps and sentinel prey in canola fields at various distances from non-crop spaces. They found that natural enemies, the amount of egg predation, and caterpillar predation was higher nearer to non-crop spaces. There was no evidence that non-crop spaces were a source of spillover of important canola pest insects.

Study 2:
Can non-crop spaces improve canola yield?

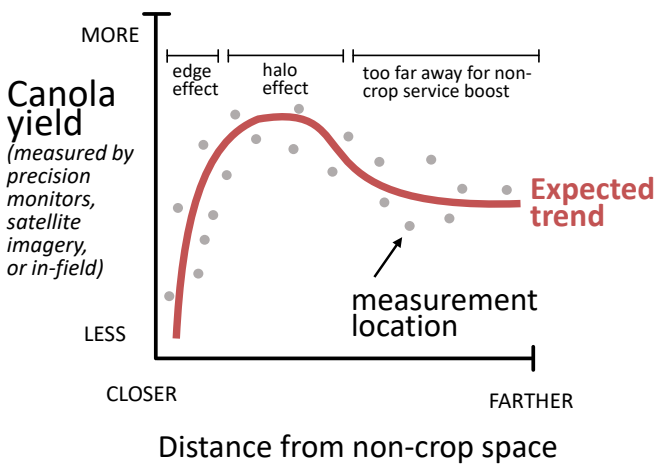
The second study investigated whether non-crop spaces create a yield halo in the surrounding crop. Researchers measured canola yield near non-crop spaces to understand if, and by how much, these features were affecting canola production.

Yield maps from producer data, precision sources and satellite images showed a halo of higher yield, typically between 25m and 175m from non-crop spaces, in the average canola field. While this pattern represents an average trend across more than 1,000 fields, researchers note that it will be challenging to predict whether a producer will see a yield boost in a particular field or year. Also, large variation in the size yield haloes may be due to differences in types of non-crop spaces, management, and local environmental conditions. Researchers conclude that boosts to yield, if they exist, will be small, but they could be large enough to offset the drop in yield commonly seen among plants growing at field edges.

Finally, using a field experiment, conducted over three years, researchers showed that pollinators living in non-crop spaces are driving yield boosts observed 25m from wetlands.

In summary, results suggest that retaining existing non-crop spaces comes at little or no cost to production, and under some circumstances may benefit overall crop yield. Non-crop spaces can offer an insurance policy against pest outbreaks (e.g., as natural enemy reservoirs) or alternatively serve as biodiversity hotspots and carbon stores. Conserving habitat near fields could therefore help canola producers contribute to sustainability objectives in the agricultural sector and do so while minimizing impacts on profitability and productivity.

What Evidence of a Yield Halo Effect Would Look Like



More plants equal more consistent yield

KEY RESULT:

In general, seeding rates of 120 and 180 seeds per square metre, which achieve 56 and 80 plants per square metre (five to eight plants per square foot), respectively, provided higher and more stable canola yield relative to the seeding rate of 60 seeds per square metre.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Manipulating agronomic factors for optimum canola harvest timing, productivity and crop sequencing," Brian Beres, Agriculture and Agri-Food Canada Lethbridge

FUNDING: AgriScience Program (Canola Cluster) under the Canadian Agricultural Partnership

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

A low seeding rate may save on seed costs, but will result in lower overall yields and greater yield variability.

This study explored the interactions between seeding rate, harvest method and timing, and cultivar maturity. Researchers wanted to see how crop density, harvest management system and cultivar influenced harvest timing recommendations.

Seeding rates were 60, 120 and 180 seeds per metre square (approximately 6, 12 and 18 seeds per square foot). Harvest methods were swathing at 60 per cent seed colour change, swathing at 90 per cent seed colour change, straight cutting at 10 per cent seed moisture and straight cutting at five per cent seed moisture. Cultivars were late-maturing L255PC and early-maturing L233P. Both had pod shatter resistance.

Trial sites were Lethbridge and Lacombe in Alberta, Indian Head in Saskatchewan and Brandon in Manitoba over four growing seasons – 2018, 2019, 2021 and 2022.

Results

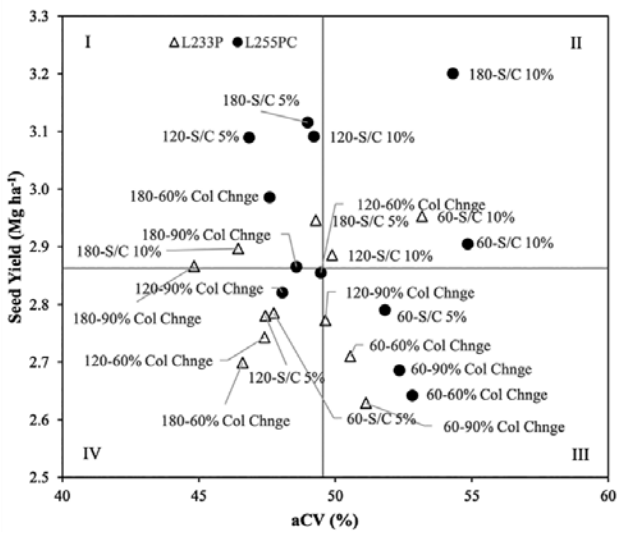
In general, seeding rates of 120 and 180 seeds per square metre, which achieve 56 and 80 plants per square metre (five to eight plants per square foot), respectively, provided higher and more stable canola yield relative to the seeding rate of 60 seeds per square metre.

A higher seeding rate was needed at site-years that experienced moderate to severe abiotic stress, while the lowest seeding rate maintained high yields when that stress was absent.

Critical yield components for canola are seed weight on the primary branches, overall plant density, and pod count on secondary branches. This would explain why the lowest seeding rate could still provide superior yields at some site-years as it caused positive compensatory responses in canopy architecture, especially pods on secondary branches. However, the lowest seeding rate also produced the fewest plants (35 plants per square metre), which would explain the highly variable nature of yield and yield stability.

The late-maturing canola hybrid (L255PC) seeded at 120 and 180 seed per square meter and managed with straight-cutting displayed a higher and more stable yield relative to other treatment combinations. (See the top left quandrant in Figure 1).

The seeding rate of 180 seeds per square metre coupled with straight-cutting also provided higher than average seed yield and yield stability for the early-maturing hybrid (L233P).



↑ This graph shows average seed yield for all treatment combinations from 2018-22. Labels indicate seeding rates (60, 120 and 180 seeds per square metre) and harvest methods (Ex. 60% Col Chnge is 60 per cent seed colour change; S/C 5% is straight cutting at five per cent moisture.) L255PC, black circles, is late maturing. L233P, triangles, is early. Grouping categories: Group I: high average yield, low variability; Group II: high average, high variability; Group III: Low average, high variability; Group IV: Low average, low variability.

Straight-cutting at 10 per cent seed moisture is superior for grain yield. If timing is delayed to five per cent seed moisture, straight-cutting yielded the same as swathing at 90 per cent seed colour change.

Both swathing treatments produced similar yields, which was likely facilitated by the use of pod shatter reduction trait hybrids.

Combining operations led to an average of 10 per cent higher seed losses with straight-cutting than with swathing. However, total seed loss with swathing was 13 per cent greater than straight-cutting because swathing has more opportunity for loss before the combining operation. Our results support Haile et al. (2014) who reported that the elimination of swathing and switching to straight-cutting did not result in a seed loss increase.

Manual versus auto adjust to reduce combine loss

KEY RESULT:

Both manual adjustments and auto-adjusting features can reduce harvest losses in canola. Auto-adjusting can respond to changing environmental conditions, but should still be calibrated and ground-truthed regularly to reduce losses and optimize yield.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Quantifying combine auto-adjusting capabilities in canola," Charley Sprenger, Prairie Agricultural Machinery Institute

FUNDING: SaskCanola, Western Grains Research Foundation

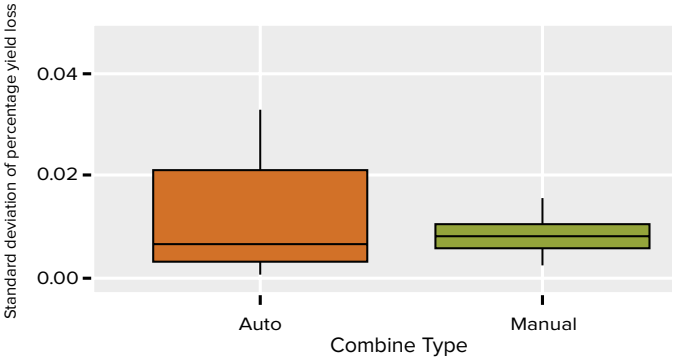
PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

Researchers examined the impact of changing weather and crop conditions during a typical harvest day on combine losses and the performance potential of combines with auto-adjusting settings.

This research builds on a 2019 survey of canola losses in Western Canada, which identified harvest factors that impact canola harvest losses. It reported that weather conditions are a key factor influencing combine losses, and that combines should be set based on these conditions. It also noted the importance for producers to reassess their combine losses as conditions change both throughout the day and harvest season.

In the current study, researchers measured combine losses from straight cut (14 fields) and swathed canola (eight fields) for 22 combines from 13 producers throughout Saskatchewan and Manitoba. Combines included 14 different models and four different makes: Case IH, Claas, John Deere and New Holland.

Half of the combines had auto-adjusting capabilities and half required manual adjustment. Researchers used drop pans to take samples (three repetitions) at three times throughout the day. They did not provide this data to farmers during the testing. Weather conditions at the time of testing ranged between 6-27°C and the relative humidity ranged between 20-80 per cent.



↑ Box and whisker graph for standard deviation of % yield loss which shows that while auto-adjusting combines had a slightly (but not significantly) lower average variation in losses, they also had a much larger range in variation than the manually-adjusted combines.

Results

Key results from this experiment included:

1. The average combine losses ranged from 0.1 to 10.6 bu./ac., or 0.2 to 29.4 per cent of total yield.
2. As average daily temperatures increased, the variation in yield losses increased significantly. However, the variation in temperature and humidity throughout the day (from three different sample times), did not effect yield loss variation.
3. There was no significant difference between swathed and straight cut operations or different ground speeds tested.
4. Calendar date (ranging from September 9 to October 10) did not have a significant impact on losses.
5. Interestingly, while there was no significant difference between losses in auto-adjusting and manual-adjusting capabilities, there was much less variation in the losses for the manual adjusting combine types than the auto-adjusting types.

This indicates that checking for losses is important and auto-adjusting combines still need calibration and monitoring to ensure that they are properly responding to changing conditions. Overall, combine operators need to know what is happening to make informed management decisions and any method of checking for losses is better than not checking at all.

Variable	Minimum	Maximum
Seeding Date	24-May-22	8-June-22
Canola Seed Rate, lb/ac (kg/ha)	3.8 (4.3)	5.2 (5.8)
Row Spacing, in (cm)	9.0 (22.9)	12.0 (30.5)
Spray or Swath Date	18-Aug-22	16-Sep-22
Cut Width, ft (m)	32.0 (9.8)	49.0 (12.8)
Harvest Date	9-Sep-22	10-Oct-22
Yield, bu/ac (MT/ha)	20.0 (1.4)	65.0 (4.4)
Moisture Content, %	5	11
Calculated Loss, bu/ac (kg/ha)	0.1 (6.7)	10.6 (712.9)
Percent of Total Yield Loss, %	0.2	29.4

↑ General data summary of 22 test combines.

New clues to sclerotinia stem rot resistance

KEY RESULT:

Researchers discover Resistance: Avirulence protein interactions between the *S. sclerotiorum* pathogen and canola plants. These interactions open the door to effector-guided breeding where one can select or engineer lines that no longer produce the corresponding necrosis-inducing protein receptor and are, therefore, immune to its effect.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Resistance to *Sclerotinia sclerotiorum* effectors in canola,"
Dwayne Hegedus, Agriculture and Agri-Food Canada Saskatoon

FUNDING: AgriScience Program (Canola Cluster) under the Canadian Agricultural Partnership

PUBLISHED ARTICLES: Seifbarghi S, Borhan MH, Wei Y, Ma L, Coutu C, Bekkaoui D and Hegedus DD (2020) Receptor-like kinases BAK1 and SOBIR1 are required for necrotizing activity of a novel group of Sclerotinia sclerotiorum necrosis-inducing effectors. Front. Plant Sci. 11: 1021. doi.org/10.3389/fpls.2020.01021. (Pub ID 48724).

Sclerotinia sclerotiorum, the fungal pathogen that causes sclerotinia stem rot in canola, produces substances that cause lesions on the plant or compromise the ability of the plant to defend itself against attack by the fungus.

Researchers aimed to dissect the processes the pathogen uses to cause stem rot disease in canola. This would give them a much better understanding of the pathogen and its relationship with the host plant, and also highly specific methods to identify *Brassica napus* (canola) lines that are resistant to the most important aspects of the disease. The goal is to advance the development of *B. napus* varieties with better tolerance to this difficult-to-control disease.

Objectives were to (1) examine the importance and mechanisms of action of *S. sclerotiorum* necrosis-inducing proteins, (2) identify effectors (secreted proteins and RNA) that *S. sclerotiorum* emits to suppress host defenses or alter host interactions, and (3) exploit these effectors/necrosis-inducing proteins to identify resistant *B. napus* cultivars.

Results

Using previous work to sequence the *S. sclerotiorum* genome, researchers identified 100 candidate genes encoding potential necrosis proteins secreted from *S. sclerotiorum*.

They then tested these candidate necrosis-inducing proteins on plants. Six of the candidates tested caused necrotic symptoms, thus validating the informatics analysis pipeline. Of the six new *S. sclerotiorum* necrosis-inducing proteins, five require interaction with a host cell surface receptor. This is similar to classic Resistance:Avirulence protein interactions, like canola has with the blackleg pathogen, for example, however, in this case the interaction of the necrosis-inducing proteins with the host receptor initiates a hyper-sensitive response that leads to necrosis.

With most other pathogens (viruses, plasmodia and biotrophs that cause diseases, such as clubroot and blackleg) the Resistance:Avirulence protein interactions would lead to resistance; however, with *S. sclerotiorum* the dead tissue provides nutrients to fuel the infection.

The principal investigator says this was an unexpected and exciting discovery. It opens the door to effector-guided breeding where one can select or engineer lines that no longer produce the corresponding necrosis-inducing protein receptor and are, therefore, immune to its effect. To this end, the researchers have now screened a diverse collection of *B. napus* accessions from AAFC and the Canadian Plant Gene Resources with a necrosis protein found in common in *S. sclerotiourum* and other canola pathogens. Accessions with reactions ranging from completely resistant to highly susceptible were identified. The genes and mechanisms underlying this phenomenon are under investigation.

Most *B. napus* (canola) lines are sensitive to *S. sclerotiorum* necrosis protein genes, so they show symptoms of disease after infection (left and centre). However, some lines (right) do not produce the corresponding necrosis-inducing protein receptor. These lines are, therefore, immune to its effect. This could be a pathway to sclerotinia resistance in canola.

Trait makes blackleg resistance more durable

KEY RESULT:

Researchers identified causative genes that provide adult plant resistance (APR) to blackleg. This quantitative trait provides more durable canola resistance against the blackleg pathogen *Leptosphaeria maculans,* particularly when combined with major race specific (qualitative) resistance genes.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Overcoming blackleg disease in canola through establishment of quantitative resistance," Hossein Borhan, Agriculture and Agri-Food Canada Saskatoon

FUNDING: SaskCanola

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

Adult plant resistance (APR) to blackleg is a quantitative trait controlled by multiple genes. Researchers have found APR genes that could increase the durability of canola resistance to blackleg pathogen *Leptosphaeria maculans.*

Researchers took advantage of the well-defined canola population that was created by crossing the *B. napus* cultivar Castle, which has APR to blackleg, and the *B. napus* cultivar Topas, which does not, to identify the quantitative trait locus (QTL) for blackleg resistance (BL-QTL). Unlike qualitative traits that are often controlled by single genes, QTLs such as crop yield are controlled by multiple genes.

Researchers developed a growth chamber APR screening method and tested the progenies of the Castle-Topas population for APR against blackleg.

Internal stem infection
Photo Credit: Justine Cornelsen

Blackleg leaf lesion

They identified a quantitative disease resistance trait and a major QTL locus candidate, named BL-QTL1 located on chromosome A08. This was the only QTL identified under the growth chamber APR assay and was also the most significant QTL under field conditions.

Building on previous APR genotyping efforts, the objectives of this four-year project were to identify and accurately map QTLs controlling APR, clone the QTLs, develop and test APR markers and understand the function and downstream pathways of APR.

Under growth chamber conditions, accurate mapping of QTLs combined with RNA-sequencing of individual progenies during response to *L. maculans* infection resulted in identification of several QTLs. Combining the mapping and gene expression data helped to identify several candidate QTLs with a high probability of controlling the APR response.

Researchers also evaluated BL-QTL performance under field conditions, and tested 53 spring type *B. napus* lines with a potentially functional BL-QTL1 trait in a blackleg field nursery in Alberta. Tests comparing 25 plants for each line in randomized replicated blocks. *B. napus* Castle and Westar, with and without APR respectively, were the controls.

At the end of growing season, researchers scored stem lesions on a 0 to 5 scale. Eleven lines showed APR to the same level or better than Castle, while in 18 lines the size of stem lesions was equal to or less than 60 per cent of the lesion size recorded for Westar.

As a result of the project, the discovery of quantitative resistance QTLs against blackleg, including the significant *Bl-QTL*1, is an important first step in understanding the molecular mechanism of QTL resistance. Canola breeders could use marker assisted selection to choose lines with this trait.

Going forward researchers will continue to investigate how to successfully apply the outcome of this research in designing canola cultivars with durable resistance to blackleg.

Gene editing turns off S genes to improve CR

KEY RESULT:

Researchers use a precise CRISPR/Cas9 based genome editing tool to confer clubroot resistance (CR) by introducing site-specific mutations to disrupt, or inactivate, susceptibility (S) genes.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Establishing transgene-free CRISPR/Cas9 based genome editing platform to improve canola resistance against clubroot disease," Wei Xiao, University of Saskatchewan

FUNDING: SaskCanola, Saskatchewan's Agriculture Development Fund

PUBLICATION: Read the full report in the Research section at saskcanola.com.

Clubroot disease significantly affects canola seed quality by reducing oil content and seed weight. The most effective solution to control this disease today is growing clubroot-resistant (CR) cultivars in appropriate rotations. However, single, race-specific, dominant resistance (R) genes cannot provide durable resistance and are easily broken down with a shift in the pathogen population.

In a three-year project, researchers investigated a new alternative strategy based on susceptibility (S) genes that have the potential to be durable in the field. Different from conventional breeding, disease resistance can be easily conferred by introducing site-specific mutations to disrupt, or inactivate, S genes using a precise CRISPR/Cas9 based genome editing tool. Inactivation of S genes can result in enhanced resistance to clubroot. CRISPR is more accurate, faster, simpler and cheaper than earlier gene editing methods. It can be used to add, delete or replace DNA sequences, and it can be used to turn a gene on or off.

The objectives for this project were to establish a CRISPR/Cas9-based genome-editing platform to support canola breeding programs against clubroot disease, to identify novel clubroot resistance genes and to create novel resistance allelic variants in elite canola germplasm.

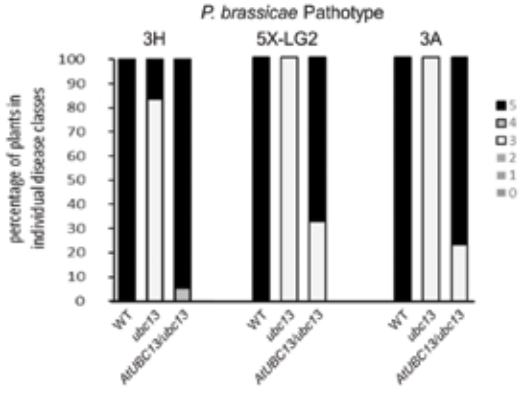


Figure 1. Canola lines with two S genes turned off have lower disease severity
This graph shows disease severity index (0-5 scale) for the arabidopsis ubc13a ubc13b (ubc13) double mutant with both S genes turned off (middle bars). The other two are the corresponding wild type Col-0 line (WT) control and the AtUBC13A-transformed ubc13 mutant line. The double mutant shows improved resistance to clubroot pathotypes 3H, 5X-LG2 and 3A.

Results

Researchers first developed an S gene strategy to improve canola clubroot resistance. They identified novel S candidate genes from the model plant *Arabidopsis thaliana* and investigated the genes' roles and function in clubroot susceptibility.

Researchers then designed CRISPR/Cas9 constructs targeting these S genes and then transformed canola plants using an agrobacterium-mediated canola transformation platform. Selected gene-edited mutant plants were assessed with clubroot disease assays to confirm their conferred clubroot resistance. The results showed that several lines significantly reduced disease severity compared to control plants. SWEET11 and 12, two well-known gene groups belonging to the sucrose transporter gene family, were also targeted for gene editing, with several lines displaying reduced disease severity to clubroot infection.

As a result of the project, researchers successfully developed and demonstrated an S gene based strategy to improve durable clubroot resistance, and established an in-house CRISPR/Cas9 based genome editing platform to accelerate gene discovery, functional characterization and agronomy trait improvement in *B. napus*. The project identified and functionally characterized two novel S genes in arabidopsis, and edited an additional 22 *B. napus S* genes through the CRISPR/Cas9 platform that will be available to improve clubroot resistance by either providing molecular markers or resistant germplasm.

Overall, this research has provided an optimized CRISPR/Cas9 tool for faster, more accurate canola breeding, to enhance clubroot resistance in canola, and to open the door to improvements in many other traits important to canola growers. Eventually, the knowledge, germplasm, molecular markers and CRISPR/Cas9 genome editing tools generated from this project will accelerate breeding cycles, which will reduce the investment costs of breeding new cultivars and benefit the Canadian canola industry.

RNAi spray for sclerotinia needs better formulation

KEY RESULT:

Species-specific RNA sprays, when applied as a topical formulation, can suppress sclerotinia infection in canola. Field tests in 2022, hampered by heavy rain and dsRNA applications without a surfactant, did not show strong results for the treatments.

PROJECT TITLE, PRINCIPAL INVESTIGATOR: "Protection of canola from pathogenic fungi using Ribonucleic acid (RNA) interference technologies," Steve Whyard, University of Manitoba

FUNDING: AgriScience Program (Canola Cluster) under the Canadian Agricultural Partnership

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

Ribonucleic acid (RNA) interference can reduce a targeted gene's expression through the application of double-stranded RNA (dsRNA), a new sector of spray treatments. A major benefit is that dsRNAs can target specific pests species, and not affect beneficial or non-target species. For this study, researchers identified dsRNA molecules that can inhibit sclerotinia growth, and tested early formulations with one site-year of field trials.

This study completed four objectives:

- Identify and nominate of sclerotinia bioactive dsRNA molecules.
- Synthesize dsRNAs and screen for fungicidal activity against sclerotinia and non-target effects.
- Develop and test topical formulations for dsRNA adhesion to leaves and durability under different environmental conditions. These were randomized complete block design field trials.
- Assess persistence of dsRNAs in the soil.

Canola infected with sclerotinia stem rot.

For the field trials, researchers seeded and fertilized a commercial canola cultivar on June 9, 2022 at a facility near Minto, Manitoba. They applied two test applications of dsRNA – July 15 at the early flowering and July 22 at late flowering. They also oversprayed the trial with disease inoculum on July 16, 21 and 25 and misted the trial with water regularly to promote disease development. Disease levels were high throughout the trial, with sclerotinia being the main disease present.

Results

Of the 100 dsRNA molecules tested on leaves at a dose of 200 nanograms, 63 showed a reduction in lesion size when applied with the adjuvant Silwet-77. The best target, Sclero-1703, showed an 85 per cent reduction in lesion size.

Formulation testing showed that spreader molecules that include Stilwet are compatible with top performing dsRNAs. Penetrant oil based molecules are not compatible, and nanoparticles are compatible but do not result in improved RNAi-mediated transcript knockdown or improved protection against fungal lesion size.

Field trial results did not show strong performance of dsRNA applications. The night following the first dsRNA application, the field sustained heavy rains, lasting for several days, which most likely led to loss of the dsRNA from the plants, as no sticking agent or penetrant was provided in the formulation. The disease severity and incidence on canola plants treated with either of the negative control treatments (Silwet or GS1+Silwet) showed no significant difference to the treatment with the sclerotinia-specific dsRNA (1703+Silwet), regardless of whether the plants were treated once or twice.

Overall, the treatment with Sclero-1703 applied at the first spraying showed the lowest incidence and severity of disease. However, the differences between treatments were slight. There were no significant differences in yield between treatments.

Consequently, researchers observed no significant impacts of the dsRNA on disease severity, incidence or seed yield. The only noteworthy and possibly favourable result was that the highest seed yield, albeit only marginally higher than the controls, was seen in plants that had two Sclero-dsRNA sprayings. For future field trials, adjuvants that improve adhesion onto or penetration into the leaves will be needed.

The persistence test, done in the lab on five Manitoba soils, showed that dsRNAs were not detectable after six hours mixed in the soil. Further tests are planned to evaluate if the dsRNA is detectable at earlier times, to determine the half-life of the dsRNA with the different soil types.

Expansive study recommends steps to boost NUE, canola yield

KEY RESULT:

Recommendations from this large study include apply 130-147 lb./ac. of nitrogen in the Black soil zone and 76-89 lb./ac. in the Brown soil zone. This is a balance between canola yield, nitrogen use efficiency (NUE) and maximum economic returns.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Improving nitrogen use efficiency and soil sustainability in canola production across Canada," Bao-Luo Ma, Agriculture and Agri-Food Canada Ottawa

FUNDING: AgriScience Program (Canola Cluster) under the Canadian Agricultural Partnership

PUBLISHED ARTICLES: Wen, G., Ma, B.L., Luce, M.S., Liu, K., Mooleki, P.S., Crittenden, S., Gulden, R., Semach, G., Tiege, P., Lokuruge, P., 2023. Optimizing nitrogen fertilization for hybrid canola (Brassica napus L.) production across Canada. Field Crops Research. 302, 109048.

Wu, W., Ma, B.L., 2022. Understanding the trade–off between lodging resistance and seed yield, and developing some non–destructive methods for predicting crop lodging risk in canola production. Field Crops Research. 288, 108691.

Researchers investigated the critical roles of root architecture in nutrient absorption, root anchorage strength (involved in lodging resistance) and genotypic variations. They identified and employed soil and plant diagnostic tools to improve NUE and yields of canola and to promote soil and environmental sustainability.

Field sites were at Ottawa in Ontario, Carman and Brandon in Manitoba, Scott, Melfort and Swift Current in Saskatchewan, and Olds and Beaverlodge in Alberta.

Results

Based on field data, researchers found that when seed yield was greater than 1.3 tonnes per hectare (t/ha) and aboveground biomass was greater than 4.0 t/ha, it was negatively correlated with safety factor of the stem and the root. In other words, higher yields reduce stem and root safety – which increases the lodging risk.

Under low-yielding conditions, split nitrogen treatments did not always show advantages over the equivalent preplant-only nitrogen treatments in terms of lodging resistance and seed yield. Whereas higher seed yields were generally attained under the split nitrogen application in all favourable environments.

Root electrical measurements and NDVI mapping can be used to predict lodging susceptibility, due to their low cost and non-destructive properties.

Using the Gini Importance Index, weather conditions (heat and drought) are identified as the most limiting factor for canola yield, followed by soil texture, and nitrogen management.

Researchers found they could more accurately predict canola yield with the random forest regression (RF) model. Applied at the four- to six-leaf canola stage, this model, which includes all available soil, weather and plant growth features, had the best performance and explained 85 per cent of the variability in canola yield from the test dataset. In contrast, the NDVI-based single-feature random forest model showed a much higher relative error. The model based on SPAD chlorophyll readings also underperforms.

Heat-stress days and rainfall distribution during the four-week period bracketing flowering largely determined the canola responses to nitrogen fertilization.

Results suggest that drought and heat stress can be managed through breeding for superior stress-tolerant canola genotypes and implementing agronomic solutions to mitigate stress, protect yield potential, and reduce the greenhouse gas emissions from fertilizer use.

Researchers recommend applying 145-165 kg/ha (130-147 lb./ac.) of nitrogen in the Black soil zone, 85-100 kg/ha (76-89 lb./ac.) in the low-yielding Brown soil zone, and 140 kg/ha for eastern Canada, preferably as a split-application strategy. This rate considers the trade-off of canola yield and NUE with maximum economic returns.

Researchers found differences in nitrogen mineralization potential among sites, which affected canola response to nitrogen fertilization. Preliminary results also suggest that nitrogen fertilization may have a greater impact than crop rotation on potential nitrogen mineralization in the short term, and hence affect soil nitrogen supply capacity.

Preliminary data analyses led to the identification of temporal shifts in the functional capacity of the soil microbiome within a growing season in response to the rate and timing of nitrogen fertilization. Over the four years, researchers found that crop rotations had a stronger impact than nitrogen fertilization rates in shaping the composition of the soil microbiome and altering the potential nitrogen cycling processes mediated by the soil microbiome.

Researchers will use information from this study to prepare site-specific nitrogen management guides for the main and potential canola production regions. These guides will take into account climate conditions, soil and cropping systems specific to each ecosite.

NUE improving more slowly than yield

KEY RESULT:

Total plant nitrogen uptake (i.e. in the leaves, stems, straw and seed) of the old rapeseed and canola varieties was actually just as good as modern hybrids, they just don't have as much seed to pack the nitrogen into as the high-yielding hybrids. Modern canola hybrids do have superior ability to utilize ammonium fertilizer.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Making of a more sustainable canola: using genetic diversity to improve nitrogen use efficiency," Sally Vail, Agriculture and Agri-Food Canada Saskatoon

FUNDING: AgriScience Program (Canola Cluster) under the Canadian Agricultural Partnership

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

Researchers are using a historic series of rapeseed and canola varieties, along with the new Nested Association Mapping resource, to compare how a diverse collection of *B. napus* lines perform under various nitrogen-related circumstances. By comparing the genetics of lines that perform well and lines that perform poorly, researchers can identify traits that improve nitrogen use efficiency (NUE) in canola.

This project included an extensive field study that focused on comparing performance and nitrogen (N) uptake for 35 *B. napus* lines developed over a 70-year period. Canola growth parameters were contrasted at low N rates (60 kg/ha of N) or high N rates (120 kg N/ha) over two years – 2019 and 2020 – and two field sites in Saskatchewan.

Researchers calculated NUE using current popular equations, and added nitrogen harvest index (NHI). (See the table. →)

Results

Generally NUpE, NUtE, and NUEyld could not detect differences in canola grown in each year (2019 or 2020), where NUEcr and NHI could.

All five metrics could detect differences in N treatment, with the greater NUE values seen with the low rate treatment. Low N treatments showed higher NUE because NUE is a calculation of yield or "N in yield" divided by a measure of supplied N (soil, available, fertilizer, or in the shoot). With the low N, yield relative to N rate is often higher, giving a higher NUE. However, this low rate is insufficient for best yield or the highest level of profit. Understanding NUE differences under low vs. high N rates and between canola varieties or lines is fundamental for developing a strategy to improve NUE.

NUE is useful for comparing varieties across the same management regime or at one environment. When comparing diverse soils, N management practices or years (environments), the amount of available N, amount of water, and amount of growth have to be qualified.

When comparing varieties by decade, yield and "N in yield," results show an improvement for the most modern canola lines. This might be because of the introduction of high-yielding hybrid varieties. A gradual improvement for NUEyld and NUEcr can be observed, as their calculations are dependent to yield and N in yield. Interestingly, the NUpE almost remained same for the oldest and newest decade group (with slight ups and downs in middle), meaning no observed progress over time was reported for this trait.

Different ways to calculate nitrogen use efficiency

NUE Type	Equation	Description
NUEyld	Yield / N available (soil + fertilizer)	Yield-based nitrogen use efficiency (NUE) represents the yield produced per unit of available nitrogen (N) in the soil.
NUEcr	N in yield / N available (soil + fertilizer)	Crop-based NUE reflects how well a crop takes N from soil and places that N in yield.
NUpE	N in shoot at harvest / N available (soil + fertilizer)	Nitrogen uptake efficiency represents how well plants take up N form the soil and place it in shoots.
NUtE	Yield / N in shoot at maturity	Nitrogen utilization efficiency reflects how much yield is produced per shoot-N content.
NHI	N in yield / N in shoot	Nitrogen harvest index represents the N remobilization within the plant, moving it from shoots to seeds.

What to make of all these NUE metrics? Use NUtE and NHI to gauge performance of moving within-plant N into yield. Of these, NHI should be more useful if lines have diverse seed oil, carbohydrate and protein concentrations. Use NUpE to gauge performance of N uptake ability into the shoot, and in studies where plants are not grown to reproduction. NUEcr may be useful in studies that have a wide range of soil N availability and only access to seed yield samples, providing that researchers stay with one crop type and do not use this metric to assess a wide range of crop types (cereals, legumes, oil crops).

Another interesting discovery. Relative to older open-pollinated lines, modern canola hybrids appear to be collectively better able to utilize ammonium as their sole N source. Selection for yield in canola may have resulted in this change.

Quest to turn off secondary dormancy

KEY RESULT:

Secondary dormancy is like a deep sleep for seeds, extending their life in the soil and increasing their weedy nature. Canola tends to have strong secondary dormancy, which is why volunteer canola can often germinate years after harvest. The goal is to find the genes responsible, and breed them out or turn them off.

PROJECT TITLE, PRINCIPAL INVESTIGATORS:
"Weeding out secondary dormancy potential from volunteer canola," Sally Vail, Agriculture and Agri-Food Canada Saskatoon, and Rob Gulden, University of Manitoba

FUNDING: AgriScience Program (Canola Cluster) under the Canadian Agricultural Partnership

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

Volunteer canola is becoming an ever-increasing problem and a concern in rotational crops and in-crop across the Canadian Prairies. The underlying mechanism contributing to increased volunteers in weed seed banks is secondary dormancy. This is a heritable trait that could potentially be selected against in breeding programs using marker assisted selection. Molecular tools could also be useful in monitoring and studying the secondary dormancy potential of volunteer weed populations. Changes or shifts in the genes for dormancy potential could describe, quantify and facilitate understanding of volunteer canola populations across the Prairies.

Objective 1: Identify the genomic regions harbouring genes (Quantitative Trait Loci; QTL) controlling secondary dormancy potential in *Brassica napus* and identify plausible candidate genes underlying these regions and then test the predictive power of identified molecular markers to validate their discovery.

Objective 2: Examine diversity in *DOG1 ("delay of germination"),* a candidate gene for secondary dormancy. Researchers want to explore the diversity in *DOG1* across a diverse selection of *B. napus* lines and explore induction potential relative to *DOG1* expression.

Results

Objective 1. Researchers examined dozens for plants from diverse canola lines and found vastly different levels of secondary dormancy. The range was basically zero to 100 per cent. Using these field results along with pedigree, environment and several other seed quality data points, researchers used statistical analysis to identify factors to explain the secondary dormancy values. Environment and seed protein had moderate effects, as discovered earlier. A surprise in this analysis was that fibre values (acid detergent fibre and acid detergent lignin) had the greatest effects on secondary dormancy amongst all the other factors examined.

Researchers suspected that control of secondary dormancy was going to be multigenic and results so far support this. Preliminary results on the association with seed fibre are novel. A more lignified seed coat may be preventing radicle emergence from the seed, creating physical dormancy rather than solely a physiological factor in the embryo or radicle. This will be further explored.

Objective 2. Researchers examined the four *B. napus DOG1* genes (on N6, N9, N17 and N19 chromosomes), looking for genetic differences within the haplotypes. A haplotype is a larger area of DNA that includes genetic codes of a specific variant, or trait. In lines with contrasting secondary dormancy phenotypes, researchers found no clear differences in haplotypes between extreme high and low dormancy potential lines. When the haplotypes of a wide range of diverse lines were examined with respect to potential dormancy values, again they found no definitive patterns to suggest linkage blocks containing any one or combination of the *DOG1* genes are associated with differences in phenotype. The only patten is that most low dormancy lines possess a specific haplotype in one chromosome location; however many lines with mid to high dormancy potential also have the same genotype.

Researchers observed a range of structural variants (SVs) around *DOG1* genes, including insertions, deletions, duplications and inversions. Very few lines showed SV in regions directly flanking *DOG1* genes. When SV between lines with contrasting dormancy values were compared, no differences were evident.

Advances in genetic resources for breeding hairy canola

KEY RESULT:

This research on hairy canola (to deter flea beetle feeding) will provide canola breeders with *B. napus* lines that produce hairs, as well as genetic markers to allow this trait to be introduced into canola varieties.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Genetic resources for flea beetle resistance in canola," Dwayne Hegedus, Agriculture and Agri-Food Canada Saskatoon

FUNDING: AgriScience Program (Canola Cluster) under the Canadian Agricultural Partnership

PUBLISHED ARTICLES: Read the full report on the Canola Research Hub at canolaresearch.ca.

Plants possess a variety of biochemical and morphological defences aimed at deterring insects from feeding and oviposition (egg laying). One is having hairs (trichomes) as a physical defence against herbivore feeding and oviposition. Mature leaves of *Brassica villosa* (a species closely related to *B. oleracea*) have an extremely high density of hairs which results in insects – including flea beetles – avoiding the leaves. These hairs deter beetles by disrupting their normal feeding behaviour.

The trait was likely lost in the breeding development of our current canola varieties. Since flea beetles are the most economically damaging pest of canola and there are currently no canola varieties with any level of natural resistance to flea beetles, Hegedus' project addressed this gap. The current research provides canola breeders with *B. napus* lines that produce hairs, as well as genetic markers to allow this trait to be introduced into canola varieties. This work builds on previous work by researchers at Agriculture and Agri-Food Canada and the University of Saskatchewan who identified lines of *B. napus*, and the related *B. villosa* species, producing hairs on their leaves and stems.

To test these lines, self-sustaining striped and crucifer flea beetle colonies were established.

Results

Genetic breeding efforts allowed the research team to identify two hairy lines from which mapping populations were used for further breeding efforts. Assessing this population also led to a discovery of the location of a major gene contributing to hair formation. These and other genetic findings from this research (which can be used to breed this trait into future canola lines and potential varieties) will be published and made available to breeders for use.

In another effort, the research team worked on accessing the *B. villosa* hairy trait to resynthesize a hairy *B. napus* and was able to identify lines with other promising properties.

They were able to separate the vernalization requirement/late flowering and self-incompatibility associated with *B. villosa* from the hairy leaf trait. Leaf wax is also known to affect flea beetle feeding. Some lines have high hair density on the leaves and other parts of the plants including the stems, stamens and pods, but also exhibit high levels of leaf waxiness as per the *B. villosa* parent.

A chemical analysis of the wax revealed that wax from each of the two parents had different compositions. Future research would be needed to examine leaf wax compositions in hairy and non-hairy plants in the population as a second physical barrier against flea beetles. Leaf pigment content, which is also known to be involved in flea beetle resistance, was found to vary between lines, but was independent of hair abundance.

Examples of hair (trichome) abundance in lines derived from a *B. oleracea* (non-hairy) X *B. villosa* (hairy) cross.
Credit: Hegedus research team.

New projects launched in the past year will look into nitrogen-fixing bacteria, humic-acid-coated phosphorus, finding resistance to verticillium stripe, and capturing ancestral diversity for developing climate ready canola. Ongoing projects include research into biologicals for insect management, phenology-based weed control, and new techniques to breed for disease resistance and environmental stress tolerance. Canola growers contribute to these projects through their levy payments to SaskCanola, Alberta Canola and Manitoba Canola Growers. Many projects are also collaborations with other commodity groups and other Prairie-wide funders, including Western Grains Research Foundation.

New Projects

Plant establishment

SEEDING DATES AND RATES

Project: Demonstrating benefits of seeding date and rate on canola yield and quality
Principal investigator: Robin Lokken, Saskatchewan Conservation Learning Centre
Funding: SaskCanola
Purpose: To demonstrate how different seeding dates and rates can improve canola yield and quality; discuss and show methods to control flea beetles.

WATER

Project: Beneficial practices for soil and water quality, excess water management and drought resiliency in an undulating soil landscape in southwestern Manitoba
Principal Investigator: David Whetter, AgriEarth Consulting
Funding: Manitoba Canola Growers
Purpose: To better understand the performance and trade-offs associated with tile drainage in undulating landscapes of Manitoba, including an evaluation of costs and benefits.

Nutrient management

NITROGEN

Project: Demonstrating the efficacy of foliar-applied nitrogen fixing bacteria for canola
Principal investigator: Chris Holzapfel, Indian Head Agriculture Research Foundation
Funding: Agriculture Demonstration of Practices and Technologies
Purpose: To demonstrate the effects of commercially-available, foliar-applied nitrogen (N) fixing bacteria products on the yield and seed quality of canola grown under varying fertility levels and contrasting environments.

PHOSPHORUS

Project: Do we need deep banding of phosphorus in no-till systems in the Canadian Prairies?
Principal investigator: Maryse Bourgault, University of Saskatchewan
Funding: SaskCanola, Western Grains Research Foundation
Purpose: To determine if deep banding phosphorus (P) fertilizer improve yields compared with P applied at 5cm depth at the same rate, and if deep banding itself impact yields.

PHOSPHORUS

Project: Strategies to build sustainable P levels and optimize water use efficiencies on low P soil
Principal investigator: Gursahib Singh, Irrigation Crop Diversification Corporation
Funding: SaskCanola, SaskWheat
Purpose: To identify appropriate phosphorus (P) fertilization strategies on an irrigated field with low soil-available P; investigate if P fertilizer additions influence plant Zn uptake.

PHOSPHORUS

Project: Response of canola and flax to humic-acid-coated phosphorus fertilizer rates
Principal investigator: Gursahib Singh, Irrigation Crop Diversification Corporation
Funding: SaskCanola
Purpose: To test the assertion that humic acid reduces the fixation of available phosphorus in the soil, activates insoluble phosphorus, and increases soluble phosphorus or directly reacts with the phosphate fertilizer to promote phosphorus absorption by plants.

Integrated pest management

DISEASE

Project: The Prairie Crop Disease Monitoring Network: Fostering further network development
Principal investigator: Kelly Turkington
Funding: SaskCanola, Alberta Canola, Manitoba Canola Growers and others
Purpose: To formalize the Prairie Crop Disease Monitoring Network; refine survey protocols; refine the Quick Disease Reporter Tool; develop disease assessment tools and blackleg pathogen mapping.

BLACKLEG

Project: Monitoring changes in *Leptosphaeria maculans* races and blackleg impact on canola after the introduction of the new *R* genes *Rlm2*, *Rlm4* and *Rlm7*
Principal investigator: Gary Peng, AAFC Saskatoon
Funding: SaskCanola, Alberta Canola, Western Grains Research Foundation
Purpose: To update on pathogen race changes and assess the impact of newly introduced R genes. The project may also identify new virulent pathogen races, providing breeders and industry early warning.

CLUBROOT

Project: Understanding the role of the clubroot pathogen kinases in disease progress and resistance
Principal Investigator: Edel Pérez-López, Université Laval
Funding: Alberta Canola, SaskCanola, Manitoba Canola Growers
Purpose: To identify and characterize the role of clubroot pathogen kinases in disease progress and resistance.

CLUBROOT

Project: Evaluation of the root-associated fungus *Olpidium brassicae* and its interactions with *Plasmodiophora brassicae*
Principal investigator: Jennifer Town, AAFC Saskatoon
Funding: SaskCanola, Saskatchewan's Agriculture Development Fund, Western Grains Research Foundation
Purpose: To examine the relationship between *Olpidium brassicae* colonization and *Plasmodiophora brassicae* infection and disease severity; analyze *O. brassicae* distribution during canola production in Saskatchewan and Alberta.

FLEA BEETLES

Project: Cover crops for flea beetle management
Principal Investigator: Yvonne Lawley, University of Manitoba
Funding: Manitoba Canola Growers, Western Grains Research Foundation
Purpose: To evaluate the impact of fall rye and oat cover crops on flea beetles and their natural enemies in canola.

INSECTS AND CLIMATE

Project: Insect response to climate change and ag-inputs across the Prairies
Principal investigator: Meghan Vankosky, AAFC Saskatoon
Funding: SaskCanola, Alberta Canola, Manitoba Canola Growers and others
Purpose: To understand insect pest population dynamics and forecast populations; assess the current status of insecticide resistance in Western Canada; develop insect information resources.

KOCHIA

Project: Balancing economic, action, and seed production thresholds for glyphosate-resistant kochia in canola
Principal investigator: Charles Geddes, AAFC Lethbridge
Funding: SaskCanola, Western Grains Research Foundation
Purpose: To determine how canola planted at five versus 10 plants per square foot changes the economic, action and seed production thresholds to manage glyphosate-resistant kochia in canola.

VERTICILLIUM STRIPE

Project: Digging out the unknown: Finding the resistance against verticillium stripe in canola
Principal Investigator: Dilantha Fernando, University of Manitoba
Funding: Alberta Canola, SaskCanola, Manitoba Canola Growers, Western Grains Research Foundation
Purpose: To identify resistance genes and sources that work against *V. longisporum*, the pathogen that causes verticillium stripe.

Genetics

DISEASE

Project: Identifying novel genetic factors contributing to durable disease resistance in canola
Principal investigator: Isobel Parkin, AAFC Saskatoon
Funding: SaskCanola, Saskatchewan's Agriculture Development Fund, Western Grains Research Foundation
Purpose: To determine epi-alleles contributing to adaptation to Prairie conditions; assess the role of DNA methylation (epigenetics) in quantitative resistance to blackleg and clubroot in canola.

BLACKLEG

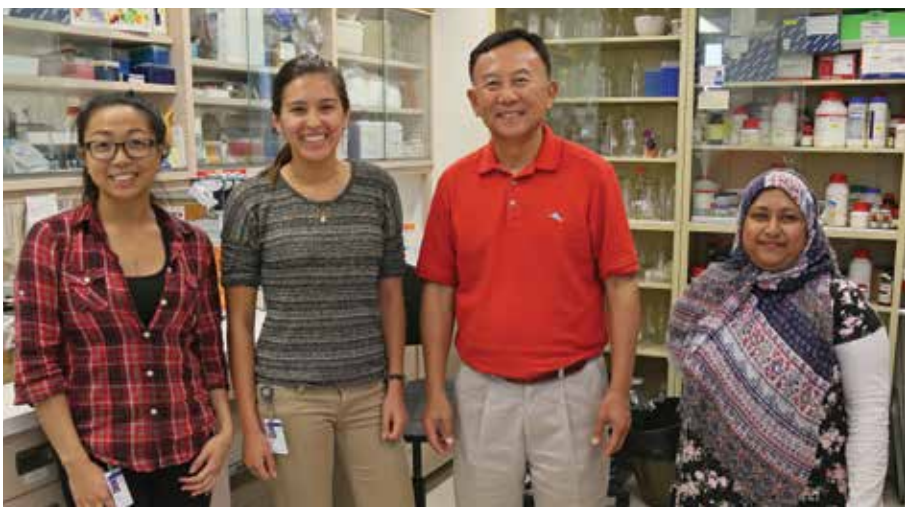
Project: Functional use of core pathogenicity genes to develop mitigation strategies against blackleg of canola and FHB of wheat
Principal investigator: Hossein Borhan, Agriculture and Agri-Food Canada
Funding: SaskCanola, Saskatchewan's Agriculture Development Fund, Western Grains Research Foundation, Manitoba Crop Alliance
Purpose: To define the core effector (pathogenicity) genes of *F. graminearum* and *L. maculans*; assess functional diversity of these core effectors; see if any induce broad-spectrum resistance.

BLACKLEG

Project: Exploiting susceptibility genes in canola to improve blackleg resistance
Principal Investigator: Gary Peng, AAFC Saskatoon
Funding: Alberta Canola, SaskCanola, Manitoba Canola Growers, Western Grains Research Foundation
Purpose: To generate novel resources and markers for blackleg resistance to be used in breeding for canola varieties with potentially broad-spectrum and durable disease resistance traits.

CLIMATE

Project: Capturing ancestral diversity for developing climate ready canola
Principal Investigator: Isobel Parkin, AAFC Saskatoon
Funding: Alberta Canola, SaskCanola, Western Grains Research Foundation



Gary Peng, research scientist with Agriculture and Agri-Food Canada in Saskatoon, relies on a team to conduct clubroot research. Here he is with some of the team – co-op student Jillian Lee (far left) from the University of Victoria, co-op student Kylie Hornaday (second from left) from the University of British Columbia, and postdoc Nazmoon Tonu (far right).

Purpose: To generate significant germplasm and data resources that could be exploited in the study of additional agronomic traits.

CLUBROOT

Project: Clubroot resistance gene function based on whole genome sequences, genome editing and resistance phenotypes
Principal investigator: Stephen Strelkov, University of Alberta
Funding: SaskCanola, Alberta Canola, Alberta's Results Driven Agriculture Research
Purpose: To characterize clubroot resistance genes based on genome-wide association analyses between clubroot disease data and the whole genome sequence data from University of Alberta clubroot resistance donors and 28 Brassica hosts.

CLUBROOT

Project: Virus-induced gene silencing in hairy roots to test root pathogen resistance
Principal investigator: Chris Todd, University of Saskatchewan
Funding: SaskCanola
Purpose: To establish protocols for virus induced gene silencing (VIGS) in *Plasmodiophora brassicae* infected canola hairy roots; to use VIGS to silence canola genes identified as interacting partners of clubroot effector proteins.

CLUBROOT

Project: Evaluation of the A-genome genes for resistance to *Plasmodiophora brassicae* pathotypes, and their combined effect with the C-genome resistance
Principal investigator: Habibur Rahman
Funding: Alberta Canola
Purpose: To investigate the combined effect of A- and C-genome resistances to different clubroot pathotypes, to be used to develop cultivars with resistance to multiple pathotypes.

CLUBROOT

Project: Dissecting the genetics of *B. napus* resistance to clubroot
Principal investigator: Hossein Borhan, Agriculture and Agri-Food Canada
Funding: Alberta Canola
Purpose: To characterize, map and develop markers for PbR1, a robust resistance gene against clubroot.

CLUBROOT

Project: Enhancing clubroot resistance in canola through regulating a transcription factor AIL7
Principal investigator: Gavin Chen, University of Alberta
Funding: Alberta Canola
Purpose: To generate canola AIL7 knockout and overexpression lines, and test their resistance to prevalent clubroot pathotypes in Alberta; to assess the value of this trait for use in commercial lines.

YIELD

Project: Elevating canola yield and oil and protein content by altering cellular carbon partitioning
Principal investigator: Gavin Chen, University of Alberta
Funding: Alberta Canola
Purpose: To generate homozygous double-haploid canola lines with high yield and seed quality.

Ongoing Projects

Plant establishment

CLIMATE

Project: Climate change resilience of Prairie oilseed crops and their below-ground microbiota under drought stress in controlled and field environments
Principal investigator: Tim Dumonceaux, AAFC Saskatoon
Funding: SaskCanola
Purpose: To examine the soil, rhizosphere and root microorganisms that canola plants recruit under stress conditions; isolate microbes (or groups of microbes) that could help plants adapt to changing conditions on the Canadian Prairies.

ON-FARM RESEARCH

Project: Using Modulated On-farm Response Surface Experiments (MORSE) to develop evidence based, agronomic recommendations
Principal Investigator: Steve Shirtliffe, University of Saskatchewan
Funding: SaskCanola, Sask Wheat, Western Grains Research Foundation
Purpose: To develop methodology that will allow crop input experiments to be performed using Modulated On-farm Response Surface Experiments, to refine image-based technology as a tool to assess crop response variables, including yield.

ROTATION

Project: Optimizing crop rotations to enhance agronomic, economic and environmental performance
Principal investigator: Ramona Mohr, AAFC Brandon
Funding: Manitoba Canola Growers
Purpose: To generate a reliable, research-based dataset of production and economic information for a range of climate smart cropping systems and crop rotations.

WEATHER

Project: A meta-analysis of small-plot trial data to examine the relationship between crop development and environmental conditions in canola
Principal investigator: Christiane Catellier, Indian Head Agriculture Research Foundation (IHARF)
Funding: SaskCanola, Western Grains Research Foundation
Purpose: To use archived small-plot canola agronomic trial data and regional weather data to conduct a meta-analysis of the relationship between environmental conditions, canola emergence, maturity and survivability.

Nutrient management

4R PLUS

Project: Using a 4Rs Plus approach to improve growth and sustainability of annual cropping systems in Saskatchewan
Principal investigator: Blake Weiseth, Discovery Farm
Funding: SaskCanola, SaskWheat
Purpose: To assess the impact of 4R Nutrient Stewardship practices on nitrogen and phosphorus crop uptake and nutrient load in run-off water. Project includes a cost-benefit analysis of 4R practices.

CARBON

Project: Collecting the carbon data needed for climate-smart agriculture in Saskatchewan
Principal Investigator: Kate Congreves, University of Saskatchewan
Funding: SaskCanola, SaskWheat, SaskOats, Saskatchewan's Agriculture Development Fund
Purpose: To provide year-round measurements of greenhouse gas emissions from a representative cropping system in Saskatchewan; to assess 4R practices

to minimize carbon footprints; to test if Saskatchewan cropping systems are a net carbon sink.

NITROGEN

Project: Climate-smart canola: quantifying soil- and fertilizer-derived nitrogen sources and greenhouse gas emissions under canola hybrids
Principal investigator: Melissa Arcand, University of Saskatchewan
Funding: SaskCanola, Alberta Canola, Manitoba Canola Growers, Western Grains Research Foundation
Purpose: To bring together physiological (plant-based; e.g. nitrogen harvest index) and agronomic (fertilizer-based; e.g. yield per unit nitrogen fertilizer) understanding of canola nitrogen use efficiency (NUE).

NITROGEN

Project: How does fall-applied nitrogen fertilizer influence soil-emitted nitrous oxide emissions during the over-winter and spring thaw period in the semi-arid Prairies?
Principal investigator: Reynald Lemke, AAFC Saskatoon
Funding: Alberta Canola
Purpose: To quantify soil-emitted N_2O from treatments of urea, dual-inhibitor urea or no nitrogen fertilizer during the non-growing season period under semi-arid conditions; examine factors affecting timing and magnitude of soil-emitted N_2O.

NITROGEN

Project: Discovering the optimal rate of a dual-inhibitor nitrogen fertilizer for maximum N_2O emissions reduction
Principal investigator: Reynald Lemke, AAFC Saskatoon
Funding: SaskCanola, Saskatchewan's Agriculture Development Fund, Western Grains Research Foundation, Sask Wheat
Purpose: To compare yield and nitrous oxide (N_2O) emissions for a dual inhibitor product applied at a reduced nitrogen rate to urea at the standard rate; assess maximum N_2O reduction with an DI fertilizer product while maintaining crop yields.

NITROGEN

Project: Evaluation of variable rate applied enhanced efficiency N fertilizers on wheat and canola – field scale management zones comparison
Principal investigator: Haben Tedla, AAFC Saskatoon
Funding: SaskCanola, SaskWheat
Purpose: To evaluate the agronomic potential of variable-rate application and performance of enhanced efficiency nitrogen fertilizer; compare SuperU, ESN-urea blend and eNtrench to urea.

NITROGEN

Project: Biological nitrogen fixation in canola
Principal Investigator: Alicja Ziemienowicz, Agriculture and Agri-Food Canada (AAFC) Lethbridge
Funding: Alberta Canola, Alberta Innovates, Western Grains Research Foundation, Alberta's Results Driven Agriculture Research
Purpose: To generate canola with "biological nitrogen fixation". This trait would allow crops to grow more efficiently in nitrogen-deficient soil, making them independent of nitrogen fertilizers.

NUTRIENTS

Project: Tracing carbon and nitrogen during crop residue decomposition to optimize C sequestration and predict N transfer credit
Principal investigator: Bobbi Helgason, University of Saskatchewan
Funding: SaskCanola, SaskWheat, SaskBarley
Purpose: To study plant residue factors controlling decomposition of wheat, barley, canola, lentil, field pea and soybean; to more accurately assess the potential contribution of residue-nitrogen to the next crop.

PHOSPHORUS

Project: Impact of phosphorus fertilizer forms on nutrition of wheat, pea and canola, soil fate and losses in run-off water
Principal Investigator: Jeff Schoenau, University of Saskatchewan
Funding: SaskCanola, SaskWheat, SaskPulse, Western Grains Research Foundation
Purpose: To assess how phosphorus fertilizer forms, placement and rate affect crop responses, fate in the soil, and run-off losses in Saskatchewan soils.

PHOSPHORUS

Project: Understanding canola root morphology and microbiomes in response to soil phosphorus fertility
Principal Investigator: Bobbi Helgason, University of Saskatchewan
Funding: SaskCanola, Global Institute for Food Security
Purpose: To determine how canola root architecture and the root-associated microbiome impact the plant's ability to forage for phosphorus.

SOIL

Project: SKSIS-3: Synergies and Sustainability for the Saskatchewan Soil Information System
Principal Investigator: Angela Bedard-Haughn, University of Saskatchewan
Funding: SaskCanola, Saskatchewan's Agriculture Development Fund, Western Grains Research Foundation, SaskWheat
Purpose: To enhance Saskatchewan Soil Information System (SKSIS) with predictive soil mapping tools, and to create a standalone SKSIS feature for efficient use in internet-deficient areas.

SOIL

Project: Enhancing the Saskatchewan Soil Health Assessment Protocol – Phase 2
Principal Investigator: Kate Congreves, University of Saskatchewan
Funding: SaskCanola, SaskWheat
Purpose: To build on the Saskatchewan Soil Health Testing Protocol so that it outputs soil zone-specific scores; to incorporate novel microbial measurements of soil health into the testing protocol; to explore early-indicators of soil health change.

SOIL

Project: Shining a light on digital agriculture: Linking soil NIR measurements, fertility and crop yields
Principal Investigator: Derek Peak, University of Saskatchewan
Funding: SaskCanola, SaskWheat, Saskatchewan's Agriculture Development Fund
Purpose: To use spectral sensing to produce spatially-resolved soil based yield potential maps; and develop methodology to link field near infrared (NIR) data and laboratory analyses.

Integrated pest management DISEASE

ASTER YELLOWS

Project: The role of insect feeding and plant defense responses in aster yellows disease epidemiology
Principal investigator: Sean Prager, University of Saskatchewan
Funding: Alberta Canola, Manitoba Canola Growers

Purpose: To quantify the feeding behaviour of aster leafhoppers on different host plants and examine the relationship between feeding time and aster yellows phytoplasma.

BLACKLEG

Project: Biocontrol of blackleg using carnivorous bacteria
Principal investigator: Paul Holloway, University of Winnipeg
Funding: Manitoba Canola Growers
Purpose: To isolate various myxobacterial and mycophagous bacteria from Manitoba sources, then determine whether the isolates can kill or inhibit the growth of *Leptosphaeria maculans*, the pathogen that causes blackleg in canola.

BLACKLEG

Project: Investigating interactions of ascospores and pycidiospores with blackleg resistance in canola and efficacy of seed applied fungicides
Principal investigator: Dilantha Fernando, University of Manitoba
Funding: SaskCanola
Purpose: To develop a protocol to efficiently produce ascospore and pycnidiospore inoculum with defined Avr profile for resistance screening; assess interactions of inoculum types with blackleg resistance; evaluate seed-applied fungicides.

CLUBROOT

Project: Influence of pH on the clubroot pathogen: are there pH-insensitive strains?
Principal investigator: Stephen Strelkov, University of Alberta
Funding: Alberta Canola, SaskCanola, Manitoba Canola Growers
Purpose: To determine whether strains of the clubroot pathogen respond differentially to soil pH and whether pathogen strains can become adapted to high pH conditions.

CLUBROOT

Project: Clubroot inoculum management for sustainable canola production
Principal investigator: Stephen Strelkov, University of Alberta
Funding: Alberta Canola, Alberta Agriculture, Forestry and Rural Economic Development
Purpose: To determine the spore population levels that are safe for the use of clubroot-resistant cultivars and develop a knowledge-based resistance deployment strategy.

University of Alberta research scientists Rudolph Fredua-Agyeman, Sheau-Fang Hwang and Stephen Strelkov work together on verticillium wilt, clubroot and other canola projects.

CLUBROOT

Project: A rapid molecular assay to identify *Plasmodiophora brassicae* pathotypes from plant and soil samples
Principal investigator: Stephen Strelkov, University of Alberta
Funding: Alberta Canola, Alberta Agriculture, Forestry and Rural Economic Development
Purpose: To generate an effective rapid molecular assay (PCR-based) to identify abundance and diversity of *P. brassicae* pathotypes in soil and plant samples; and to use genetic variability among pathotypes to identify genes of interest.

CLUBROOT

Project: Study of the effects of Brassica root architecture and fertilizer application on clubroot disease severity
Principal investigator: Stephen Strelkov, University of Alberta
Funding: Alberta Canola, Western Grains Research Foundation, Alberta's Results Driven Agriculture Research
Purpose: To investigate the association between brassica root architecture and nitrogen treatments on clubroot severity and crop yield.

CLUBROOT

Project: Managing small patches of clubroot infestation in canola fields
Principal investigator:
Bruce Gossen, AAFC Saskatoon
Funding: SaskCanola, Manitoba Canola Growers
Purpose: To develop practical recommendations to manage small patches of clubroot.

CLUBROOT

Project: Application of hyperspectral imaging for detection and mapping of small patch clubroot infestations in commercial canola fields
Principal investigator:
David Halstead, Saskatchewan Polytechnic
Funding: SaskCanola, Saskatchewan's Agriculture Development Fund
Purpose: To identify readily applied diagnostic features for mapping small clubroot patches and develop a diagnostic tool; to refine and validate diagnostic tool for identifying small patch clubroot infestations.

FUSARIUM WILT

Project: Understanding fusarium wilt and root rot of hybrid canola occurrence, host range, disease development, resistance and yield
Principal investigator:
Sheau-Fang Hwang, University of Alberta
Funding: Alberta Canola, Alberta's Results Driven Agriculture Research
Purpose: To optimize cultural methods to control the fusarium pathogens causing seedling blight and root rot and wilt of canola.

SCLEROTINIA STEM ROT

Project: Biopesticides as a novel management strategy for sclerotinia in canola
Principal investigator:
Tim Dumonceaux and Susan Boyetchko, AAFC Saskatoon
Funding: SaskCanola, Manitoba Canola Growers
Purpose: To screen and evaluate the biopesticide potential of selected bacterial strains that are indigenous to the Canadian

Prairies and determine their ability to control disease development and growth of *Sclerotinia sclerotiorum* in canola.

VERTICILLIUM STRIPE

Project: Verticillium stripe - The disease management
Principal investigator:
Sheau-Fang Hwang and Stephen Strelkov, University of Alberta
Funding: Alberta Canola, SaskCanola, Manitoba Canola Growers
Purpose: To determine the effects of growth stage and inoculation techniques on host infection, and to evaluate the effects of disease severity on plant growth and yield at different inoculum concentrations.

Integrated pest management INSECTS

BENEFICIAL INSECTS

Project: Identifying key predators and their role in canola insect pest suppression
Principal investigator: Boyd Mori, University of Alberta
Funding: Alberta Canola, Manitoba Canola Growers, Western Grains Research Foundation
Purpose: To identify the key natural enemies in the canola agroecosystem by detecting pest insect DNA in guts of predators, and to begin quantifying their pest suppression ability.

BIOCONTROL

Project: Exploring further possibilities and advancements of using bio-control entomopathogenic nematodes (EPNs)
Principal investigator: Shabeg Briar, Olds College of Agriculture & Technology
Funding: Alberta Canola
Purpose: To assess the management of cabbage root maggots and cutworms to determine the persistence of entomopathogenic nematodes in Prairie soils.

FLEA BEETLES

Project: Insecticide susceptibility and resistance monitoring of flea beetles in canola
Principal investigator: Boyd Mori, University of Alberta
Funding: Alberta Canola, Western Grains Research Foundation, Alberta's Results Driven Agriculture Research
Purpose: To determine the susceptibility of the striped and crucifer flea beetle to various registered insecticides and investigate the mechanisms of insecticide tolerance.

FLEA BEETLES

Project: Incorporation of abiotic and biotic factors for development of stage-structured predictive models of flea beetles
Principal investigator: Maya Evenden, University of Alberta
Funding: Alberta Canola, Alberta's Results Driven Agriculture Research
Purpose: To develop a weather-dependent, stage-structured deterministic developmental model for both flea beetle species and evaluate appropriate base temperature thresholds for predictions of flea beetles in canola.

LEAFHOPPERS AND DIAMONDBACK MOTH

Project: Continuing to watch the winds: the origin and arrival of migrant aster leafhoppers and diamondback moths
Principal investigator: Tyler Wist, AAFC Saskatoon
Funding: SaskCanola, Western Grains Research Foundation
Purpose: To pinpoint the southern origins of diamondback moth and aster leafhopper; to see if alfalfa could be a "green bridge" for aster yellows phytoplasma in Saskatchewan; to develop aster yellows risk index.

LYGUS

Project: Biological control of lygus plant bugs in established and emerging crops
Principal investigator: Hector Carcamo, AAFC Lethbridge
Funding: Alberta Canola
Purpose: To determine the impact of an exotic parasitoid of lygus bugs on native parasitoids, to determine if relocation of an exotic parasitoid would be beneficial for lygus control.

PESTICIDES

Project: Comprehensive investigation of pesticides in honey, pollen, bees and soil collected from canola fields
Principal investigator: Elemir Simko, University of Saskatchewan
Funding: SaskCanola, Saskatchewan's Agriculture Development Fund
Purpose: To accurately document residues of 93 pesticides (including all neonicotinoids and their metabolites) in honey, pollen, bees and soil samples collected from canola fields and boreal regions across Saskatchewan.

POLLEN BEETLE

Project: Develop and assess different strategies to reduce the impact of pollen beetle *Brassicogethes viridescens (Coleoptera: Nitidulidae)*, a new invasive insect pest on canola
Principal investigator: Christine Noronha, AAFC Charlottetown
Funding: Alberta Canola, Manitoba Canola Growers, Alberta's Results Driven Agriculture Research and Western Grains Research Foundation
Purpose: To evaluate the efficiency of monitoring techniques for pollen beetles; survey fields in Alberta, Saskatchewan and Manitoba for pollen beetles; and survey for parasitoids in the Maritimes.

POLLINATORS

Project: Effects of heat and drought on canola – pollinator interactions and crop yield
Principal investigator: Shelley Hoover, University of Lethbridge
Funding: Alberta Canola, Alberta's Results Driven Agriculture Research
Purpose: To analyze the effects of heat and drought on seed yield and quality for five canola cultivars, with and without supplemental pollination by bees; examine benefits of supplemental pollination prior to heat and drought stress versus at the time of stress.

Integrated pest management WEEDS

CHAFF LINING

Project: Suitability and efficacy of chaff lining for weed control in western Canada
Principal investigator: Breanne Tidemann, AAFC Lacombe
Funding: Alberta Canola
Purpose: To see if weed seeds under chaff lines (from four different crops) have reduced viability over winter. Also ran pot studies to see how much chaff is needed to reduce weed emergence.

CLEAVERS

Project: Enhance understanding of cleavers populations in western Canada
Principal investigator: Breanne Tidemann, AAFC Lacombe
Funding: Alberta Canola, Western Grains Research Foundation
Purpose: To look for cleavers biotypes on the Prairies, evaluate emergence timing of cleavers populations, screen for quinclorac resistance.

CLEAVERS

Project: Screening false cleavers from the Prairie Herbicide Resistance Surveys for quinclorac and glyphosate resistance
Principal investigator: Breanne Tidemann, AAFC Lacombe
Funding: Alberta Canola
Purpose: To indicate how quickly quinclorac and glyphosate resistance in cleavers may be increasing or spreading on the Prairies.

CRITICAL PERIOD

Project: Updating the critical weed free period in canola
Principal investigator: Rob Gulden, University of Manitoba
Funding: SaskCanola, Alberta Canola, Manitoba Canola Growers, Alberta's Results Driven Agriculture Research
Purpose: To update the critical weed-free period (CWFP) for canola using modern canola hybrids, and determine how crop density affects CWFP; collect data from sufficient locations and years to make sound recommendations for various scenarios.

HR WEED SURVEY

Project: Herbicide-resistant weed survey in the Prairies
Principal investigator: Charles Geddes, AAFC Lethbridge
Funding: Alberta Canola
Purpose: The current round of herbicide-resistant weed surveys ends this year with the Alberta survey.

SEEDBANK

Project: Manipulating weed seed production through phenology-based weed control
Principal investigator: Charles Geddes, AAFC Lethbridge
Funding: Alberta Canola, Alberta Wheat Commission, SaskWheat, Western Grains Research Foundation
Purpose: To improve our understanding of weed phenology in Western Canada, and use that information to develop strategies to reduce the amount of weed seed returned to the soil.

WEED SURVEY

Project: Prairie weed surveys
Principal investigator: Julia Leeson, AAFC Saskatoon
Funding: Western Grains Research Foundation, SaskCanola and other commodity groups
Purpose: To determine the distribution and abundance of glyphosate-resistant or auxinic-resistant kochia and other targeted weeds, including Russian thistle, waterhemp, and ragweed species in Manitoba, Saskatchewan and Alberta.

Integrated pest management OTHER

IPM

Project: Promotion of wetland stewardship best management practices through a targeted water monitoring project
Principal investigator: Tony Ciarla, Millenium EMS Solutions
Funding: Alberta Canola and various other public and private funders
Purpose: To evaluate wetland management practices in mitigating the movement of crop protection products into wetlands and aquatic ecosystems.

Genetics

BREEDING STRATEGY

Project: Preserving hybrid vigour through a novel apomixis breeding strategy in brassica crops
Principal investigator: Tim Sharbel, University of Saskatchewan
Funding: SaskCanola, Saskatchewan's Agriculture Development Fund
Purpose: To generate diploid, hybrid unbalanced apomictic boechera backcrosses; to transfer apomixis from these lines into sexual bridging species; to generate apomictic brassica crops via intergeneric crosses.

BLACKLEG

Project: Towards better understanding of genetics in *Leptosphaeria-Brassica* interactions via international collaborations to standardize the nomenclature of blackleg resistance genes
Principal investigator: Hossein Borhan, AAFC Saskatoon
Funding: Alberta Canola, SaskCanola
Purpose: To help in the international effort to locate new blackleg resistance genes, researchers need a universal protocol so they're not finding the same gene multiple times but giving it different names.

BLACKLEG

Project: Developing allele specific molecular markers for the *B.napus* blackleg resistance (*Rlm*) genes
Principal investigator: Hossein Borhan, AAFC Saskatoon
Funding: SaskCanola, Western Grains Research Foundation
Purpose: To sequence blackleg resistance genes *Rlm1* and *Rlm11* and PCR-based markers for these genes as well as *Rlm2*. This information will be publicly available.

BLACKLEG

Project: Identification of genetic mapping of novel genes for resistance to blackleg in Chinese and Canadian *Brassica napus*
Principal investigator: Dilantha Fernando, University of Manitoba
Funding: SaskCanola, Alberta Canola
Purpose: To identify and map new sources of blackleg resistance.

BLACKLEG

Project: Building bridges to success - Accessing brassica diploid variation for canola improvement
Principal investigator: Steve Robinson, AAFC Saskatoon
Funding: Alberta Canola, Manitoba Canola Growers, SaskCanola
Purpose: To test new technology for blackleg resistance breeding. Domesticated diploid bridging species in combination with targeted diploid germplasm will increase the efficiency to introduce and evaluate new resistance alleles into *B. napus*.

CLIMATE

Project: Drought tolerance in canola through modulating the Kanghan gene family
Principal investigator: Zou Jitao, National Research Council
Funding: SaskCanola, Manitoba Canola Growers, Western Grains Research Foundation
Purpose: To conduct CRISPR gene editing of the Kanghan genes in canola to generate knockout lines with improved drought tolerance; demonstrate the Kanghan technology under field conditions.

CLIMATE

Project: Modification of surface waxes for improved water retention in canola
Principal investigator: Mark Smith, AAFC Saskatoon
Funding: SaskCanola, Saskatchewan's Agriculture Development Fund, Western Grains Research Foundation
Purpose: To study the role of wax components in maintaining the cuticular water barrier of canola; to use genome editing to prevent expression of target genes

in the epidermis without disrupting wax in other parts of the plant, such as pollen.

CLIMATE

Project: Modified lipid metabolism to deliver improved low temperature tolerance in *Brassica napus*
Principal investigator: Mark Smith, AAFC Saskatoon
Funding: SaskCanola, Saskatchewan's Agriculture Development Fund
Purpose: To apply a targeted approach to identify new traits to confer improved low temperature tolerance in seedling canola.

CLIMATE

Project: Increasing abiotic (drought) and biotic (clubroot) resistance in Brassica species by modifying auxin response
Principal investigator: Jocelyn Ozga, University of Alberta
Funding: SaskCanola, Alberta Canola, NSERC
Purpose: To develop novel genetically-improved canola, using a biotechnological approach, that is more resistant to both biotic (clubroot disease) and abiotic (drought) stress.

CLIMATE

Project: Improving heat and drought resistance in canola through regulating diacylglycerol acyltransferase activity
Principal investigator: Gavin Chen, University of Alberta
Funding: SaskCanola and Western Grains Research Foundation
Purpose: To diversify Canadian canola with stress-resistance genes, identify candidate genes involved in the control of heat and drought resistance, and collaborate with canola breeders to develop molecular markers for these genes.

CLUBROOT

Project: Using avirulence markers to predict the phenotypes of clubroot pathotypes
Principal investigator: Edel Pérez-López, Université Laval
Funding: Alberta Canola, Manitoba Canola Growers, Western Grains Research Foundation
Purpose: To optimize a hydroponic bioassay to phenotype the interaction between canola and *P. brassicae*; to identify *P. brassicae* avirulence markers; to design and implement a multiplex PCR assay to differentiate *P. brassicae* isolates.

CLUBROOT

Project: New clubroot pathotypes and second generation resistance
Principal investigator: Stephen Strelkov, University of Alberta
Funding: Alberta Canola, SaskCanola, Western Grains Research Foundation
Purpose: To evaluate the infectivity of the most important *P. brassicae* pathotypes on a suite of canola cultivars with second-generation resistance.

CLUBROOT

Project: Efficient identification of *Plasmodiophora brassicae* pathotypes by metabardocing
Principal investigator: Stephen Strelkov, University of Alberta
Funding: Alberta Canola
Purpose: To generate a DNA metabarcoding assay that can aid in efficient, accurate, replicable and high-resolution identification of clubroot pathotypes to allow early detection.

CLUBROOT

Project: Understanding the molecular basis of NLR-mediated clubroot resistance in *Brassica napus*
Principal investigator: Edel Pérez López, University Laval
Funding: SaskCanola, Alberta Canola, Western Grains Research Foundation
Purpose: To identify clubroot-resistance genes of the nucleotide-binding leucine-rich repeat (NLR) family and characterize their mechanisms in existing commercial canola germplasm.

CLUBROOT

Project: A proteomics-based approach towards identifying host and pathogen proteins critical to clubroot establishment in canola
Principal investigator: Christopher Todd, University of Saskatchewan
Funding: SaskCanola, Western Grains Research Foundation
Purpose: To identify *P. brassicae* effector proteins and to identify differentially expressed proteins in clubroot-susceptible and clubroot-resistant canola lines.

CLUBROOT

Project: Developing single-spore isolates of pathotypes of *Plasmodiophora brassicae*
Principal investigator: Mary Ruth MacDonald
Funding: SaskCanola
Purpose: To develop techniques for whole-genome sequencing of single spores of *P. brassicae*, the pathogen that causes clubroot.

CLUBROOT

Project: Purifying genotypes of *P. brassicae* and developing markers linked to races of *P. brassicae* collected in Western Canada
Principal investigator: Fengqun Yu, AAFC Saskatoon
Funding: SaskCanola, Manitoba Canola Growers, Western Grains Research Foundation
Purpose: To develop markers linked to races of *P. brassicae*, the pathogen that causes clubroot. This would be similar to the technology used to identify blackleg races.

CLUBROOT

Project: Exploring *Brassica oleracea* for resistance to the newly emerged *P. brassicae* pathotypes.
Principal investigator: Habibur Rahman, University of Alberta
Funding: Alberta Canola, Alberta Agriculture & Forestry
Purpose: To introgress clubroot resistance genes from the cabbage/cauliflower-type plant species *(B. oleracea)* into Canadian canola, and develop molecular markers for these genes.

CLUBROOT

Project: Improvement of the clubroot-resistant canola germplasm of canola × rutabaga cross, and fine mapping of the resistance gene
Principal investigator: Habibur Rahman, University of Alberta
Funding: Alberta Canola, Alberta Innovates, Alberta Agriculture & Forestry
Purpose: To develop canola lines that carry the clubroot resistance gene of rutabaga, resulting in clubroot-resistant hybrid canola cultivars.

CLUBROOT

Project: Introgression of clubroot resistance from *B.rapa* into *B.napus* canola and identification of molecular markers for resistance
Principal investigator: Habibur Rahman, University of Alberta
Funding: Alberta Canola, SaskCanola
Purpose: To introgress clubroot resistance (CR) from *B.rapa* to *B.napus* canola. The *B.rapa* germplasm used in this research carries resistance to pathotypes 3 and 3A. This could be a new source of resistance.

CLUBROOT

Project: Cloning clubroot resistance genes from *B. nigra* and transferring the genes into canola through a CRISPR/Cas9 based technology
Principal investigator: Fengqun Yu, AAFC Saskatoon
Funding: SaskCanola, Saskatchewan's Agriculture Development Fund, Western Grains Research Foundation
Purpose: To identify best candidates among the clubroot resistance genes identified in B. *nigra*; then isolate those genes and deliver candidate genes into canola using CRISPR/Cas9.

CLUBROOT

Project: Re-synthesizing *Brassica napus* with clubroot resistance from C-genome
Principal investigator: Fengqun Yu, AAFC Saskatoon
Funding: Alberta Canola, Alberta Innovates
Purpose: To generate new and unique germplasm and make it available to canola breeders to develop cultivars with broad spectrum of resistance to clubroot in Western Canada.

CLUBROOT

Project: From field to the genome. Application of third generation sequencing to direct genotyping of canola pathogens
Principal investigator: Hossein Borhan, AAFC Saskatoon
Funding: Alberta Canola, SaskCanola
Purpose: To develop a sensitive and rapid diagnostic tool to detect the presence of clubroot pathogen and determine the pathotypes present and the relative abundance.

DISEASE

Project: Deploying calcium-dependent protein kinases to fight canola pathogens
Principal investigator: Jacqueline Monaghan, Queen's University
Funding: SaskCanola, Alberta Canola, Manitoba Canola Growers, Western Grains Research Foundation
Purpose: To use precision gene editing to enhance the function of single genes that could provide canola plants with enhanced, durable, broad-spectrum resistance to disease without any growth tradeoff.

GENERAL

Project: Identification and exploitation of genome structural variants for trait improvement in Prairie crops
Principal investigator: Andrew Sharpe, Global Institute for Food Security
Funding: SaskCanola, SaskWheat, Alberta Grains, Western Grains Research Foundation
Purpose: To develop canola and wheat pan-genome structural variant (PanSV) atlases; to develop high-throughput structural variant (SV) genotyping pipeline; to associate SVs with important agronomic traits.

GENERAL

Project: Manipulating recombination in crop polyploids
Principal investigator: Isobel Parkin, AAFC Saskatoon
Funding: SaskCanola, National Research Council (NRC), SaskWheat
Purpose: To identify homologues of gene candidates controlling homoeologous recombination in wheat and *Camelina sativa*, to develop constructs for gene knock-outs using CRISPR technology.

NITROGEN

Project: Identifying the optimal root system architecture (RSA) for Brassica crops
Principal investigator: Isobel Parkin, AAFC Saskatoon
Funding: SaskCanola, Saskatchewan's Agriculture Development Fund
Purpose: To understand the level of natural variation of root system architecture (RSA) for *Brassica napus*, to identify the regions of the genome contributing to variation in RSA and to assess the variation for improving nitrogen-use efficiency.

PHOTOSYNTHESIS

Project: Evaluating Canola germplasm for photosynthetic efficiency
Principal investigator: Linda Gorim, University of Alberta
Funding: Alberta Canola
Purpose: To identify canola germplasm with superior photosynthetic efficiency, to contribute to the development of high yield varieties.

SCLEROTINIA STEM ROT

Project: Pre-breeding lines combining canola quality with sclerotinia resistance, good agronomy and genomic diversity from PAK93
Principal investigator: Sally Vail, AAFC Saskatoon
Funding: Alberta Canola, Manitoba Canola Growers, SaskCanola, Western Grains Research Foundation
Purpose: To develop resistant pre-breeding lines that combine desirable traits in PAK93 with canola seed quality and shatter resistance from AAFC's elite lines; form a consortium of breeding companies to fund final selection of pre-breeding lines.

SCLEROTINIA STEM ROT

Project: Determine the contribution of specific defense genes to *Sclerotinia sclerotiorum* resistance in canola *(Brassica napus)*
Principal investigator: Lone Buchwaldt, AAFC Saskatoon
Funding: SaskCanola, Saskatchewan's Agriculture Development Fund
Purpose: To determine the contribution of lectin genes, penetration-resistance genes and other candidate defense genes to sclerotinia resistance in canola.

YIELD

Project: Addressing yield stability drivers of canola in a changing climate using high throughput phenotyping
Principal investigator: Sally Vail, AAFC Saskatoon
Funding: Manitoba Canola Growers, SaskCanola, Western Grains Research Foundation
Purpose: To run field trials of the *B. napus* nested association mapping (NAM) germplasm resource in contrasting climatic environments; provide a sufficient datatset to test and apply phenotyping and selection techniques to improve canola yield stability.

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