ALBERTA CANOLA
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Science Edition 2019

canola DIGEST

The Source For Canada's Canola Growers

SCIENCE EDITION

Canola farmers can use these results to make better disease, insect, weed, seed, fertilizer and harvest decisions to reduce risk, improve logistics, limit input losses and increase returns.

THE CANOLA DIGEST IS A JOINT PUBLICATION OF:

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Growers at the table

Canola growers, through their provincial canola organizations, are helping to drive the research priorities for canola in Canada. Provincial research committee chairs explain the benefit of grower-funded and grower-directed research.

BERNIE MCCLEAN
SaskCanola
Research Committee Chair
Glaslyn, Saskatchewan

I can't imagine where farming would be today without research. With inspiration from research findings, I have and will continue to change my on-farm practices. The advent of herbicide-resistant varieties and the ability to farm with no-till practices has been major for my land's soil health. This year was also my first growing season where I seeded every canola acre with clubroot-resistant varieties.

Our number one priority at SaskCanola is research, with 40 per cent of our budget committed to new and ongoing projects. All SaskCanola-funded research project summaries are available on our website at **saskcanola.com** and we extend knowledge to growers throughout the year primarily at events and through social media.

Research summaries and ongoing research reports are shared in this Science Edition of Canola Digest. As you read through, if a question, idea, or concern comes to mind, please get in touch with a member of our dedicated team. Our door at SaskCanola is always open.

RON KRAHN
Manitoba Canola Growers
Research Committee Chair
Rivers, Manitoba

Unbiased research helps us, as canola growers, make crop management decisions that improve the business. On the research committee, we're pushing for projects that we, as growers ourselves, want done. We take leadership in setting priorities based on risk and cost to production, communicating these priorities with the research community, and encouraging proposals that match those priorities.

The benefit to canola growers is that the research we fund through your check-off dollars is unbiased. We're not trying to sell anything and we don't cherry pick the results.

You'll see a lot of recently completed and ongoing research described in this Science Edition of Canola Digest. I encourage you to read through it and take note of results that can help your farm, and tell us about projects we might be missing. I know that after the growing season we had in 2019, I'll be looking at results that will help me increase seed survival, manage flea beetles and reduce storage risks for high-moisture canola.

JOHN MAYKO
Alberta Canola
Research Committee Chair
Mundare, Alberta

Research is the cornerstone to the existence of canola. Through the pioneering work of Drs. Baldur Stefansson and Keith Downey, canola was transformed from rapeseed into a unique crop with healthy and unique properties which drives an industry that contributes $26.7 billion to the Canadian economy each year.

Grower-funded research results have been key to the success of canola on my farm and in Western Canada. Alberta Canola supports research to help farmers succeed in growing canola. Unbiased research on the importance of seeding depth on crop establishment, clubroot prevention and management and delaying swathing to maximize yield and quality are all results making a difference on my farm.

Of course, this information is of little value if canola growers and their support team of advisors and extension agents never see the results. This is why Alberta Canola has been a strong supporter of the Canola Digest and especially this edition, the Science Digest edition. I hope you make as much use of it as I will.

canola DIGEST
Science Edition 2019

PROVINCIAL RESEARCH BULLETINS

REPORTS FOR RECENTLY COMPLETED RESEARCH

PLANT ESTABLISHMENT

FERTILIZER MANAGEMENT

INTEGRATED PEST MANAGEMENT

How the CCC shares research

The Canola Council of Canada uses a variety of knowledge translation and transfer (KTT) tools to share research-driven best management practices. These include:

Canola Encyclopedia. This online growers manual at **canolaencyclopedia.ca** has science-based detail, including citations, on everything to do with canola production.

Canola Watch. Sign up at **canolawatch.org/signup/** for timely alerts and tips throughout the growing season. See all archived articles at **canolawatch.org**.

Canola Research Hub. With new funding from Agriculture and Agri-Food Canada's Canadian Agricultural Partnership, the Hub is getting an upgrade this winter. The Hub at **canolaresearch.ca** is a collection point for recent canola research reports, podcasts, videos and publications.

Events. CCC and the provincial canola grower organizations work together on various agronomy events and speaking engagements. See the 'events' listings at **canolacouncil.org**, **albertacanola.com**, **saskcanola.com** and **canolagrowers.com**.

Videos. Watch how clubroot works, how blackleg works and ways to reduce harvest losses, to give just three examples, in the Video Gallery under the 'Resource' tab at **canolacouncil.org**.

Online tools. Try the seeding rate, target plant density and combine optimization tools at **canolacalculator.ca**, spray-to-swath interval finder at **keepingitclean.ca**, and variety comparisons at **canolaperformancetrials.ca**.

Social media. CCC shares agronomy information on Facebook **@CCCagronomy**. On Twitter, follow **@CanolaWatch** and the individual agronomy specialists.

Credit: Clint Jurke

Investing in a Resilient Canola Future – Mitigating Clubroot Risks in Saskatchewan

Clubroot is a devastating disease and the canola industry has been investing in research of this pathogen for a number of years. SaskCanola's priority with clubroot is to find ways to prevent the spread in the province. Currently there are relatively few confirmed cases in commercial canola fields and by helping raise grower awareness about prevention of spreading clubroot contaminated soil alongside of strategic use of resistant varieties, there is a unique opportunity to contain these cases. SaskCanola invests grower dollars into research that leads to new resistant varieties for growers to use, but this is only one tool available. By managing for the disease before it becomes visible in the field, growers will continue to be successful.

In addition to incorporating clubroot-resistant varieties, growers can also:

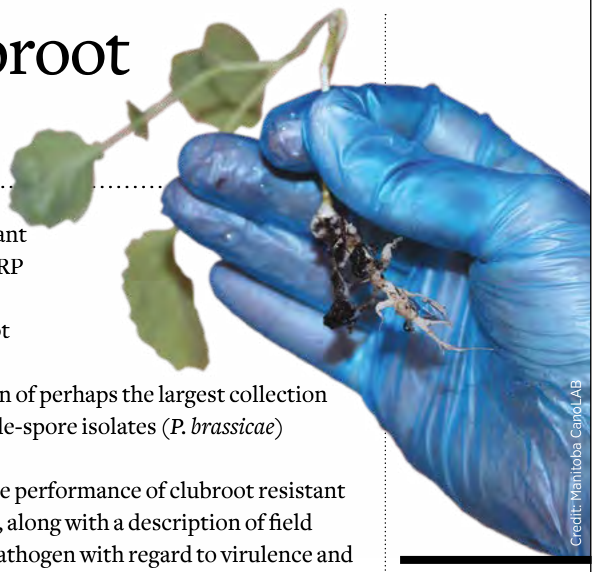
- Grow canola as part of a three-year crop rotation (minimum two-year break).
- Soil test each year canola is grown to understand the spore level in the field and on the farm.
- Scout fields regularly to detect the presence of aggressive pathotypes.
- Control volunteer canola and other host weeds throughout the rotation.
- Seed clubroot patches to a perennial grass to prevent spread within the field and further reduce spore numbers.

Enhancing the durability of clubroot resistance with multiple resistance genes —*Peng/Song*

Major gene resistance can be very effective in reducing disease severity and progression in crops in general. Due to selection pressure in the field for diseases like clubroot, it is only a matter of time before a pathogen population can break any mechanism of major resistance, especially under conditions of high spore loads in the field. One way to improve the durability of major gene resistance is to stack multiple resistance genes with different modes of action together in one canola line. This makes it much more difficult for a clubroot pathogen population in a field to evolve to break resistance because it needs to overcome combined multiple sources of resistance at the same time.

This project studied the simulated effect of high selection pressure over five generations of canola grown in the same soil that was inoculated initially with either high or moderate spore loads. Any galls that formed in each generation in any given pot were cut up, allowed to mature, and then added back to the same potted soil. Over the course of five generations of canola planted in re-infested potted soil, the spore load was expected to be maintained or increased in the case of sensitive canola lines, and potentially decrease over time for resistant canola lines.

Monitoring the threat of clubroot in Saskatchewan —*Strelkov*



Credit: Manitoba CanoLAB

The primary purpose of the project titled *Clubroot Surveillance and Pathotype Monitoring* was to map the spread of clubroot in Western Canada and determine if there have been any changes to the pathogen itself. Some of the findings contained in the project's final report had been expected, but still proved to be quite sobering.

The clubroot map continues to expand in Alberta and Manitoba, and the pathogen has now established a foothold in Saskatchewan. It is important to note that what is known as first generation resistance, that is, the first type of resistance bred into commercial varieties, is now breaking down in Alberta. Pathogen types that have overcome varietal resistance have been found in Manitoba as well, but none have yet been detected in Saskatchewan, so there is still an opportunity to stay ahead of this devastating disease.

Credit: Dan Orchard

Some of the significant outcomes of the CARP project are:

1. Maps of clubroot distribution.
2. Characterization of perhaps the largest collection of clubroot single-spore isolates (*P. brassicae*) in the world.
3. Evaluation of the performance of clubroot resistant canola cultivars, along with a description of field isolates of the pathogen with regard to virulence and pathotype designation.

It is important to note the two interdependent elements in the battle against clubroot: strategy and tools. The strategy involves reducing the movement of soil from field to field, extending rotations and eliminating alternate hosts such as wild mustard, stinkweed and volunteer canola.

The most effective tool that farmers have is varietal resistance, but this should not be expected to shoulder the entire burden of protecting Saskatchewan fields from clubroot. Incorporating an effective clubroot strategy which includes a three-year crop rotation and incorporating resistant varieties are the best ways to make sure Saskatchewan growers can stay ahead of clubroot.

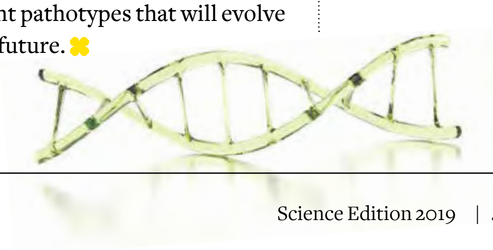
*For more details on this research project, search Strelkov in the "Research" section at **saskcanola.com***

Stacking multiple clubroot resistance genes increases the durability of those genes and expands the range of protection against additional clubroot pathotypes that those individual resistance genes cannot protect against.

The use of five generations of canola in continuously re-infested soil was also expected to show potential timelines of resistance breakdown. At high spore loads in the soil, resistance can be broken quickly, even by the third generation of back-to-back canola and this caused continually increasing spore loads over the successive generations. Under lower initial spore loads, as can be achieved through proactive clubroot management practices, the resistance was not broken, even after four generations. This validates the importance of using at least a three-year canola rotation to keep clubroot spore loads under control and to prevent the rapid breakdown of resistance of the major R genes which are needed by all producers.

Combining two to three resistance genes in canola lines also had added benefit of greatly reduced disease severity compared to lines with only a single resistance gene. This effect was observed in canola challenged with either common 'old' pathotypes such as 3H and even the 'new' highly virulent 5x clubroot pathotype. This is an important distinction in that the stacking of two major resistance genes, that individually are unable to protect canola lines against pathotype 5x, was then able to provide intermediate protection against 5x. This opens the door to more research to discover the best combinations of existing R genes which can be given new life to provide resistance against virulent pathotypes that will evolve in the future.

*For more details on this research project, search Peng in the "Research" section at **saskcanola.com***



Credit: iStock.com/D3Damon

I dream of being able to grow it in 15 years

By Ward Toma

Credit: Gregory Sekulic

Ward Toma, Alberta Canola General Manager, presenting at the 2019 International Rapeseed Congress.

"I dream of being able to grow it in 15 years." A wishful statement, not expressed by a wide-eyed farmer seeing a new crop with incredible potential, but instead by a farmer that has serious doubts about his ability to continue to grow this incredible crop. Hubertus Paetow, president of the German Agricultural Society, in his welcoming remarks to the nearly 900 attendees of the 2019 International Rapeseed Congress this past June in Berlin, spoke of the challenges of farming in modern Germany. His dream was one of ***still*** being able to grow canola on his farm in Germany in 15 years down the road. Research keeps his dream alive.

I was attending the International Rapeseed Congress, having been invited to present a review on the status of clubroot in North America at a pre-conference workshop. After the EU and China, at just under 100 attendees, Canada had the third largest contingent of researchers, agronomists, extension agents and students attending the largest gathering of the greatest minds in canola research worldwide. While clubroot is endemic throughout most of the canola growing region in Europe, it is easily kept at bay with rotations. A larger number of economically viable cropping options allows for this and clubroot only becomes a problem when volunteers and susceptible weeds are not controlled.

While Europe has a relatively easy solution for clubroot, the same cannot be said for insects or plant diseases. Long rotations are not stopping the devastation of canola crops by the pollen and flea beetles. Just like in Canada, diseases such as blackleg, sclerotinia and fusarium can severely impact production. Unfortunately, it appears the largest force behind the growing appearance of these insects and diseases is the consumer.

Germany is one of the top four agricultural producing member countries of the EU; over half of the country is farmland. It is a major producer of fresh vegetables, cereals, and rapeseed (they just cannot bring themselves to call it canola!), as well as meat and dairy. A quick stop at a Berlin grocery store confirms this: fresh and locally made products are high quality, diverse and plentiful. However, as large as agriculture is, it represents under one percent of gross domestic product. Just over one percent of the German workforce is employed directly in agriculture. And while these numbers are somewhat larger in some other EU member states, it quickly becomes apparent that agriculture is not in charge of its own future. This is further supported by the fact that most financial support for agriculture in the EU is delivered through environmental budgets for ecological services such as land set aside and wildlife habitat.

We in Canadian agriculture still take pride in the role we played in feeding Europe after the devastation of the Second World War. But in Europe, recent generations are concerned about more than the availability of food. Various failures and scandals by governments, regulatory agencies and large companies have reduced the general sense of trust amongst consumers that the right thing is being done by those in agriculture to protect their food and the environment it is produced in. This sense of distrust has been extended to the research that developed the tools farmers use to manage pests. More than a few EU researchers at the International Rapeseed Congress began their presentations expressing frustration because the solution often put forward by their governments, and farmers like Hubertus Paetow, is research.

This was very apparent in the presentations and poster sessions at the Congress. Leading edge research in certain areas is not being done by EU research institutions as modern biotech tools are not available to them. Groundbreaking work in biotech was increasingly presented by Chinese, Australian and Canadian researchers, with some EU scientists watching wistfully from the audience. However, while their research toolbox has shrunk, it has not been emptied.

The greatest outcome of events like the International Rapeseed Congress is that in bringing together scientists from around the world, from vastly different climates, geographic and political realities, different points of view and ideas are shared. More than a few conversations took place in which phrase *"now **that** is an interesting idea"* was uttered, and a new line of research subsequently pursued. My colleagues from Canada and I, along with the attendees left the Congress less frustrated and with a renewed sense of hope.

—Ward Toma is the general manager of Alberta Canola.

2018/2019 Alberta Canola Research Numbers

Project Title	Alberta Canola's Active Projects	Total project $
Agronomy	$1,123,537.99	$4,523,808.60
Genetics	$462,932.83	$1,939,863.00
Insects	$1,073,845.42	$3,808,051.00
New Product Development	$886,081.00	$2,085,157.00
Pathology	$1,938,896.67	$8,288,500.00
Canadian AgriScience Canola Cluster - 25 projects over 5 years	$1,030,142.00	$20,100,000.00
TOTAL	**$6,515,435.91**	**$40,745,379.60**

ALBERTA CANOLA

SOIL SAMPLING FOR CLUBROOT

TIME: Soil sample the fall after canola harvest or the spring immediately following.

SANITIZE: Use a fresh 2% bleach solution or "Spray Nine" to disinfect tools.[1]

SAMPLING TOOL: Use a tool that can measure the top 2 to 4" of soil (ex: dutch auger).[2,3]

HIGH-RISK AREAS: Field entrances, high-traffic areas, low spots, waterways, and low pH areas.[2]

SAMPLE: Collect 2-3 cups of soil from each high-risk area.[2] Place in a paper bag labeled with date and location sampled. Sanitize tools between sampling sites to avoid false positives.

TEST OPTIONS: PCR will detect the *presence or absence* of clubroot spores. qPCR will give an *approximation of spores* per gram of soil.[2]

DISCLAIMER: Due to the patchy distribution of clubroot spores, results are not indicative of the spore presence and/or concentration throughout the field. False negatives in the field are possible by missing an infested patch.[2]

1. Preventing Clubroot, Agriculture Sanitation – Government of Alberta, 2019 | 2. Clubroot soil sampling on the Prairies – Publication by Province of Manitoba and Government of Saskatchewan , 2019 | 3. Clubroot.ca

Manitoba Canola Growers work to fund, direct, develop and distribute practical, science-based research focused on agronomy. Grower funded research and extension is one of the most valuable services we offer to our membership. Focusing on research that no one else is doing and digging deeper to strengthen our network of research collaborations allows us to increase the value of every research dollar invested.

2018-19 Research Investment

In 2018–19 MCGA invested over $700,000 into research which was leveraged 8 times by partnered funding resulting in a collaborative research investment of $6.2 million.

Extremes of Moisture Initiative

A constant threat to grain production in Manitoba is extreme moisture, both too little and too much. How do researchers approach such a large and complex problem? How do you find, fund and prioritize research projects that have any hope of making a difference?

The Manitoba Canola Growers Association (MCGA), Manitoba Wheat and Barley Growers Association (MWBGA) and Manitoba Pulse Growers Association (MPGA) are collaborating on the"Extremes of Moisture" initiative; a bundle of projects aimed to identify, develop and implement a wide range of multi-disciplinary water management tools and techniques for producers to reduce the negative impact of extreme moisture (with an emphasis on excess moisture).

The multi-disciplinary approach brings unique knowledge, perspectives and ideas to Manitoba from six different technical working groups: engineering, agronomy, genetics and plant physiology, systems and rotations, big data and forecasting, and socio-economic.

Why does this matter to your farm? No single farm or region will be able to resolve their extreme moisture challenges with just one farm management solution. The development of multiple tools addressing the problems from various angles is intended to expand the toolbox of options for each farm, finding the unique combination of tools that best address your evolving challenges.

Nine projects totaling $1.4 million in targeted high-impact research activities have been successfully approved for Canadian Agricultural Partnership funding and are now underway. Two additional projects are proposed and under review.

The approved projects are as follows:

1. **Prairies East Sustainable Agriculture Initiative (PESAI) tile drainage in heavier soils:** Using a research protocol from a previous highly successful Winkler project with different soils to create the basis for modeling the requirements for all variations of soil combinations between the two.

2. **Genetic selection:** Adding extreme moisture (excess moisture) stress evaluation to a portion of Manitoba Crop Variety Evaluation Trials in Manitoba.

3. **Genetic resilience:** A moisture resilience marker Phytoglobin has been identified in corn and soybeans. Important implications for early screening of crop varieties of all types.

This Collaborative Project is Funded By:

Manitoba Canola Growers | Manitoba Wheat and Barley Growers Association | Manitoba Pulse Soybean Growers

Connect with the Research Committee

If you have thoughts or questions regarding Manitoba Canola Growers research, please contact the Research Committee. You are also invited to join us at this year's Annual General Meeting Feb. 13, 2020 at Crop Connect in Winnipeg and please stop by to see us at Ag Days in Brandon.

Chair: **Ron Krahn,** Rivers
ron@canolagrowers.com

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Charles Fossay, Starbuck
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John Sandborn, Benito
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4. **Soil moisture monitoring:** Refining moisture predictability and crop health/risk implications in near real time from existing soil monitoring infrastructure.

5. **Soil moisture capacity:** Organic matter is the single most important soil characteristic for moisture resiliency. Review, standardize and compare multiple techniques for dramatic organic matter increases (including landscape restoration).

6. **Cropping systems one:** Integration of intensive measurement and monitoring systems into existing long-term rotation studies.

7. **Cropping systems (two projects):** Integration of intensive measurement and monitoring systems into existing crop intensification studies.

8. **Optimum nutrient:** Development of improved data based decision systems for Nitrogen management under extreme moisture conditions. Emphasis on extremes rather and averages.

9. **Science to socio economic:** A framework for quantitative analysis of produce and community economic impact of various farm based extreme moisture management options. Direct linkages and defendable economic consequences of captured and uncaptured opportunities.

Projects proposed and under review for funding:

1. **Trafficability:** Yield and profit consequences of various tire/track configurations of seeding equipment in sub optimal conditions. Measures of the impact of soil compaction in current and subsequent crop year resulting from each option.

2. **Water management options in undulating terrain (surface/subsurface):** Considerable emphasis on the unique climate and soil conditions of western Manitoba and the complicating challenges of salinity management. Development of best management practices for soil moisture management in undulating landscapes based on the application of core principles and the experimentation of practices from other jurisdictions.


Credit: iStock.com/ysbrandcosijn

Heavy tillage on moist fields increases compaction, reduces yield

KEY RESULT:
Heavy tillage can increase soil compaction, reduce soil strength and reduce canola yields, especially when carried out under higher moisture conditions and in the spring, prior to planting.

PROJECT TITLE, PRINCIPAL INVESTIGATOR: "Compaction Impacts on Canola Establishment" Curtis Cavers, Agriculture and Agri-Food Canada (AAFC) Portage la Prairie

FUNDING: Manitoba Canola Growers

Excessive precipitation and limited drying weather around the time of various field operations (ex. seeding, input application and harvest) can lead to growers driving heavy equipment over the soil at less favourable moisture conditions, which can result in increased soil strength (soil compaction). This can negatively impact soil health and reduce the long-term productivity of the soil.

Credit: Curtis Cavers

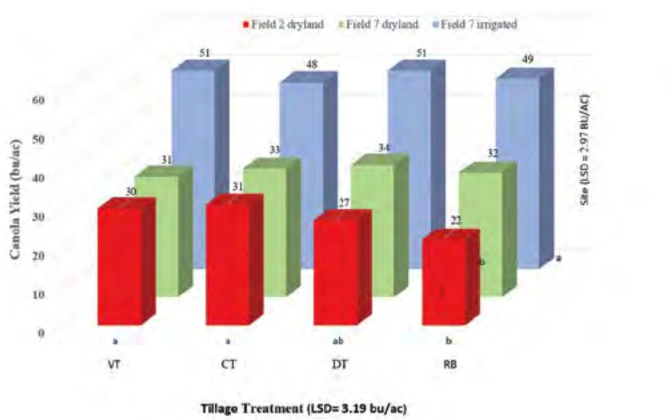
To better quantify the impacts of compaction and determine the best management strategies to reduce negative impacts, this two-year study examined the differences in soil strength and canola stands under four tillage treatments (vertical tillage, conventional tillage, deep tillage with subsoiler and rotovator, and raised bed/controlled traffic agronomy) at varying depths and intensities in both dryland (rain-fed) and irrigated conditions.

A significant difference in canola yields was found among sites, tillage treatments and plant populations. Vertical and conventional tillage produced significantly higher yields than the raised bed system (which had compromised the seedbed conditions). In addition, the deep tillage and raised bed methods had less soil compaction (at eight-inch soil depth) than the other two treatments with more distinct differences in the first, rather than the second year. At this depth, conventional tillage retained the most soil moisture.

Since spring tillage operations prior to planting had a negative impact on the seedbed, fall tillage operations would be preferred (if required).

Plant stand results support previous work on the relationship between stand and yield. Plots with four plants per square foot yielded significantly less than the higher plant populations (seven, 10, 13 plants per square foot), which supports the recommendations that a target plant population of five to eight plants per square foot provides the best stand for achieving agronomic and economic goals for canola production.

Figure 1. Effect of tillage on canola yields by site



Yield results for this Manitoba compaction study. Note: the different tillage types are shown across the x-axis, yield values are shown up the y-axis and the different sites are shown in different colours along the z-axis. Abbreviations: VT, vertical tillage; CT, conventional tillage; DT, deep tillage; RB, raised bed.

Hybrid and seed lot choice could influence seeding rate

KEY RESULT: This study compared three canola seeding rates (5, 10 and 15 seeds per square foot) with small and large seed size lots from two different hybrids. It concluded that the most economic and least risky seeding rate to achieve adequate plant stand population is about 10 seeds per square foot because the response to seeding rate differed between hybrids and seed sizes.

PROJECT TITLE, PRINCIPAL INVESTIGATOR: "Optimal Seeding Rate Based On Seed Size In Canola," Christiane Catellier, Indian Head Agricultural Research Foundation

FUNDING: SaskCanola

Every farm and every field is different, so blanket recommendations for canola seeding rate and stand establishment is difficult. Research was conducted in 2018 to build upon previous seeding rate trials to determine optimal seeding rate across various environmental conditions in Saskatchewan, and to determine if seeding rate varies with seed size and hybrids.

The Canola Council of Canada recommends a canola seeding rate that targets a stand establishment of five to eight plants square foot (50 to 80 plants/m2). This plant stand allows for in-season plant losses due to stresses such as insect, frost or disease while maintaining the four to five plants per square foot population required to reach maximum canola yield. Seed size also varies considerably between and within hybrid seed lots, and is a major factor in establishing seeding rate based on thousand seed weight.

A small-plot field trial was conducted at five Saskatchewan locations (Indian Head, Yorkton, Melfort, Scott,and Outlook). The trial included two hybrid canola varieties, one Liberty Link and one Roundup Ready. Each variety had seed sourced from two seed lots, one with smaller seed and one with larger seed. For the Liberty Link hybrid, small seed was 4.3 grams per thousand seeds and large was 5.5 grams. For the Roundup Ready, small was 4.8 grams and large was 5.9 grams. All four seed lots (LL large and small, RR large and small) were sown at seeding rates of five, 10 and 15 seeds per square foot.

In general, all locations experienced above-average temperatures and below-normal precipitation in 2018. Emergence rates were very high at all locations in 2018, and in-season mortality was minimal. As a result, seeding rates required to achieve adequate plant populations and optimum yield were likely lower than would be expected.

The recommended target spring plant density of five to eight plants per square was attained by seeding at 10 plants per square foot for all four seed lots. Per cent emergence and per cent survival decreased with higher seeding rates, which is typical, but the rate of decrease differed between seed lots. Also, as seeding rate increased, days to maturity decreased by up to two days.

YIELD RESPONSE VARIED BETWEEN HYBRIDS.

Yield of the Liberty Link hybrid did not respond to seeding rate or resulting plant population, and was not affected by seed size. Yield of the Roundup Ready hybrid was significantly lower with a smaller seed lot, and the yield was optimized at the moderate seeding rate. However, if emergence and survival rates had not been so good in 2018, a greater yield penalty may have occurred with lower seeding rates.

The research concluded that the most economic and least risky seeding rate to achieve adequate plant population was found to be 10 seeds per square foot. Growers could also consider using larger seed lots, or a slightly higher seeding density with smaller seeds lots to optimize yield. The effect of seed size may or may not be important depending on the hybrid.

Figure 1. Use enough seed to meet target stand

The effect of hybrid, seed size, and seeding rate on spring plant density in canola, averaged over multiple environments in 2018. The error bars indicate the standard error within treatments. The area within the dashed grey lines indicates the industry recommended target spring plant density.

Seed cost function at the Canola Calculator

The Seeding Rate calculator at **canolacalculator.ca** now has a new seed cost feature to help canola growers set seeding rates that balance agronomy and economics. Enter different scenarios into the calculator to see the economic impact of seed size, percent emergence and target plant density.

The CCC recommends a target plant density of five to eight plants per square foot. Growers can use the target density calculator to determine where in that range they want their individual fields to be, and then measure the economic impact of that density.

Seed early and fertilize well for economics and environment

KEY RESULT:

High-yielding canola with high inputs can be sustainable in an area in which it is adapted. Early-planted full season canola will provide the most sustainable "on-farm" footprint. Canola with high inputs can be the focal point of a crop rotation and can create economic flexibility to allow for a broad crop rotation plan.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"The environmental foot print of canola and canola based products,"
Vern Baron, AAFC Lacombe

FUNDING:
Growing Forward 2

Baron, V.S. (2016). Canola. Life cycle assessment of canola production Science News From the Prairies, March 2017

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Research shows that if Canadian canola growers follow best practices for high-yielding early-planted canola, then their crop will have a lower carbon footprint.

Since 1990, the environmental profile of canola production per tonne has improved, largely as a result of increased yields and plant biomass from enhanced genetics (including herbicide tolerance (HT) and hybrid canola) and improved management practices. In an industry-wide life cycle analysis (LCA) comparing canola greenhouse gas intensity between 1990 and 2010, researchers found that for canola produced in the Black Soil Zone of Alberta, nitrogen fertilizer inputs had increased from 71.6 to 97.2 kg N/ha, but N-use per tonne of seed yield had actually gone down slightly (57.7 to 54.6 kg-N/tonne of seed). That's because average canola seed yield had increased from 1,242 to 2,032 kg/ha for black soils in Alberta over that time.

Researchers next addressed the question of "what is the role of a high-input high-yielding canola crop in a sustainable cropping strategy?" Their objective was to determine the carbon footprint of early- and late-planted canola and early planted barley on a field scale using prevalent "on-farm practice" in central Alberta. Over six years, they compared early-planted canola with high inputs (125 kg N/ha) to both early-planted barley and late-planted canola with lower inputs (80 kg N/ha). From an economic perspective, high-yielding crops in high-yielding areas require less land, enabling extended rotations. In the study, the land base required to net $100,000 was 442 acres for early-planted canola, 946 acres for late-planted canola, and 1,000 acres for the barley. Early-planted canola yielded on average 1,400 kg/ha more than late-seeded canola and overall provided more environmental benefits.

Researchers wanted to determine the greenhouse gas (GHG) intensity (including carbon sequestration) for canola production, and environmental impacts on a product intensity basis (i.e. GHG emitted per kg of seed or oil produced). The study showed that early planting provided the better (lower) GHG intensity. On a seed dry-matter (DM) basis, early barley and canola were lowest (best) and similar. Early-planted canola has a very low GHG intensity on an oil basis, with late-planted canola about 2.5 times larger, and early barley 10 times larger. Overall, on a protein, total energy and oil harvested basis, early planted canola with high inputs was the most sustainable crop management practice.

The carbon balance for all crops and planting dates on average was negative. Higher yielding early-planted canola removes more CO2 equivalent in the harvested oilseed crop, but also returns more in higher crop residues, with net carbon losses half of late-planted canola. Early-planted canola benefits as a full season crop, averaging 100 days of CO2 uptake (net photosynthesis and CO2 sequestration) compared to 84 for late-planted canola and 76 for barley. The system losses in carbon found in this field research project were similar on average to comparable losses in soil carbon predicted by the Century model, a computer simulation model, for these cropping practices. Overall, the research shows a high-input, high-yielding canola crop does play a big role in a sustainable cropping strategy.

GHG Intensity in DM, Protein, Total and Oil Energy Yield for Early Planted Barley, Canola and Late Planted Canola

Crop	DM	Protein	T. Energy	Oil
	—kg CO_2e kg^{-1}—		—kg CO_2e GJ^{-1}—	
Early barley	0.74a	5.8a	40.8b	988a
Early canola	0.67a	3.1b	23.6c	35c
Late canola	1.41b	5.7a	50.2a	78b

Early-seeded canola has a lower environmental impact or greenhouse gas (GHG) intensity on both a seed dry-matter (DM) basis and an oil basis compared to late canola and early barley (circled in red on the graph). The GHG intensity of DM is measured as kg of CO_2 e (carbon dioxide equivalent) emissions per kg of DM or seed produced. GHG intensity of oil is measured as kg of CO_2 e (carbon dioxide equivalent) emissions per gigajoule (GJ) of oil produced. The CO_2 equivalent takes into account the different impacts of nitrous oxide, carbon dioxide and carbon on global warming when all are converted to the same level or basis as CO_2.

FERTILITY MANAGEMENT

Band nitrogen to reduce losses, improve NUE

KEY RESULT:

This one-year study supports previous recommendations that in-soil banding of nitrogen fertilizers during seeding or near to the time of seeding is a best management practice to enhance nitrogen use efficiency (NUE).

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Impact of Source and Placement of Nitrogen and Sulphur Fertilizers on Canola," Ramona Mohr, AAFC Brandon

FUNDING:
SaskCanola

Increasing farm size in western Canada has led many farmers to move back to less efficient broadcast nitrogen application in an effort to hasten spring seeding operations. However, surface application of nitrogen (N) fertilizer can increase the potential for volatilization losses, which reduces the nitrogen use efficiency (NUE) of the crop. Selecting appropriate combinations of N fertilizer source and placement method can potentially reduce volatilization losses and improve fertilizer nitrogen use efficiency by canola.

Researchers conducted two field trials in 2017 to identify fertilizer management practices that reduce the potential for volatilization losses, and improve fertilizer nitrogen use efficiency for canola. The objective of the study was to determine the effect of fertilizer source and placement on canola yield, nitrogen and sulphur (S) use efficiency by the canola crop, and nitrogen volatilization losses on calcareous and non-calcareous soils in the Aspen Parkland ecoregion.

In 2017, small-plot field experiments were conducted on calcareous and non-calcareous soils near Brandon, Manitoba. Various treatments were compared, including a control receiving no N or S fertilizer, and a combination of various N and S liquid and granular fertilizers and placement methods, for a total of 18 treatments. Fertilizer sources included ammonium sulphate, ammonium thiosulphate, urea, potassium sulphate, urea ammonium nitrate (with and without Agrotain or ATS), SuperU and/or urea impregnated with ammonium sulphate. Placement methods included pre-plant broadcast, pre-plant band or dribble band after seeding. An N rate of 60 kg/ha, which was expected to be less than that required to achieve optimum yield, was applied to allow differentiation among the N fertilizer treatments.

Banding often reduced early-season volatile N losses compared to surface-applied fertilizer N applications, particularly at the calcareous site. Banding also showed increased N uptake at flowering, suggesting that in-soil banding contributed to a higher available N supply. Pre-plant banding at the calcareous site consistently increased canola yield compared to surface application of granular fertilizer N products, while pre-plant banded urea increased yield compared to surface application of both conventional and enhanced efficiency fertilizers. The per cent fertilizer N recovery was typically higher for banded than broadcast granular fertilizers at the calcareous site.

At the non-calcareous site, the differences among the fertilizer management practices were less frequent. This is likely due to lower soil carbonate concentration and slightly lower soil pH, which may have reduced the potential for volatilization losses. Under the 2017 growing season conditions, the findings showed that surface-application of select fertilizers produced similar canola yields and per cent fertilizer N recoveries as banded treatments. However, researchers caution applying these findings more broadly, given the many growing season and other factors that may influence N volatilization, fertilizer use efficiency and yield response.

Although in some cases in the current study, surface-applied conventional or enhanced efficiency fertilizers performed as well as banded treatments, in no case did surface-applied fertilizer N outperform banded urea in terms of nitrogen use efficiency or crop performance. Decisions regarding surface-application versus in-soil banding of fertilizer N require consideration not only of operational requirements and the direct costs of fertilizer applications, but also of the relative risk of N loss of surface-applied N and the implications with respect to return per fertilizer dollar.

Overall the study findings reflect previous research in western Canada which supports the use of in-soil banding of N fertilizers during seeding or near to the time of seeding as a best management practice to enhance nitrogen use efficiency in canola and other crop production systems.

Work is underway to combine the current findings with previous site-years of data in order to better understand the relative efficiency of various fertilizer management practices under a range of environmental conditions.

Credit: Ramona Mohr

Canola yields lower with fall surface-placement of nitrogen

KEY RESULT:

This Manitoba study found that nitrogen source did not affect canola yield, but fertilizer placement did. Fall surface application of granular urea and enhanced efficiency fertilizer products produced lower yield (13 bu./ac.) than spring surface applications of the same products. For spring applications, surface placement had lower yields (3 to 5 bu./ac.) than shallow or deep banding.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Canola Response and Minimizing Nitrogen Losses in Two-Pass Seeding-Fertilization Systems with Varying Placement Methods in Manitoba," Mario Tenuta, University of Manitoba

FUNDING:
Manitoba Canola Growers, SaskCanola, KOCH Agronomic Services

Due to increasing pressure to complete field operations in a timely manner and the increased use of custom fertilizer applicators, some Western Canadian canola growers have shifted towards surface applications of granular urea. This is a departure from the recommended practice of deep banding, which greatly reduces nitrogen loss through ammonia (NH_3) volatilization.

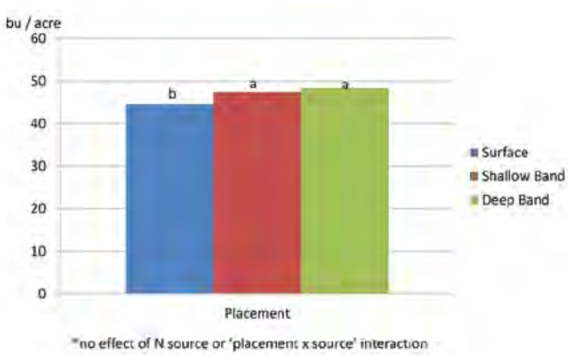
While deep banding is a superior technique with respect to protecting nitrogen fertilizer from gaseous losses via NH_3 volatilization or N_2O emissions, the placement technique does require additional horsepower, can slow field operations at seeding time, and may also have undesirable effects on seedbed quality and moisture content. As a compromise, many canola growers are shallow banding (<1") urea or using commercially available enhanced efficiency fertilizers (e.g. SuperU or Agrotain) to reduce NH_3 losses from surface application.

This project evaluated the agronomic and environmental performance of surface broadcast, shallow banding and deep banding methods of applying nitrogen fertilizer to canola in order to maximize yield and reduce nitrogen losses.

Six research trials were run from 2014–16 in the Red River Valley of Manitoba to evaluate the agronomic and environmental performance of treatment combinations of source (urea, Agrotain, SuperU), placement (surface, shallow and deep mid-row banded) and rate (100 and 70 per cent of soil test recommendation) for spring applications. The inclusion of a 70 per cent rate in the experiment was to (purposely) provide less nitrogen than is needed by the canola crop in order to highlight treatments providing better nitrogen use efficiency as yield improvements. In addition, fall surface placement treatments were done for the 2016 growing season. Nitrous oxide (N_2O) emissions from urea and SuperU as well as ammonia volatilization using dosimeters were also detailed.

Sampling nitrous oxide (N_2O) emissions from chambers following planting and nitrogen application. N_2O emissions were lower with SuperU than they were for urea, and lower with subsurface banding than with surface placement.

Figure 1. Yields are better with banding



For spring applications, surface placement (blue) had lower yields (3 to 5 bu./ac.) than shallow (red) or deep banding (green). These results are from five of the six trial sites in response to spring nitrogen placement at the 70 per cent of the recommended nitrogen rate. Data for one site (Carman2) is not included as that site had poor emergence. Mean grain yield for columns topped by different letters are significantly different $P < 0.05$.

The results of the study indicate that the nitrogen source products examined did not affect canola yield, but the fertilizer placement did. For spring applications, surface placement had lower yields (3 to 5 bu./ac.) than shallow or deep banding (Figure 1). Fall surface application of granular urea and enhanced efficiency fertilizer products with urease and nitrification inhibitor (at 100 per cent of the Manitoba Agriculture recommended rates) produced lower yield (13 bu./ac.) than spring surface applications of the same products.

Across the full study, NH_3 volatilization was low but there was a clear trend of reduced losses with surface-placed SuperU when compared to surface-placed urea, and lower losses with the sub-surface banding when compared to surface urea treatments. Similarly, N_2O emissions were lower with SuperU than they were for urea, and lower with subsurface banding than with surface placement.

These results verify past research that subsurface banding of granular urea improves yields compared to surface application. As well, fall surface applications are less efficient than spring applications.

Foliar-applied P can help with in-season deficiency

KEY RESULT:

While this Saskatchewan study did show a yield response for foliar-applied phosphorus (P) when compared to a control without any P fertilizer, the best practice is still to meet crop needs with fertilizer applications before or at the time of seeding.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Crop response to foliar-applied phosphorus fertilizers," Jeff Schoenau, University of Saskatchewan (with Masters student Stephen Froese)

FUNDING:
Saskatchewan Agriculture Development Fund, SaskWheat, SaskCanola, SaskPulse

This study evaluated the response to foliar phosphorus (P) fertilization of canola, pea and wheat grown in Brown, Dark Brown and Black soils in Saskatchewan.

In controlled environment (growth chamber) and field trials, all treatments received equivalent P fertilizer rates of 20 kg of phosphate (P_2O_5) per hectare. Mono-ammonium phosphate (MAP) was used for seed-placed treatments. Mono-potassium phosphate (KH_2PO_4) was used for the foliar applications.

KH_2PO_4 was used for foliar applications because it is more soluble than MAP and has been used in previous studies of foliar P nutrition (e.g. Green and Racz, 1999). With higher solubility, KH_2PO_4 produces a solution of reasonably high concentration so that huge volumes of liquid do not have to be applied. Any potential effect of K in the foliar treatment was assumed to be negated by high available K content of soils at the sites, with soils deemed not deficient in K according to soil test. Further, a blanket application of K fertilizer was made to override possible influence of the treatments on K nutrition and yield.

The five treatments were: (1) control with no added P; (2) 20 kg/ha of phosphate as seed-placed; (3) 15 kg/ha seed placed and 5 kg/ha foliar applied; (4) 10 kg/ha seed placed and 10 kg/ha foliar applied; and (5) all 20 kg/ha foliar applied.

Foliar treatments were made at canopy closure, which was the rosette stage for canola. Controlled environment studies were conducted with two soils (Echo and Krydor soil associations) and field studies with four soils (Echo, Krydor, Sutherland and Weyburn soil associations) in 2016 and 2017.

RESULTS

Uptake of nutrients through leaf tissue is a passive process where nutrients will diffuse from areas of high concentration (such as from a droplet on the leaf surface) to areas of low concentration (such as inside a P-deficient leaf). While yield results for canola do suggest some uptake of P through leaf material, foliar P application did not effectively balance off the yield lost when rates of seed-placed MAP fertilizer were reduced. Foliar P applied mid-season appeared most effective as a top-up rather than a replacement for seed-row applied P.

Of the three crops, canola was the most responsive to P fertilization in terms of yield and P uptake response, followed by wheat and pea.

In conclusion, the foliar option for P fertilizer is not a good alternative to seed placed – unless the field is known to be highly deficient (less than 10 parts per million of P in the top 6" of soil) and no other applications were made to address this deficiency.

The better approach for these fields would be to apply phosphate fertilizer in the soil at a time when the crop can access early on in its growth cycle. This could be done with a combination of seed-row placement (at safe rates, like those used in this study) and side-band or spring-band placement to achieve the recommended application rate as dictated by soil tests.

Figure 1. Grain yield (kg/ha) for all five treatments at four Saskatchewan trial locations

	Pilger		Central Butte		Rosetown	Mawer
	Black Soil Zone		**Brown Soil Zone**		**Dark Brown Soil Zone**	
	2016	2017	2016	2017	2016	2017
Soil test P levels* (ppm)	7	6	11	9	12	8
Control (no added P)	1,322 c	1,365 b	4,470 a	863 ab	4,956 a	1,792 a
Seed-placed only	4,966 a	1,856 a	3,656 ab	851 ab	3,474 b	1,495 ab
Foliar 25%, seed-placed 75%	2,184 b	1,877 a	3,069 b	1,072 a	4,463 ab	1,502 ab
Foliar 50%, seed-placed 50%	2,181 b	1,646 ab	4,680 a	835 ab	4,770 a	1,325 b
Foliar only	2,177 b	1,590 ab	4,658 a	727 b	4,544 ab	1,783 a

*Phosphate rates totalled 20 kg/ha for all treatments (except the control). For each column, yields that share a letter are considered statistically the same. *Soil test P levels are based on Modified Kelowna extractable P, given as mg per kg of soil (or parts per million) in the top 15cm.*

Above Table: All of these soils tests would be considered 'low' for P. In general, the yield response for canola decreased as the proportion of seed placed MAP decreased and proportion of foliar P increased. But you can see that results were not consistent for all locations and all years.

Placement outside the seed row is fine for phosphate

KEY RESULT:

Placing phosphate fertilizer in the seed row has its challenges because seed damage can occur at fairly low rates. Rather than short the crop with a low seed-placed rate, this study found that the full recommended rate placed outside the seed row is the better option.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Enhancing Canola Production with Improved Phosphorus Fertilizer Management," Jessica Pratchler and Stewart Brandt, Northeast Agriculture Research Foundation

FUNDING:
SaskCanola

This study shows promise for placing all phosphate fertilizer outside the seed row versus in the seed row, especially at rates required to meet canola's season-long demand for the nutrient.

Most soils in Saskatchewan are deficient in available phosphate (P_2O_5) and this macronutrient typically limits crop growth and yield. (Average available phosphate levels in Alberta and Manitoba are slightly higher, but not much.) Furthermore, canola has a relatively high phosphate requirement compared to cereals. With the ever-increasing yield potential of newer canola hybrids, phosphate nutrition in this crop is crucial to ensure that yield potentials are optimized.

Phosphate is relatively immobile, so placement of the fertilizer can influence when and how the crop can use it. The common recommendation for canola is to band fertilizer phosphate in the seed-row, but high seed-placed rates can reduce emergence. Fertilizer damage to canola seedlings and stand establishment has been shown in various recent studies, including this one. This study took the research a step further to see how modern hybrids could perform with all phosphate placed outside the seed row.

The trial was designed as a two-factor factorial with treatments arranged in a four-replicate randomized complete block design. The first factor was five fertilizer P_2O_5 rates ranging from 0, 20, 40, 60, and 80 kilograms per hectare. (20 kg/ha is around 18 lb./ac.) The second factor was placement, which compared side-band, seed-placed, and seed-placed in combination with ammonium sulphate (at a fixed 15 kg/ha rate). Small plot trials were established at Indian Head, Melfort and Scott, Saskatchewan over a three-year period (2016 to 2018).

Results of this research showed damage to canola stand establishment even from very low rates of seed-placed phosphate, but the level of damage was not as severe as with previous studies. Researchers wonder if that's the result of using a hoe-type opener, which has higher seed-bed utilization (and thus improved seed safety from fertilizer), instead of disc opener. However, researchers found that predicting the degree of damage caused by seed-placed fertilizer is very difficult as it is influenced by other factors such as soil texture, soil organic matter and moisture. Since these factors vary considerably across most fields, damage can be quite variable across the various landscape positions. Furthermore, even adding a small amount of ammonium sulphate to P in the seed-row can increase damage to seeds and reduce canola emergence. Therefore, this practice should be discouraged.

Overall, the researchers found no evidence of better responses associated with seed-placed P over side-band P, even at low rates, and that high rates of side-banded P are always equal to or greater than seed-placed. This was true for stand establishment and yield.

Yield improved with higher phosphorus rates in general, and in some cases, were found to be even greater with side band treatments, especially at higher rates.

Figure 1. Phosphorus placement effect on plant density

Phosphorus placement can have an effect on plant density (plants per square metre), as shown with these plant counts taken two weeks after seeding at Scott from 2016 to 2018. Scott was the only location were fertilizer placement had a significant effect on initial plant density (measured two weeks after seeding). The effect of fertilizer placement at the other two study locations (Indian Head and Melfort) was dependent on the study year.

Optimal canola yields were reached between 70 and 80 kg/ha of fertilizer P. Therefore, if high rates of phosphorus are required, fertilizer P should be side-banded to minimize seed damage and maximize yields as it was the most consistent and beneficial application method. Due to minimized seed damage, the high plant populations achieved as a result of side banding can provide the added benefit of reduced days to maturity, which will lower green seed risk.

The researchers conclude that the optimal phosphorus management practices have changed for growing canola in Saskatchewan, and that all or most of the phosphorus fertilizer applied should be side-banded, especially when higher rates are needed.

Credit: Clint Jurke

Glucosinolates in canola residue could influence nitrogen release

KEY RESULT:

This study confirms there is significant potential for canola residues to enhance N_2O emissions relative to those associated with wheat, flax and pea residues. This potential appears to be associated with the release and subsequent transformation of glucosinolates into a variety of bioactive compounds during crop residue decomposition.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Identifying the mechanisms responsible for greater-than-expected residue-induced N_2O emissions from canola and flax,"
Richard Farrell, University of Saskatchewan

FUNDING:
SaskCanola, Agriculture Development Fund

Previous research found a higher potential for nitrous oxide (N_2O) emissions from decomposing canola and flax residues compared to wheat or pea residues. This project aims to identify the reasons for this and provide guidance for future studies to develop and test strategies to minimize N_2O emissions from oilseed residues and retain more residue-derived N in the soil for subsequent crop growth.

The overall study consisted of a series of lab and greenhouse studies undertaken to test the factors thought to contribute to N_2O emissions from canola, flax, pea and wheat residues.

In the first experiment, soil from a canola field was amended with residues from all four crops. These soils were then moistened and incubated at room temperature to promote nitrification and denitrification. Results suggests that soil incorporation of crop residues promotes N_2O production. It also found that for the soil amended with canola residue, N_2O emissions went up while abundance of the *nosZ* gene abundance—the gene that codes for the soil-bacteria enzyme that reduces N_2O to N_2 — went down. Thus, while all residues promoted N_2O production, canola residue also inhibited N_2O consumption thereby increasing the "yield" of N_2O emitted.

The second experiment, also lab-based, want to test an old theory that glucosinolates in canola residue somehow increased N_2O emissions. The experiment involved spiking fertilized soil with freshly ground seed meal that either did (rapeseed meal) or did not (pea meal) contain glucosinolates. Results demonstrated that glucosinolates strongly impacted the N processing dynamics in such a way as to produce a dramatic increase in N_2O emissions. Moreover, there was a strong interaction between fertilizer-N addition and the incorporation of glucosinolate-containing seed meal. This finding, together with those of the first experiment, strongly suggest that one or more of the derivatives of glucosinolate decomposition "turns off" the expression of the *nosZ* gene, the soil-bacteria gene known to promote denitrification of N_2O into the benign N_2. The result is an increase in N_2O yield.

The third experiment involved a greenhouse study in which wheat was grown in soil from a field that had been in a cereal/pulse crop rotation for four years and was amended with canola, flax or wheat residues and fertilizer-N. Unlike in the lab-based experiment one, which did not include plants, this experiment showed no significant treatment (residue) effect on total N_2O emissions, while residue-derived emissions from the soil amended with canola residue were lower than those from the wheat-amended soil. These results likely reflect differences in the experimental conditions; e.g., the presence of plants in the soil is expected to exert a significant influence on both N and water availability—reducing both and limiting the formation of conditions favouring denitrification (the process most influenced by glucosinolates).

Conclusion: Taken together, results from this study show that (1) there is there is significant potential for canola residues to enhance N_2O emissions relative to those associated with wheat, flax, and pea residues; and (2) emissions enhancement is a result of canola residues releasing bioactive compounds during their decomposition that influence denitrifier communities in the soil—effectively increasing the yield of N_2O by inhibiting its reduction to N_2.

Future studies will need to determine appropriate mitigation strategies to reduce emissions associated with canola residues. These strategies may include the use of a nitrification inhibitor (applied either alone or as an enhanced efficiency fertilizer) or the use of a fall cover crop to reduce fall nitrate-N levels in the soil.

Tips for a more integrated approach to flea beetle control

KEY RESULT:

This study validated the nominal economic threshold of 25 per cent defoliation. It also determined significant associations between landscape structure and flea beetle abundance, weather and flea beetle abundance, and plant density and flea beetle damage. As well, two flea beetle predators were confirmed.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Integrated approaches for flea beetle control – economic thresholds, prediction models, landscape effects, and natural enemies," Alejandro Costamagna, University of Manitoba

FUNDING:
AAFC Agri-Science Project, Alberta Canola, SaskCanola and Manitoba Canola Growers

Flea beetles are a major insect pest, threatening the establishment of canola by feeding on emerging seedlings. This project aims to investigate natural enemies impacting crucifer (*Phyllotreta cruciferae*) and striped (*P. striolata*) flea beetle populations, identify landscape features promoting effective natural enemies, develop models for flea beetle populations based on weather and crop variables to provide timely prediction of the flea beetle population, and to determine a nominal threshold for flea beetles in canola.

Through 2015-17, researchers conducted 41 economic threshold field trials, sampled 78 grower fields to investigate landscape features promoting effective natural enemies and lower infestation levels, and made 563 observations at 71 locations to develop predictive models for flea beetle populations based on weather and crop variables. In addition, laboratory work was conducted to develop molecular tools to identify predators that impact flea beetle populations.

KEY RESULTS:

1. Analyses suggest that the nominal economic threshold of 25 per cent is correct, pending further replication in the final year of the project. The study also observed that neonicotinoid seed treatment produced the highest numerical yield in the early-seeded trials. Applying foliar insecticide also provided some yield protection compared to the plots without control measures.

2. The lab study found primers to identify striped and crucifer flea beetle DNA in the gut contents of insect predators. These primers were used to assess which insects may be predating on striped or crucifer flea beetles. Two carabid (ground) beetles – *Pterosticus melanarius* and *Amara torrida* – were found to attack flea beetles. Management strategies that increase the population of these ground beetles could help reduce flea beetle populations in growers' fields.

3. Significant relationships between flea beetle abundance, plant density and canola damage were determined. This can guide growers to increase flea beetle monitoring in higher risk areas. The percentage defoliation generally increased with the greater number of flea beetles. It was also found that the defoliation never exceeded the nominal threshold of 25 per cent, which either suggests that seed treatments gave adequate protection against flea beetles or that flea beetle abundance was not high enough to cause economic damage. The negative interaction between the number of plants and the number of flea beetles implies that varying plant densities would produce different amounts of defoliation for the same number of flea beetles. While plant density is important in determining of flea beetle economic thresholds, more analysis and investigation is required to provide recommendations on the ideal plant density to reduce to best manage flea beetle damage.

WEATHER EFFECT ON STRIPED FLEA BEETLE:

Regarding weather impacts, a warmer April and May, a cooler and wetter June, and accelerated plant growth were positively correlated with greater spring striped flea beetle populations. May had the most impact temperature-wise, as warmer temperatures signaled larger beetle pressure whereas cooler temperatures signaled lower beetle pressure. However, striped beetle pressure in the spring did not mean they wouldn't be active in the summer.

Right: Sticky cards were used to assess flea beetle and natural enemy populations in the economic-threshold plots.

WEATHER EFFECT ON CRUCIFER FLEA BEETLE:

More rainy days in May and June were positively correlated with spring crucifer flea beetles populations, although too much rain in June had a negative impact. Warmer Mays were positively correlated with higher spring crucifer populations. Low crucifer pressure in the spring also seemed to show low probability of crucifer populations in the summer.

Researchers did note, however, that modelling using only weather data was difficult because there were instances where locations less than 20 km apart (which had the same weather) reported different flea beetle patterns.

Credit: iStock.com/Antagain

Pollinators increase yield and mitigate drought impacts

KEY RESULT:

Pollinators increased canola yield by promoting earlier flowering and reducing loss associated with drought. However, pollinators were unable to compensate for suboptimal seeding rate or low nitrogen fertility.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Getting more bang for your buzz: Does pollination compensate for canola yield lost under sub-optimal soil moisture, nitrogen fertilization and/or seeding rates?"
Ralph Cartar, University of Calgary

FUNDING:
Alberta Canola, Manitoba Canola Growers, SaskCanola, Alberta Beekeepers' Commission

Get more bang for your buzz. This project consisted of three experiments that investigated whether pollinators could help maintain yield under drought (which they could, to an extent) or while reducing inputs like fertilizer and seed (which they couldn't).

EXPERIMENT 1: HIGHER YIELD WITH POLLINATORS

In a greenhouse experiment, 23 varieties (9 open-pollinated and 14 hybrid) were grown in the presence or absence of pollinators. Total canola yield and quality were higher in canola plants exposed to insect pollination, even though the presence of pollinators reduced plant size. By shifting peak flowering earlier, pollinators increased yield, and reduced the crop's dependency on aborted pods (scars) or later reproduction (branch pods).

EXPERIMENT 2: POLLINATORS INCREASED YIELD BY 20% DURING DROUGHT

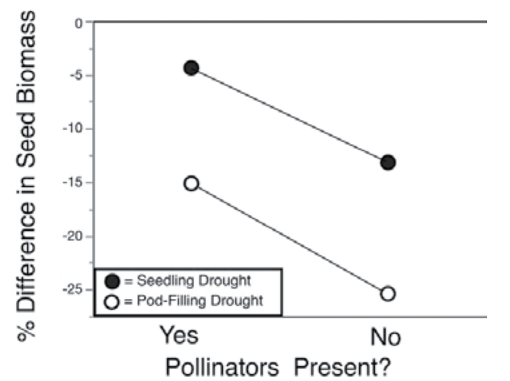
In this greenhouse experiment comparing pollinators with non-pollinator treatments, canola was subjected to moisture stress by receiving 30 per cent of normal watering at the vegetative stage (from the fourth leaf to the first visible petal, called "seedling drought") and the pod-filling stage (end of flowering to harvest, called "pod-filling drought").

Pollinators reduced the negative effects of drought with approximately 20 per cent higher yield, regardless of whether the drought was experienced during the seedling or the pod-filling stage. The fitness "bump" provided by pollinators was accomplished primarily by shifting the plant's flowering phenology earlier and narrower.

EXPERIMENT 3: POLLINATORS COULD NOT COMPENSATE FOR POOR PLANT STANDS

This field experiment examined three treatments using four hybrid varieties of canola grown in 80 experimental plots at the AAFC Research Station in Beaverlodge, Alberta. Two plant spacing treatments (half of conventional at 75 seeds/m2 and conventional, 150 seeds/m2) and two fertilizer rates (none, conventional) were compared with pollinators present or absent. This was controlled using screen tents installed just before 10 per cent bloom.

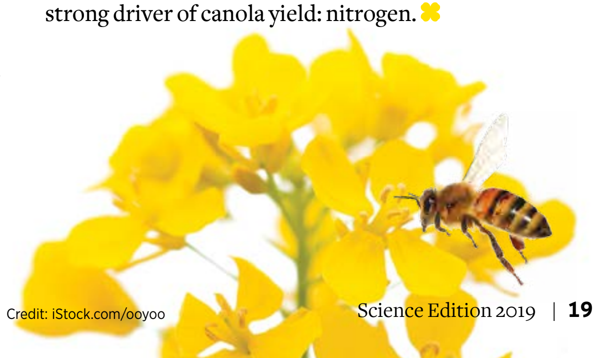
Figure 1. Pollinators help plants under drought stress



Pollinators can help preserve canola yield when plants encounter drought at seedling and pod-filling stages. The top of the graph ("0") represents baseline yield. Points on the graph show the seed biomass drop from drought when pollinators are present (left) or not (right).

In the field over two summers, pollinators did not buffer yield in the face of less costly inputs (lower seeding amounts, lower N fertilization). Instead, pollinators were usually associated with equal or lower yields relative to plants in a screen tent. Pollinators marginally reduced the oil content of unfertilized plants, and marginally reduced the protein content of fully fertilized plants.

The research found that nitrogen was the principal determinant of plant yield and seeding rate was the second biggest factor. Overall, the importance of pollinators in the Experiment 3 field trials was dwarfed by the strong driver of canola yield: nitrogen.



Credit: iStock.com/ooyoo

New tool forecasts Sclerotinia risk

KEY RESULT:

The canola growth stage prediction model and sclerotinia stem rot risk index deployed on **www.canoladst.ca** are useful tools for managing the disease.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Operational models to forecast canola growth stage, Sclerotinia risk, and yield in Western Canada,"
Rishi Burlakoti, Agriculture and Agri-Food Canada

FUNDING:
Growing Forward 2

Credit: iStock.com/Farknot_Architect

The web-based sclerotinia stem rot risk assessment tool at ***canoladst.ca*** *shows the expected date for key flowering stages for fungicide application. It also uses weather data to estimate the disease risk, shown as "Moderate" in this example*

The major objectives of this project were to develop and deploy forecasting tools for canola growth stages, a sclerotinia stem rot risk model, and a yield model to forecast local and regional canola production.

Small plot and field-scale trials were conducted from 2014 to 2017. Each small plot trial had three varieties (representing short-, medium- and long-season cultivar groups) with four replications. The field-scale trials had one cultivar with four replicates within a large field.

In all locations, canola growth stages were recorded using time-lapse cameras and also observed manually once a week. On-site, in-canopy and outside-canopy weather conditions were monitored during the entire growing season. In one location in Manitoba, sclerotia depots were deployed and sclerotia germination (apothecia) was counted. Sclerotinia stem rot was recorded two to three times after crop maturity before swathing.

Accumulated growing degree days, physiological days and crop heat units (CHU) models were compared for 14 selected crop stages from emergence (BBCH 9) to ripe (BBCH 89). Physiological days were selected as the best model for predicting growth stages for short, mid, and long season varieties. This model successfully predicts growth stages in canola, and meets expectations for the most important canola stages of flowering, BBCH 60 and BBCH 65.

Sclerotinia stem rot incidences were widespread ranging from zero to 55 per cent in the four years of research trials. Based on sclerotinia biology and disease cycle as well as sclerotinia stem rot checklists previously developed by the Canola Council of Canada, a sclerotinia stem rot score card was developed. The score card has both weather and agronomic factors as input variables.

Based on the growth stage and sclerotinia stem rot models, a web-based tool was developed by Weather INnovations. It provides a risk assessment as well as an estimated date when the canola will reach 14 different growth stages. These models provide canola growers with decision support to apply or forego fungicide application. This is important for grower profitability, reduced production risk and environmental sustainability.

Both the web-based tool can be found at **www.canoladst.ca** or at **www.decisionfarm.ca**. The websites are free and can be used to deploy site-specific advisory for growth stage prediction and sclerotinia stem rot risk in Manitoba, Saskatchewan and Alberta. Weather data from Weather Farm stations and other networks owned by Weather INnovations as well as Environment Canada stations are integrated with GIS system to provide field-specific information.

A yield model was not produced because of variables outside of Weather INnovations control such as insect damage, severe flea beetle damage, blackleg, root rot lodging, nutrient deficiencies and club root damage.

Tests to improve *Sclerotinia sclerotiorum* control

KEY RESULT:

Heads Up, a resistance activator applied to seed, was found to enhance resistance against *Sclerotinia sclerotiorum* causing white mould in dry bean, but showed no benefit for canola. Adding a micronutrient to a foliar fungicide improved control of *S. sclerotiorum* for two of the six fungicides tested.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Improving Sclerotinia disease control in edible beans and canola," Michael Harding, Alberta Agriculture and Forestry

FUNDING:
Alberta Crop Industry Development Fund (ACIDF)

Harding, M.; Nadworny, P.; Buziak, B.; Omar, A.; Daniels, G.; Feng, J., Improved Methods for Treatment of Phytopathogenic Biofilms: Metallic Compounds as Anti-Bacterial Coatings and Fungicide Tank-Mix Partners. Molecules 2019, 24, 2312.

Researchers continue to work to provide growers with a 'heads up' for sclerotinia stem rot in canola and white mould in dry bean, both caused by *Sclerotinia sclerotiorum*. While a foliar fungicide is an important tool for management of the pathogen, researchers continue to look for additional ways to improve disease control.

This project evaluated two ways to improve *S. sclerotiorum* disease control. The first was through improved fungicide control using a micronutrient tank mix partner. The second investigated activation or enhancement of host resistance with seed treatments. Both have been effective in research on crops other than canola and dry bean.

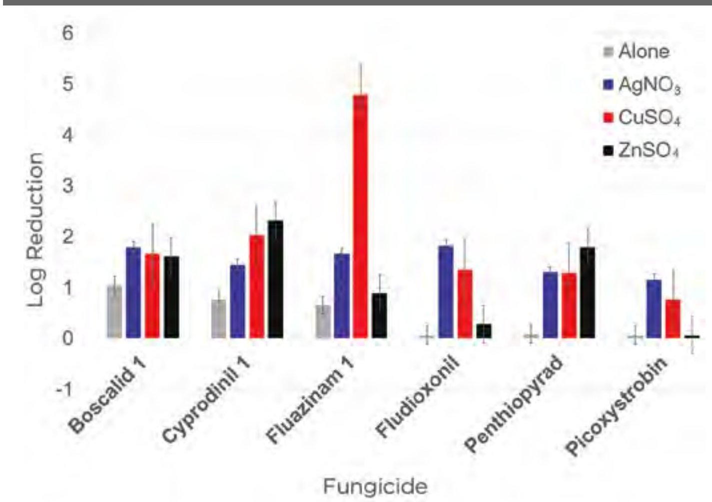
To investigate improved foliar fungicide control, six fungicides (boscalid, fluazinam, penthiopyrad, picoxystrobin, cyprodnyl, fludioxinil) and six micronutrients (silver, Ag; boron, B; calcium, Ca; copper, Cu; manganese, Mn; and zinc, Zn) were screened for synergistic interactions against *S. sclerotiorum* biofilms. (The term 'biofilm' means a microorganism growing attached to a surface, and often encased in a slimy, self-produced layer. Virtually all microorganisms (bacteria and fungi) grow as biofilms in natural environments, including agricultural environments.) Biofilm testing offers a high-throughput laboratory screening of fungicide effectiveness. This biofilm testing identified the most promising combinations from the 324 fungicide/trace element combinations.

Fluazinam activity was the most responsive to the micronutrient tank-mix in reducing *S. sclerotiorum* biofilms. For example, efficacy went from a 1-log (90 per cent) reduction when the fungicide was used alone, to more than a 4-log (99.99 per cent) reduction when the copper compound $CuSO_4$ was added. Fluazinam was also responsive to $AgNO_3$. Cyprodinil was the next most responsive, and its activity was increased with $AgNO_3$, $CuSO_4$ and $ZnSO_4$.

The top 10 combinations were used in field trials at two locations for white mold on dry bean (Brooks, AB and Lethbridge, AB), and two locations for stem rot on canola (Brooks, AB and Edmonton, AB from 2014 through 2016 (no canola data in 2015). While the effects of tank-mixing of some micronutrients with fungicides were easily measurable, and statistically significant, in laboratory testing, their efficacies in the field were often not discernible due to low disease pressure and other variables that could be controlled in the field. As a result, any consistent beneficial effect due to tank-mixing fungicides with micronutrients could not be confirmed in the field trials.

Field evaluations of the plant resistance activators were performed from 2013 through 2016 at the same locations (no canola data in 2013 and 2015). A bio-fungicide, Heads Up, was the best at reducing white mould in dry bean for three out of eight site years. Heads Up had the highest seed yield for dry bean in five of eight site year, and has rapidly become a standard treatment on all dry bean seed planted in Alberta. Unfortunately the effect was only observed on dry bean and not on canola. However, most of the canola work was done using seed already treated, which could have interfered with the resistance activators.

Figure 1. Do micros improve fungicide performance on sclerotinia?



A "log reduction" is a term used to describe the efficacy of a disinfectant. 1 log is 90%, 2 is 99%, 3 is 99.9%, 4 is 99.99% and so on. For Fluazinam, for example, the product alone was less than 90% effective but with copper sulphate ($CuSO_4$) added was over 99.99% effective.

Fumigant may be practical treatment for small clubroot patches

KEY RESULT:

Soil fumigation with metam sodium can reduce clubroot severity and improve plant health in the subsequent canola crop. But because of high rates required and high cost per acre, fumigation may have a role in the eradication of localized or isolated areas of infestation.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Toward a Strategy for Reducing the Spore Density and Dissemination of Clubroot of Canola in Alberta,"
Sheau-Fang Hwang, University of Alberta

FUNDING:
Alberta Canola, ACIDF, WGRF

Hwang, S.F., H.U. Ahmed, S.E. Strelkov, Q. Zhou, B.D. Gossen, G. Peng, G.D. Turnbull. 2018. Effects of rate and application method on the efficacy of metam sodium to reduce clubroot (Plasmodiophora brassicae) of canola. European Journal of Plant Pathology doi.org/10.1007/s10658-017-1281-y

Hwang, S.F., H.U. Ahmed, Q. Zhou, S.E. Strelkov, B.D. Gossen, G. Peng and G.D. Turnbull. 2014. Efficacy of Vapam fumigant against clubroot (Plasmodiophora brassicae) of canola. Plant Pathology 63: 1374-1383. http://Doi: 10.1111/ppa.12207

Hwang, S.F., H.U. Ahmed, S.E. Strelkov, Q. Zhou, B.D. Gossen, M.R. McDonald, G. Peng, and G.D. Turnbull. 2018. Suppression of clubroot by dazomet fumigant. Can. J. Plant Sci. 98: 1-11. https://doi.org/101139/CJPS-2017-0099

Clubroot continues to spread through Alberta and the Prairie provinces. In Alberta, clubroot occurrence expanded from 1,064 fields in 24 counties at the beginning of the project in 2014 to more than 3,000 fields in 40 counties by 2018. Preventing the establishment of clubroot in a field can save producers millions of dollars both in control measures and in lost crop revenue and land value. Fumigation at field entrances reduces spore populations in newly-introduced infestations and reduces the risk of more widespread clubroot establishment in a field.

The aim of this three-year project was to develop a better understanding of the distribution and dispersal of clubroot and to develop methods to eradicate or reduce newly established infestations within fields and on a regional basis. The research continued clubroot surveillance and added pathotype monitoring, which will allow for better risk assessment and the selection of appropriate management strategies.

Experiments were conducted to evaluate the effect of metam sodium (Vapam) fumigant and application methods including watering, soil surface covering and soil incorporation on clubroot of canola.

Application of metam sodium reduced clubroot severity and increased stand establishment, plant growth and yield. Vapam application was effective at 400-800 litres per hectare, with some residual toxicity noted at higher rates. (This is equivalent to the 40 to 80 millilitres per square metre in the photo.) The application was most effective and resulted in the highest yields when the treated area was sealed under plastic for 12 days, but sufficient ventilation time (one to two weeks) must be allowed afterwards before seeding to avoid residual toxicity. Researchers also assessed the biofumigant MustGro at several rates, but few treatment effects were observed.

Soil fumigation methods give producers the option to eliminate new clubroot infection sites before they become firmly established, thereby slowing the spread of the disease and minimizing its impact. Fumigation treatments may not be feasible or economical on a whole-field scale, but may be effective when targeted to localized spots in a field. Use of resistant cultivars will further reduce the risk of establishment of clubroot in a field. However, repeated cultivation of resistant cultivars in fields with established infections increases the risk of the development of new strains of clubroot that can defeat resistance resources.

Visual results for application of metam sodium fumigant (Vapam) in a growth chamber study in clubroot infested soil. Left is control with no Vapam. Next is the result with Vapam at a rate of 40 millilitres (mL) per square metre, followed by 80 mL per square metre and 160 mL per square metre.

KEY RESULT:

Researchers developed the Canadian Clubroot Differential (CCD) Set, which represents an improved system for the identification of new virulence profiles of *Plasmodiophora brassicae* and their classification into pathotypes. The CCD Set is an important new tool that can be applied directly on the ground by the sector, including agronomists, breeders and researchers.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Characterization of new strains of the clubroot pathogen in Alberta," Stephen Strelkov, University of Alberta

FUNDING:
Alberta Canola, SaskCanola, ACIDF, WGRF

Holtz, M., Hwang, S.F., and Strelkov, S.E. 2018. Genotyping of Plasmodiophora brassicae reveals the presence of distinct populations. BMC Genomics, 19: 254

Strelkov, S.E., Hwang, S.F., Manolii, V.P., Cao, T., Fredua-Agyeman, R., Harding, M.W., Peng, G., Gossen, B.D., McDonald, M.R., and Feindel, D. 2018. Virulence and pathotype classification of Plasmodiophora brassicae populations collected from clubroot resistant canola (Brassica napus) in Canada. Can. J. Plant Pathol., Accepted 25 Mar. 2018

Zhou, Q., Hwang, S.F., Strelkov, S.E., Fredua-Agyeman, R., and Manolii, V.P. 2018. A molecular marker for the specific detection of new pathotype 5-like strains of Plasmodiophora brassicae in canola. Plant Pathol., Accepted 6 April 2018

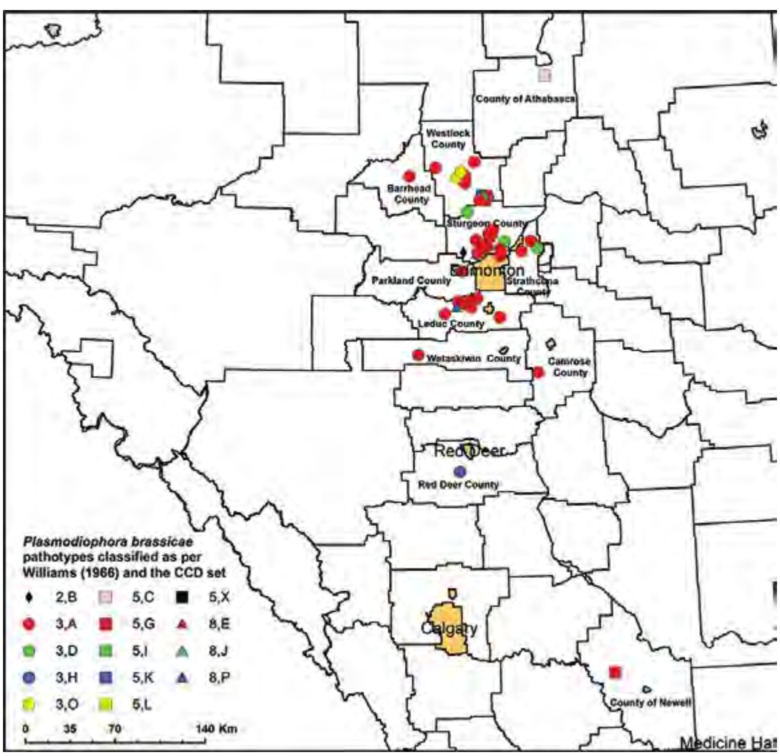
Toward matching clubroot resistance to pathoypes in the field

By the end of 2018, more than 3,000 clubroot-infested fields, the majority of which are located in central Alberta, have been confirmed in Western Canada. This represents a large increase since clubroot was first identified in a dozen canola fields in 2003. Although clubroot-resistant (CR) cultivars have been available since 2009, a new strain capable of overcoming resistance to *Plasmodiophora brassicae* in canola was identified in central Alberta in 2013, which appeared to be highly virulent on all canola cultivars available on the market. The understanding of the new strains of *P. brassicae* that have emerged in Western Canada in recent years has improved through this study and improved practices for their identification and management have been developed.

The objectives of this three-year project were to monitor the spread of novel clubroot strains through surveys, assess the potential of novel pathotypes to reappear, characterize the pathotypes of clubroot that appear where resistance has broken down and multiply inoculum of novel pathotype(s) for resistance screening. Field surveys were conducted in commercial canola crops in Alberta representing 40 counties and municipalities from 2014 to 2017. The virulence of 151 *P. brassicae* populations (clubbed roots) was tested on a suite of CR canola cultivars, representing one club from each field in which clubroot was found on a CR canola crop. Surveys identified a total of 17 known pathotypes in Canada, including at least 11 of which can break resistance in CR canola (and five of which are the original "old" ones).

Researchers identified the virulence pattern of each of the *P. brassicae* populations and assessed the pathotypes on 13 Brassica hosts representing the CCD Set. Each unique virulence pattern on the hosts of the CCD Set was regarded as a distinct pathotype and assigned an identifying letter. The resulting CCD Set has a greater differentiating capacity than the systems that were previously in use, and has allowed the identification of many new pathotypes of *P. brassicae* that would have otherwise gone undetected. Since this system also includes the differentials of Williams and Somé et al., it allows users to obtain pathotype designations according to those systems as well.

The CCD Set will serve as an effective method to identify novel pathotypes and quickly determine their ability to overcome certain key sources of resistance. The *P. brassicae* populations representing key pathotypes have been made available to private and public breeders (subject to appropriate biosafety considerations) for screening purposes, in order to assist with the identification of effective resistance sources and the development of new CR canola products. The genomic information obtained and analyses conducted provide an excellent resource for quickly identifying potential molecular markers, and for comparing genetic similarities or differences between different populations of the pathogen. It is clear that an integrated approach, combining other tools in addition to genetic resistance, will be needed for sustainable clubroot control.



Map showing the distribution of 'new' pathotypes identified through this project with the CCD Set from collections of clubroot made from 2014-16. The map continues to be updated as new information becomes available.

Clubroot nursery at Brooks provided natural test site

KEY RESULT:

The maintenance of a naturally-occurring clubroot nursery provided an evaluation site for over 60 canola lines, varieties and cultivars over four years. The nursery site was also used extensively for training and extension activities.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Supporting continued development of clubroot-resistant canola and early detection of clubroot outbreaks," Michael Harding, Alberta Agriculture and Forestry

FUNDING:
ACIDF

Howard, R. J., D. A. Burke, S. E. Strelkov, D. C. Rennie, C. A. Pugh, S. L. I. Lisowski, M. W. Harding, and G. C. Daniels. (2014). Evaluation of methods for cleaning and disinfesting equipment contaminated with clubroot. Can. J. Plant Pathol. 36(2): 266-266. (Abstract)

S.E. Strelkov, V.P. Manolii, M.W. Harding, S.F. Hwang, E. Manolii, K. Zuzak, D.C. Rennie, J. Feng, M. Raham, G.C. Daniels, D.A. Burke, T.B. Hill, K. Zhar and D. Feindel. 2017. Occurrence and spread of clubroot on canola in Alberta in 2016. Canadian Plant Disease Survey, 97: 164-167.

When you get served lemons, make lemonade. In 2007, an irrigated canola crop west of Brooks, Alberta was discovered to have a severe infestation of clubroot caused by *Plasmodiophora brassicae*. From 2008 to 2016 the infested field provided an opportunity for clubroot research, extension and training in southern Alberta.

The primary goal of this project was to maintain a clubroot nursery in southern Alberta to allow the consistent testing, and continued development, of clubroot-resistant canola varieties. The site was a naturally-occurring clubroot disease nursery in southern Alberta where hybrid canola seed companies could screen for clubroot resistance to Williams pathotype 5, which is predominant in that field. The pathotype 5 and sandy brown soil with neutral to alkaline pH provided a testing site unlike any other in Canada.

Maintenance of the site and screening of clubroot resistance for hybrid canola seed companies resulted in:

a. In 2013 there were two of four lines evaluated showed significant resistance to clubroot pathotype 5.
b. In 2014 there were 20 of 21 lines with resistance to clubroot pathotype 5.
c. In 2015 there were four of 21 lines with resistance to clubroot and 10 with intermediate resistance.
d. In 2016 there were no lines with resistance and one out of 11 with intermediate resistance to clubroot pathotype 5.

As part of this project, a clubroot surveillance program sampled approximately 900 fields between 2013 and 2016 in southern Alberta. The survey provided early detection of new outbreaks and allowed proactive management responses. The survey has also helped identify fields with new virulent pathotypes of clubroot.

The comprehensive clubroot surveillance and early detection in southern Alberta found the following:

a. In 2013 no new clubroot-infested fields found in any of the 220 fields assessed.
b. In 2014 no new clubroot-infested fields discovered in any of the 210 fields assessed.
c. In 2015 there were no new clubroot-infested fields discovered in any of the 300 fields visited, however, a confirmed field in Mountain View County was reported by the local Agricultural Service Board Fieldman. Additionally, a new pathotype that was virulent on clubroot-resistant canola cultivars was discovered at a naturally-infested field in the County of Newell.
d. In 2016 there was a second field in Mountain View County reported.

The clubroot nursery site has also been a valuable staging point for demonstration plots used in extension and training activities. These activities have improved the awareness of, and scouting for, clubroot in southern Alberta.

Mapping the spread of clubroot

KEY RESULT:

A set of clubroot surveillance practices was developed for effective monitoring of the occurrence and severity of *P. brassicae* in commercial fields.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Clubroot surveillance and epidemiology," Stephen Strelkov, University of Alberta

FUNDING:
Growing Forward 2

Clubroot, we're watching you. A major focus of research into clubroot disease caused by *Plasmodiophora brassicae* is surveillance of the geographic spread of the disease, and developing an understanding of the pathotypes causing the disease.

Clubroot first emerged as an issue in canola on the prairies in 2003, when 12 clubroot-infested fields were identified in central Alberta. By 2013, more than 1,400 clubroot infestations were confirmed in the province. The objectives of this research were to monitor clubroot infestations to see how prevalent it is in particular regions, and how quickly clubroot is spreading. In addition, the research tracked the predominant pathotypes or strains of *P. brassicae* on the Prairies, and looked at whether genetic resistance was holding up in the field.

Annual field surveys were conducted across Alberta from 2013 through 2017. The majority of fields were visited shortly after swathing from late August to September, and had either not been inspected for clubroot previously or had been inspected and found to be free of the disease.

Using 2017 survey results as an example of the importance of the research findings, a survey of 554 canola crops in central and southern Alberta resulted in the identification of 72 new cases of the disease. These included the first records of clubroot in Big Lakes County, Brazeau County, Lac La Biche County, the County of Paintearth and the Municipal District (M.D.) of Wainwright. The identification of clubroot in Big Lakes County was particularly significant because it represented the first confirmed occurrence of the disease in the Peace Country of northwestern Alberta.

In addition to the 72 new cases of clubroot found in the Alberta-wide survey in 2017, a further 229 new records of the disease were confirmed in field inspections carried out by municipal and county personnel, for a total of 301 new clubroot-infested fields in 2017.

While most severely infested crops were confirmed to be susceptible canola hybrids, significant symptoms of clubroot were identified in at least 45 fields planted to resistant canola cultivars.

By the end of the study, a grand total of 2,744 clubroot-infested fields had been confirmed in Alberta since 2003. Since then, the number has continued to increase.

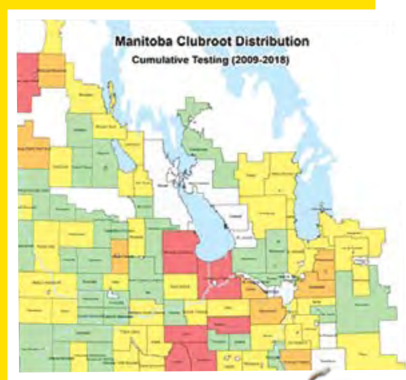
In addition to the clubroot surveillance in Alberta, 42 soil samples collected in Manitoba were evaluated for the presence of *P. brassicae* DNA by PCR analysis. Four root samples infected with P. brassicae were also collected in Saskatchewan and evaluated for pathotype designation.

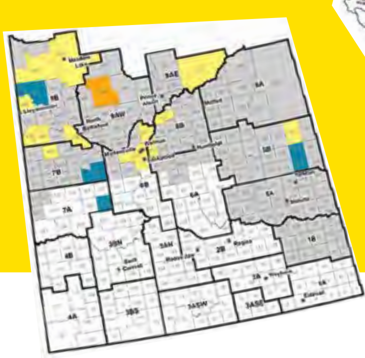
Of the 42 soil samples received from Manitoba, only one tested positive for the presence of *P. brassicae* in 2017. The four populations from Saskatchewan in 2017 were not found to have pathotypes capable of overcoming resistance (three populations were classified as pathotype 3H, while one was classified as 5L).

The surveillance results are widely reported, and serve as a critical resource for understanding the nature and extent of the clubroot outbreak. In addition, the material collected and characterized as part of this work, along with the data on clubroot severity, serve as a foundation for nearly all other clubroot-related conducted in Canada.

Maps and management at clubroot.ca

All the latest on clubroot spread, including the provincial maps, and clubroot management tips, including the list of clubroot-resistant (CR) varieties available, is all found at **clubroot.ca**. This web address goes direct to the clubroot content at the Canola Encyclopedia at **canolaencyclopedia.ca**. If you want to see the maps referenced in the article on this page, go to the 'Affected Regions' tab at **clubroot.ca**





Credit: Ian Epp

The science behind blackleg resistance rotation

KEY RESULT:

SaskCanola administered Growing Forward 2-funded blackleg research projects that concluded over the past year or so. Results from these studies make it possible for farmers to test for the predominant blackleg races in a field and use this information to make strategic decisions for the deployment of varieties. This will reduce blackleg severity and hopefully increase the longevity of genetic resistance.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
For full names of the studies, please read "Canola disease management tools for the Prairies – Blackleg and Sclerotinia" at **saskcanola.com/research**

FUNDING:
Growing Forward 2

RAPID FIELD DIAGNOSTICS TEST FOR BLACKLEG DISEASE

Hossein Borhan with Agriculture and Agri-Food Canada (AAFC) Saskatoon led the study to develop a rapid DNA test to identify blackleg races present on canola stubble. The polymerase chain reaction (PCR) biomarkers, which is a common method for DNA analysis, were shared with public and private pathology labs across Western Canada. Four labs now have the markers for commercial evaluation. When growers detect significant amounts of blackleg in their field they may now send stubble samples to pathology labs for genetic testing. The pathology lab will then provide the grower with information on the specific races of blackleg in their field. This will enable canola growers to make informed decisions about choosing the appropriate blackleg resistance in their canola variety that best matches the profile of the blackleg strain in the field. This is an important tool for managing blackleg in the field and addresses a concern of a major trading partner.

IDENTIFICATION OF NEW SOURCES AND GENES FOR BLACKLEG RESISTANCE

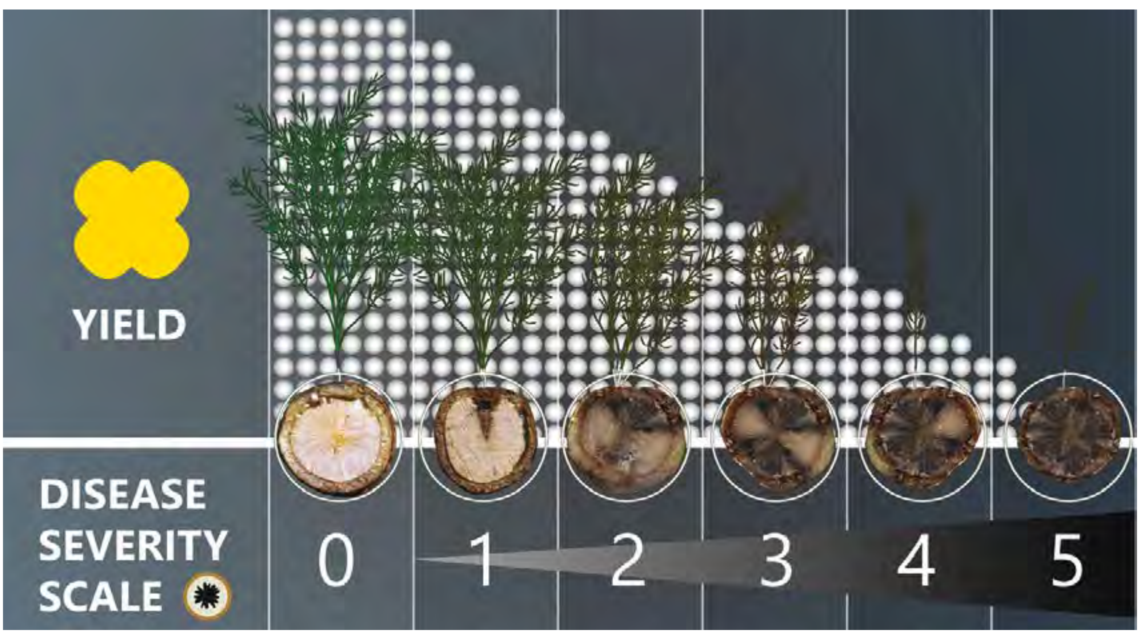
Hossein Borhan at AAFC Saskatoon and Genyi Li and Dilantha Fernando at the University of Manitoba led projects to identify new genes for blackleg resistance. Several novel blackleg resistance genes were identified, which can be used by seed companies to improve their genetic base. Preliminary mapping conducted on one of these lines support presence of a novel broad spectrum resistance (R) gene against blackleg disease. A total of 58 lines with quantitative resistance to blackleg disease were identified and presence of quantitative resistance was confirmed. While not major gene resistance, quantitative is a durable form of resistance and protects canola against the blackleg infection.

DEVELOPMENT OF BLACKLEG RESISTANCE GENE LABELS

Dilantha Fernando at the University of Manitoba, Gary Peng with AAFC Saskatoon and Ralph Lange with Innotech in Alberta led projects to enhance our understanding of the durability of some R genes used within commercial cultivars. This helped form the foundation for major gene resistance labels now used in blackleg resistance identification. Producers can now choose varieties with R genes that are durable to the specific blackleg races identified through the new commercial stubble tests. This will play a significant role in reducing blackleg in the field in Canada, and assist breeders in advancing cultivar resistance and durability.

DEVELOPMENT OF A BLACKLEG YIELD LOSS MODEL

To demonstrate why these blackleg management steps are so important for farmers, Stephen Strelkov with the University of Alberta led a project to study the relationship between blackleg severity and yield loss. Producers



Stephen Strelkov's blackleg yield loss model

(CONTINUED ON PG. 27)

Study shows how quantitative resistance to blackleg works

KEY RESULT:

Quantitative resistance to blackleg can work to reduce disease severity even when the major resistance gene is no longer effective. The mechanism for QR, at least in the one variety tested, is possibly through programmed cell death (PCD) and reactive oxygen species (ROS) to cut off the growth of *L. maculans.*

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Understanding the mechanisms for race-specific and non-specific resistance for effective use of cultivar resistance against blackleg of canola in Western Canada," Gary Peng, AAFC Saskatoon

FUNDING:
Alberta Canola, SaskCanola, Manitoba Canola Growers

Most canola varieties grown in Western Canada carry the specific blackleg resistance (R) genes *Rlm1* and/or *Rlm3*, but recent field monitoring data indicate that these R genes are no longer effective. Despite this, severe blackleg damage is still uncommon on these resistant cultivars, suggesting additional resistance mechanisms, known as quantitative resistance (QR), may be present.

QR has the potential to provide a more durable, if less complete, protection of canola against blackleg. However, the effectiveness of QR may also vary widely in the field, and it has long been suspected that elevated temperatures may negatively affect the expression of QR. This study set out to understand more about QR.

Researchers took three blackleg-resistant canola cultivars carrying *Rlm1* and *Rlm3* and inoculated them with virulent isolates of *Leptosphaeria maculans* that should overcome these two major resistance genes. The variety Westar was used as a susceptible control.

All inoculated cotyledons showed infection symptoms, but the severity was lower for the R-rated cultivars, relative to Westar. These results indicate that quantitative resistance (QR) plays a role for these R-rated canola cultivars.

To figure out the mechanisms underlying QR, researchers studied the variety 74-44 BL, which has QR against a range of *L. maculans* isolates without the direct involvement of any major R genes. In response to *L.maculans* infection, 74-44 BL showed high expression for genes involved in programmed cell death (PCD), reactive oxygen species (ROS) generation and/or intracellular endomembrane transport. Inoculated 74-44 BL cotyledons also produced hydrogen peroxide, a trigger of PCD, in a larger area than was colonized by hyphae. These mechanisms are quite different from those of the major gene *Rlm1*. The result suggests that QR for 74-44 BL is achieved through increased PCD and ROS to limit the growth of *L. maculans* inside the plant.

To test the potential temperature effect, researchers used three common canola cultivars (74-44 BL, PV 530 G and 45H29) known to show QR. Plants were treated with seven-hour daily exposure to 32°C for one week during early plant flowering under controlled-environment conditions. The impact of elevated temperature on the susceptibility of these cultivars was compared to performance of the same cultivars under a moderate 22°C day-time high. Westar was used as a control. The elevated temperature often increased blackleg severity on Westar, occasionally on PV 530 G, but generally not on 74-44 BL or 45H29.

These findings suggest that the QR traits are highly useful for blackleg management in Western Canada, even with warmer temperatures encountered during rosette to early flowering stages.

(CONTINUED FROM PG. 26)

can now estimate the amount of yield loss from blackleg in their canola fields. To use the blackleg yield loss model, producers need to complete a pre-harvest survey of 50-100 plants that well present the field. Clip these plants near the base of the root tissue to determine the incidence and severity of blackleg infection. Severity of blackleg is rated on a 0-5 scale, with 0 being a healthy clean plant to 5 showing internal blackening across the entire cross-section of the stem. For every unit of increase in blackleg severity (from a 1 rating to a 2 rating, for example), roughly 20 per cent yield loss can be expected per plant. Take the field yield average, the average BL severity and the percentage of plants infected (incidence) to determine the amount of yield lost.

COMBINE THE RESULTS FOR BETTER BLACKLEG MANAGEMENT

When these research findings are used together, they help to provide a full IPM toolkit; providing producers with more options to manage this disease. The new resistant sources will take some time before being found in commercial varieties but will provide diversity in sources being deployed. The blackleg race ID test provides more information for making variety decisions. This is where the new blackleg resistance labels come in handy and allows the industry to see what sources of genetics are being deployed. Knowing this information will help the industry better steward these resistance genes and hopefully minimize the risk of overcoming the genes. The yield loss model has been a first in Canada, which lets us see the economic impact blackleg has to canola production. Putting a dollar value on the damage helps to promote all the other tools we have for managing this disease.

*For more on blackleg and disease management, go to **blackleg.ca**.*

Pathogenic *Verticillium longisporum* found in Canada but yield loss is low, so far

KEY RESULT:

The exact mode of arrival of *V. longisporum* from other countries to Canada is still unknown, but presence of the pathogen across six provinces of Canada can be attributed to the favourable environmental conditions available to the pathogen.

PROJECT TITLE, PRINCIPAL INVESTIGATOR: "*Verticillium longisporum* in Manitoba: Understanding the pathogen and establishing surveillance capacity," Mario Tenuta, University of Manitoba

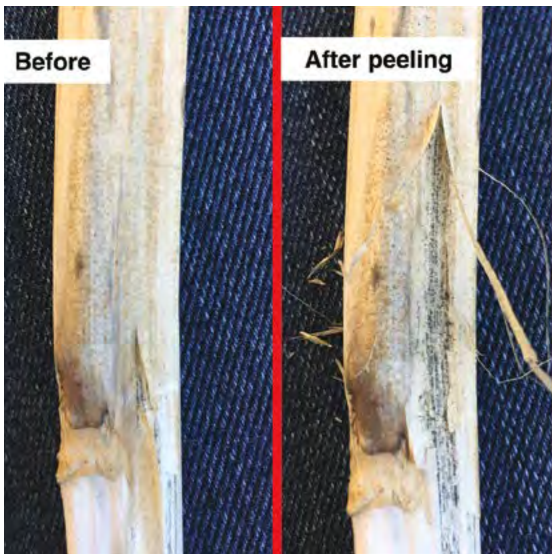
FUNDING: Manitoba Canola Growers, Richardson International, MB Grain Hub, Growing Forward 2, WGRF

Verticillium longisporum of canola is found in Europe, Russia, China and Japan. In 2014, it was discovered on canola on a research farm in Manitoba. Follow up soil surveys by the Canadian Food Inspection Agency in 2015 found *V. longisporum* in Alberta, British Columbia, Manitoba, Ontario, Quebec and Saskatchewan.

This study started in 2016 to find out more about the Canadian version of the pathogen, concentrating on the Manitoba research farm where it was first detected. Of the 194 soil samples collected and analyzed from the farm, 39 per cent tested positive for the pathogen. DNA analysis showed it to be the most aggressive type of *V. longisporum*. While there were some hotspots of high levels of the pathogen in soil, the fungus was located widely across the farm. Cropping history was not a factor in determining the levels and location of the pathogen on the farm.

The pathogen can produce up to 50,000 viable propagules (microsclerotia) in the decaying host stem during the end of the disease cycle. Dispersal of propagules occurs in two episodes; the first dispersal episode occurs at the beginning of the growing season when infected plants from the previous season are worked into the soil. The second dispersal episode occurs as microsclerotia reach the soil in high numbers upon the decay of diseased canola residue. Microsclerotia in the soil are dispersed by tillage, combining, vehicle wheels, footwear, animals, water and wind. Long distance dispersal of fungal propagules can occur via transport of other non-host infested crops and seeds.

The exact mode of arrival of *V. longisporum* from other countries to Canada is still unknown, but presence of the pathogen across six provinces of Canada can be attributed to the favourable environmental conditions available to the pathogen, such as ideal soil pH range of 5-8, soil temperatures of 15-19°C and air temperature of 15-23°C, all of which are found during the growing season across Canada.



Verticillium was found in greater numbers in canola fields in 2019. CCC agronomy specialist Justine Cornelsen provided these photos from her in-field observations. Note that with verticillium stripe, the spots are under the outer layer of stem tissue.

IDENTIFICATION AND MANAGEMENT OF VERTICILLIUM

Disease symptoms in canola include leaf chlorosis, early ripening, stunting and, as the disease progresses, necrosis and shredding of the stem tissue. Faint black (vertical) striping can be seen on the stems which, when rubbed can appear darker and more obvious. Once the plant is fully ripe, the stem peels to reveal tiny black microsclerotia, which resemble ground pepper in appearance. These microsclerotia remain on the plant stem or fall to the soil. While this may seem similar to the blackleg symptom, these specks are under the stem surface for Verticillium stripe and always on the surface for blackleg. At the end of ripening, the microsclerotia will begin to germinate and produce conidial spores externally, giving the outside of the stems a powdery look.

Treatment options are not available at this time. No foliar or seed treatment fungicides are registered for control of Verticillium stripe in canola and canola hybrids in Canada haven't been bred for clear host resistance to *V. longisporum*. But, while no commercial varieties are considered resistant, Eastburn and Paul did note differences in susceptibility varieties. (See their work in the Compendium of Brassica Diseases, 2007). Also, the low susceptibility of other Brassica species could provide breeding solutions, if Verticillium is determined to be a significant disease in canola in Canada. For more on Verticillium stripe, please read the chapter at canolaencyclopedia.ca and read 'Stem infections: How to tell them apart' at **canolawatch.org.**

Use pre-seed burnoff and pre-harvest herbicide for cleavers control

KEY RESULT:

Cleavers can germinate very early in the spring, making pre-seed burnoff a good way to control the weeds when they're small and limit cleavers seed in harvested canola. Pre-harvest saflufenacil plus glyphosate may also provide short- and long-term management.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Assessing the influence of base germination temperature and chemical desiccants on the recruitment biology of cleavers," Chris Willenborg, University of Saskatchewan

FUNDING:
SaskCanola

This study shows that cleavers populations in Western Canada have a base germination temperature of around 2°C. This is the temperature at which seeds will start to germinate. Willenborg and his team also found that 50 per cent of cleavers will germinate by around 6°C or 7°C, which means the weed can start growing within the first couple weeks of April, most years. This provides a good opportunity for farmers to control the weed with a pre-seed application of herbicide.

Galium aparine L. (cleavers or catchweed bedstraw) and *Galium spurium L.* (false cleavers) are problematic weed species in canola. A survey by AAFC's Julia Leeson in 2016 ranked them 7th and 6th in abundance in all annual crops and canola, respectively. Cleavers reduce yield, increase crop lodging, interfere with harvest operations, and reduce canola grades through seed contamination. Seed contamination is an issue because both cleavers and canola are similar in size and shape, making them difficult to separate. In addition, about 20 per cent of cleavers surveyed in Saskatchewan have evolved resistance to Group-2 herbicides and research by Hugh Beckie considered cleavers a high-risk weed for evolved glyphosate resistance, which is why pre-seed and fall applications should include a tank mix with glyphosate.

The objective of this study was twofold: to determine the differences in base germination temperatures of *Galium* spp. populations from different locations in western Canada, and to investigate options for reducing cleavers seed return in canola crops.

The first experiment was conducted at Agriculture and Agri-Food Canada in Saskatoon, using eight *Galium spurium* populations collected from across Western Canada and one *Galium aparine* population from the Saskatoon area. The seeds were subjected to germination studies on a thermogradient plate that included a range of temperatures (1-10° C) set at 1°C increments. Base temperature for germination was a consistent 2°C for all *Galium spurium* populations and 4°C for the *Galium* aparine population.

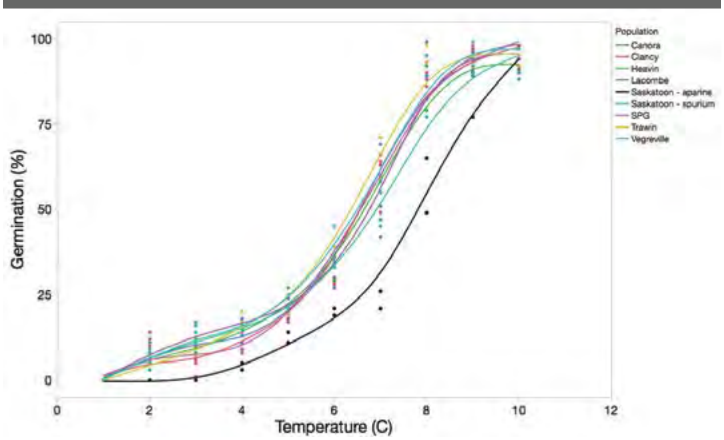
The second experiment was a field study conducted at two sites (Saskatoon and Scott, Saskatchewan) in 2016 and 2017. This experiment evaluated the effect of pre-harvest herbicides on cleavers contamination in canola crops, as well as cleavers seed viability and vigour. Herbicides evaluated included saflufenacil, diquat, glufosinate, saflufenacil plus glyphosate, diquat plus glyphosate, and glufosinate plus glyphosate.

All pre-harvest applications were made when 60-75 per cent of the canola plants had changed colour from green to brown. (Note: This does not match the label-approved timing for each product.)

The percentage of cleavers found in the harvested sample for all treatments was < 2.0 per cent, and the only treatment to reduce cleavers contamination below 1.0 per cent was saflufenacil plus glyphosate. However, all pre-harvest treatments significantly lowered cleavers seed viability compared to the untreated check. This means a smaller viable seedbank for those cleavers seeds shed before combining.

Using pre-harvest herbicides is a production practice that can improve the harvestability of standing canola and can also reduce the viability of seeds for weeds that still have seeds at the time of application. Cleavers management may benefit from such an approach as it retains a high percentage of its seed until crop harvest.

Figure 1. Cleavers germination starts at 2°C in Western Canada



This graph shows the effect of temperature on percent germination for eight Galium spurium populations and one Galium aparine population from different locations on the Canadian Prairies. Data points represent the means of two trial runs.

Understand the limitations of combine grain-loss monitors

KEY RESULT:

Existing combine grain loss monitors could not be correlated to an actual grain loss measurement. However they did provide an indication if grain loss was increasing or decreasing with different feed rates.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Investigation into converting a combine grain-loss signal into a grain-loss rate," Zachary Kendel, Prairie Agricultural Machinery Institute (PAMI)

FUNDING:
Saskatchewan Ministry of Agriculture, Canada-Saskatchewan Growing Forward 2, SaskCanola, SaskPulse, SaskWheat

You can't manage what you can't measure. That adage from the business world also applies to harvest grain losses. While current grain loss monitors have been slowly improving over time, they still do not directly correlate actual grain loss to the grain loss signal. As a result, grain loss monitors do not provide operators with the information required to realize the impact of harvest loss, while also allowing them to decide what level of loss they are willing to accept under the conditions in which they are harvesting.

This study investigated the feasibility of converting a combine's loss sensor signal into a grain loss rate – for example, bushels per acre or dollars per acre read-outs. A review of other sensing technologies was also completed to determine if other technologies would be able to provide a more accurate grain loss measurement.

Field testing was completed using PAMI's combine test equipment to collect the loss sensor signal from a combine and the actual grain loss in peas, wheat and canola. The loss data was collected over a range of feed rates to create loss curves, and the relationship between the grain loss curve and loss sensor signal curve was then graphically compared through the use of relationship equations.

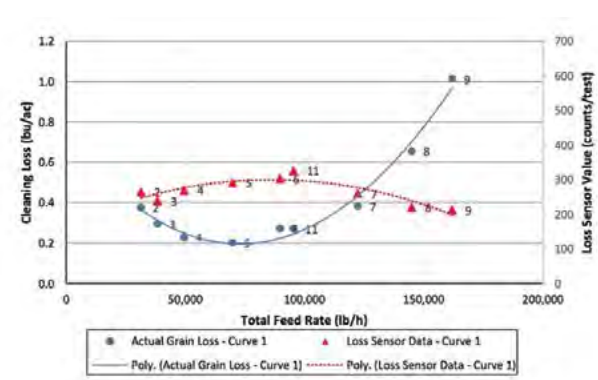
The research found that the correlation between the actual grain loss and loss sensor data using existing sensing technology in the separator area proved to be relatively strong when testing in peas and wheat, but showed a relatively poor correlation in canola. For both the separator and cleaning shoe, the grain loss correlation was dependent on feed rate, which current combine technology has no means of measuring, and as a result, underestimated grain loss as feed rate increased in most cases.

In large grain crops, a grain loss rate could likely be determined through the use of relationship equations and correction factors. However, in small grain crops, sensor resolution proved to be insufficient to accurately support an actual grain loss rate, especially on the cleaning shoe. Some improvements to solve this issue included mounting the cleaning shoe loss sensor independent of the cleaning shoe, or implementing multiple sensors across the rear of the cleaning shoe to effectively increase sensor resolution.

The researchers concluded that existing loss sensing technology is limited in the ability to provide an actual grain loss rate. However, the grain loss monitor system tested did provide a reliable indication of when actual loss was increasing or decreasing.

Other sensing technologies that rely on various sensors including photoelectric, ultrasonic, microwave, microphone, and accelerometer were found to show potential in detecting grain loss. However, further research is required to determine their full capabilities for this application.

Figure 1. Sensors may not pick up cleaning loss



The blue line is the actual cleaning loss indicated by field testing. The red line is what the combine sensor thinks is happening.

Root 'electricity' measurement will help breed more resilient canola

KEY RESULT:

Electrical properties of *Brassica* roots accurately reflect root morphology and anchorage strength. This study refined the non-destructive method to breed *Brassica* lines that are more resistant to environmental stresses and have stronger root architecture to prevent root lodging.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Investigating tolerance of canola genotypes to heat and drought stresses, and root traits estimation by electrical capacitance," Bao-Luo Ma, AAFC Ottawa

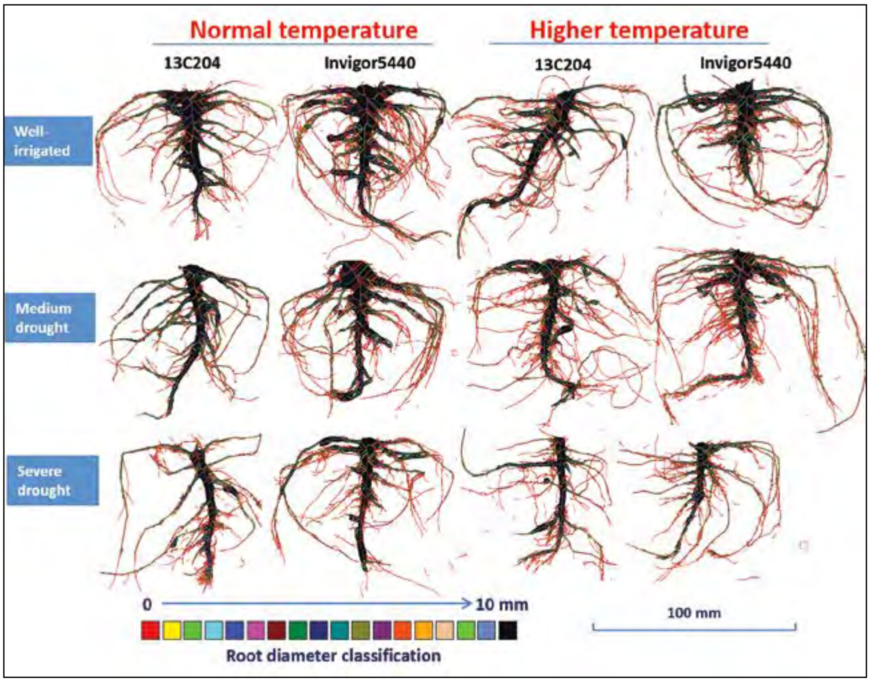
FUNDING:
Growing Forward 2

"Enhancing Rapeseed Tolerance to Heat and Drought Stresses in a Changing Climate: Perspectives for Stress Adaptation from Root System Architecture," Wei Wu, Bao-Luo Ma, and Joann K. Whalen, Advances in Agronomy 2018

"Assessment of canola crop lodging under elevated temperatures for adaptation to climate change," Wei Wu, and Bao-Luo Ma, Agricultural and Forest Meteorology 2018

Roots function as an early warning system for Brassica crops, detecting and responding to environmental stresses. Understanding root biology will help scientists and farmers create sturdier, stress-resistant crops. But root systems are complex, and difficult to study in a non-destructive manner.

Bao-Luo Ma's team investigated the feasibility of measuring electrical properties of roots to investigate morphology (root surface area, length and volume) distribution and function. His team, over multiple studies, improved the feasibility of this promising, non-invasive strategy.



Above: Roots of Brassica napus genotypes after being subjected to environmental stresses. Roots are colour-coded by diameter length. High temperature and severe drought reduce root diameter and surface area, which also correspond to lowered electrical charge within roots. Non-invasive methods such as electrical measurements can accurately assess effects of environmental stresses on roots and help select more robust crop lines.

Source: "Quantification of canola root morphological traits under heat and drought stresses with electrical measurements," —Wei Wu, 2017

For the latest study, two canola genotypes were tested in controlled environments at AAFC Ottawa. Seedlings were sown in plastic pots containing dried greenhouse soil mix. After rearing crops in growth chambers for two weeks at 23/17 °C (day/night), researchers subjected them to varying temperature and water levels to simulate environmental stresses of heat and drought. After 15 days of treatment, the taproot and lateral roots were evaluated for their electrical properties (capacitance, resistance, impedance) and compared that to their root length, surface area and volume.

Electrical measurements, they found, are a significant indicator of root morphology and anchorage strength. The current study adds to Ma's earlier research, which showed that electrical measurements could potentially predict canola seed yield and seed quality. The work improves our understanding of root function under heat and drought stress and contributes to more effective genotype selection and improvement.

The current research's non-invasive method gives scientists and canola breeders a simple, fast, and accurate way to better gauge root function, and then to harvest breeder seed from plants that have the desired traits. (A destructive test does not allow for this.)

A deeper understanding of root biology will help breeding programs select for crops that are heat- and drought-resistant and have more rigid root systems to decrease lodging risk under global warming. It will also help in agronomic improvements by contributing to sustainable canola production and maintain Canada's food security in future climate change scenarios.

Multiple genes and crop rotation enhance the durability of clubroot resistance

KEY RESULT:

A three-year study showed that including two resistant genes with different modes of action in clubroot resistant canola cultivars is more durable than single resistance genes against the new virulent pathogen pathotype 5X. To improve durability of resistance, growers also need a break of at least two years between canola crops.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Enhancing the durability of clubroot resistance with multiple genes," Gary Peng, Agriculture and Agri-Food Canada, Saskatoon SK

FUNDING:
AAFC, WGRF, SaskCanola

Cultivar resistance is the key to managing clubroot, which continues to spread on the Canadian prairies. Recently in Alberta, 17 "new" pathogen pathotypes were identified and all appeared virulent to previous resistant cultivars in the marketplace. This erosion of single-gene resistance is also being reported across western Canada, including a new variant of pathotype 3A in Manitoba. To address this challenge, researchers investigated the efficacy and durability of canola lines carrying single and multiple clubroot resistance (CR) genes against "new" and "old" pathotypes. Researchers also assessed resistance durability under heavy (Alberta) and lighter (Saskatchewan and Manitoba) infestation situations against the predominant pathotype 3H to better understand the risk of resistance erosion in recommending a CR canola cultivar in regions with different clubroot pathogen inoculum load on the Prairies.

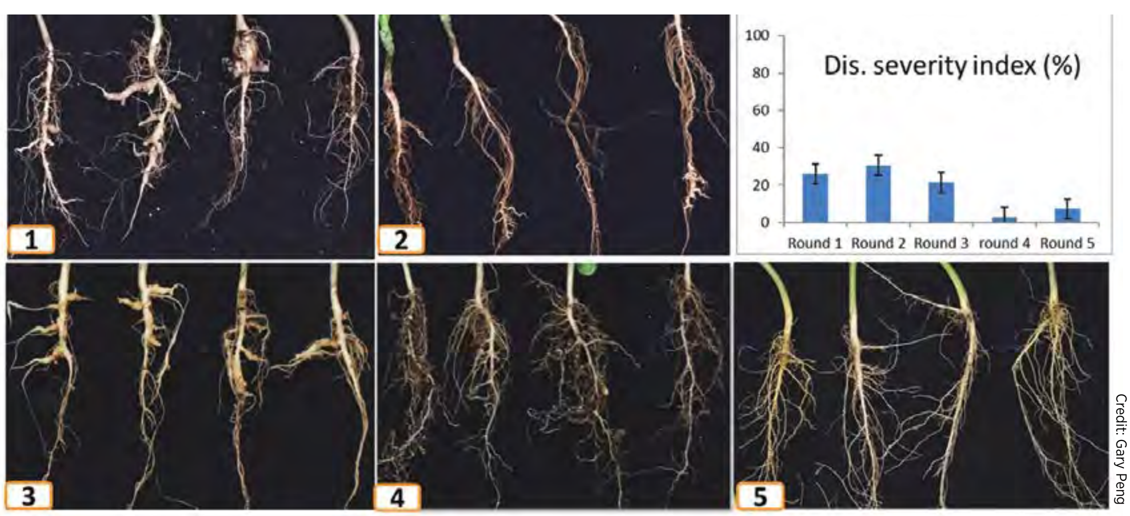
For this three-year study, 20 canola-quality *B. napus* inbred and hybrid lines carrying single, double and triple CR genes were produced in collaboration with Nutrien Ag Solutions. Advanced RNA sequencing methods were used to compare single- and double-gene lines to determine the modes of action of the different genes. All of the genotypes selected were resistant to the predominant pathotype 3H and other 'old' pathotypes (2, 5, 6, 8), however resistance to new pathotypes was unknown.

Westar and 45H29 (resistant to old pathotypes), both susceptible to the newly identified pathotype 5X, were included as controls. These lines were assessed for resistance against three field populations of the pathotype 5X using inoculum from Stephen Strelkov's lab at the University of Alberta and under simulated intensive canola-growing conditions. The lines went through five generational cycles of exposure, with all root galls recycled back into the growth media at the end of each generation.

The experiment lasted about 18 months for each pathotype and repeated once.

Researchers found that using a variety with double CR genes located on two different chromosomes of the A genome, A8 (CRB) and A3 (*Rcr1 or CRM*), provided moderate resistance against all 5X populations, as well as the immunity to the old pathotypes 2, 3, 5, 6 and 8. The study also showed that in response to 5X infection, many genes involved in host immunity pathways were more strongly activated in lines carrying these two CR genes, relative to those controlled by either of the single CR genes alone. Although the resistance provided by stacking two CR genes with different modes of action only increased to a moderate level, this resistance to 5X proved to be quite robust and more durable than expected. Over the five generations of exposure to the inoculum, the clubroot galls were smaller and fewer, and the inoculum levels did not increase. In some cases, inoculum levels even went down slightly.

The study also confirmed that higher inoculum loads tend to accelerate the resistance erosion, especially for canola varieties carrying only a single CR gene. Therefore, for producers with fields of heavy clubroot infestation, an extended rotation is necessary to protect the performance and durability of clubroot resistance. Previous research by Peng shows that a two-year break between canola crops can potentially reduce the pathogen inoculum in the soil by up to 90 per cent relative to one-year break. Current study results also suggest that even in areas with low levels of clubroot infestation, such as Saskatchewan and Manitoba, using CR varieties is recommended to keep inoculum levels low and delay potential outbreak. Researchers plan to see if this successful strategy of stacking two CR genes to manage 5X also applies to other new virulent pathotypes in future research.



This shows the size of galls for canola hybrid lines carrying the two resistance genes Rcr1 and CRB exposed to a population of pathotype 5X in five simulated generational cycles under controlled-environment conditions. In this experiment, lines with only one gene had much higher disease severity across all five generations.

'New' clubroot pathogen pathotypes were always present

KEY RESULTS: Whole-genome sequencing showed that the new, virulent pathotypes causing the breakdown in clubroot resistance were almost certainly always present in the pathogen population, and increased rapidly (positive selection) when the first generation of resistance to clubroot was added to canola cultivars.

PROJECT TITLE, PRINCIPAL INVESTIGATOR: "Using SNP markers to assess genetic variability of *Plasmodiophora brassicae* in Canada," Bruce Gossen, AAFC Saskatoon

FUNDING: Alberta Canola, SaskCanola, Manitoba Canola Growers

Objectives of this project were to assess the genetic similarity among populations of *Plasmodiophora brassicae* from various collections and to examine pathogen variability at various levels, from a single clubbed root, to a field, to a region and then among regions. Researchers collected isolates of *P. brassicae* from across Canada, including several examples of breakdown of genetic resistance from Alberta and from other sites across Canada, as well as from recent infestations in Saskatchewan, Manitoba and North Dakota. Other collections were obtained from the U.S. and China. In total, more than 80 collections are now available at Saskatoon.

Researchers developed a DNA extraction protocol for *P. brassicae* suitable for whole genome sequencing. Next-generation sequencing, high-speed computers and specialized software were used to compare the genetic similarity among strains of the pathogen at many spatial levels: field, region, province, country and continent. It showed that the new virulent pathotypes that have been identified in Alberta and across Canada were almost certainly always present in the pathogen population, and so were able to increase as soon as genetic resistance to clubroot was added to canola cultivars.

Black mustard provides new source of disease resistance

KEY RESULTS: Researchers successfully transferred both clubroot and blackleg resistance into *Brassica napus* canola breeding lines from a unique black mustard *(B. nigra)* line.

PROJECT TITLE, PRINCIPAL INVESTIGATOR: "Introgression of disease resistance from *Brassica nigra* into canola using new-type *Brassica napus*," Fengqun Yu, AAFC Saskatoon

FUNDING: SaskCanola, ADF

Canola with genetic resistance remains the most important management strategy for blackleg and clubroot, however virulent pathogen populations have recently been reported that are able to overcome the resistance of canola cultivars for both diseases. In this four-year study, researchers studied black mustard (*B. nigra*), which is highly resistant to canola diseases, to identify unique and novel sources of clubroot and blackleg resistance genes and transfer those genes into *B. napus* breeding lines. Researchers identified and genetically mapped a novel clubroot resistance gene highly resistant to pathotypes 3 and 5X, and other new pathotypes. They then successfully transferred this resistance into the *B. napus* (BC4) from the *B. nigra*. For blackleg, BC4 populations with resistance to two highly aggressive isolates collected in the Prairies were developed. The molecular markers and the new *B. napus* breeding lines will be made available to canola breeders for new cultivar development.

Screening *B. napus* lines uncovers better clubroot resistance

KEY RESULTS: More than ten *Brassica napus* lines highly resistant to the clubroot pathotype 5X, and five to pathotypes 3A, 2B, 3D and 5X were identified in the project. One of the best lines has been distributed to canola seed companies and several double haploid (DH) segregating populations are under development.

PROJECT TITLE, PRINCIPAL INVESTIGATOR: "Identification and genetic mapping of *Brassica napus* for resistance to pathotype 5X of *Plasmodiophora brassicae*," Fengqun Yu, AAFC Saskatoon

FUNDING: SaskCanola, Alberta Canola, Manitoba Canola Growers, Growing Forward 2

Recent emergence of new clubroot pathotypes and the erosion of clubroot resistance (CR) is of concern. The most efficient way to develop canola resistant to new pathotypes is to identify resistance in the species and then transfer resistance into elite canola breeding lines by intraspecific crosses.

The aim of this three-year project was to identify new sources of *B. napus* for resistance to the pathotype known as 5X, map clubroot resistance (CR) genes and develop markers tightly linked to the genes for use in marker-assisted breeding. A total of 845 *B. napus* lines collected worldwide were tested for resistance to pathotype 5X. In addition, a total of 53 *B. napus* with different levels of resistance to pathotype 5X were screened against three new pathotypes 3A, 2B, and 3D based on the Canadian Clubroot Differential (CCD) in 2017, and five *B. napus* lines highly resistant to the new pathotypes were identified. Three out of these five lines were found to be resistant to all of the new pathotypes used for this study. One of the best resistant lines has been distributed to canola seed companies for incorporation into elite canola breeding lines.

CANADIAN AGRICULTURAL PARTNERSHIP

CAP UPDATE: SUSTAINABLE, RELIABLE SUPPLY FOR A CHANGING WORLD

The Canola AgriScience Cluster is a partnership between Agriculture and Agri-Food Canada (AAFC) and the canola industry under the Canadian Agricultural Partnership. Over a five-year period, this initiative will invest $20 million in research aimed at sustainably growing the canola industry. This includes the following 16 projects to optimize yield and quality, improve nutrient and water use efficiency, and enhance integrated pest management practices. These projects were initiated in 2018.

MANIPULATING AGRONOMIC FACTORS FOR OPTIMUM CANOLA HARVEST TIMING, PRODUCTIVITY, AND CROP SEQUENCING

PRINCIPAL INVESTIGATORS: Brian Beres, AAFC Lethbridge

PURPOSE: Objectives for this project are to (1) understand how manipulations to seeding density, hybrid maturity rating, and swath/straight-cut timing alter crop yield and quality, (2) refine best practices in relation to the determination of optimal swath/straight-cut timing as plant density changes and as subsequent changes to canopy architecture, whole plant moisture, seed colour and moisture changes occur, (3) determine how the integration of seeding density, cultivar selection and harvest management system influence canola canopy architecture (pods and branches per plant and per unit area, for example), and (4) provide an economic analysis for low versus high seeding density systems, and straight-cut versus swathing scenarios.

ENHANCING YIELD AND BIOMASS IN CANOLA BY MODIFYING CARBOHYDRATE METABOLISM

PRINCIPAL INVESTIGATOR: Michael Emes, University of Guelph

PURPOSE: In a previous study, when the Arabidopsis endogenous leaf starch branching enzymes (SBEs) were replaced with maize endosperm homologues ZmSBEI or ZmSBEIIb, the Arabidopsis plants demonstrated significant increases in starch biosynthesis and a dramatic increase in seed production. The result was a 250 per cent increase in total seed oil produced per plant. This project will conduct lab research to see if the corn genes could provide a yield benefit for *Brassica napus* plants.

WEEDING OUT SECONDARY DORMANCY POTENTIAL FROM VOLUNTEER CANOLA

PRINCIPAL INVESTIGATOR: Sally Vail, AAFC Saskatoon

PURPOSE: Volunteer canola is becoming an ever-increasing problem. Secondary dormancy, which allows for shed canola seed to remain viable for years in the soil, is a heritable trait that can be selected against in breeding programs. This study will look for the genomic regions harbouring the genes controlling secondary dormancy in *Brassica napus*, to identify molecular markers to facilitate selection. Once these markers are identified, the project will scan *B. napus* lines for lower secondary dormancy, perhaps identifying parent lines that are less likely to become volunteer canola plants in the future.

ADVANCING THE FUNCTIONAL, NUTRITIONAL AND ECONOMIC VALUE OF PROTEIN IN CANADA

PRINCIPAL INVESTIGATOR: Robert Duncan, University of Manitoba

PURPOSE: *Brassica napus* varieties with enhanced protein and nutritional qualities could revolutionize meal utilization and functionality in Canada. Objectives of this study are to (1) screen several Brassica populations for diversity of protein quality and digestibility, and (2) map the genes responsible for protein quality and digestibility. It will also (3) compare conventional, cold pressing and modified processing methods for their impact on protein quality and digestibility.

IMPROVING NITROGEN USE EFFICIENCY AND SOIL SUSTAINABILITY IN CANOLA PRODUCTION ACROSS CANADA

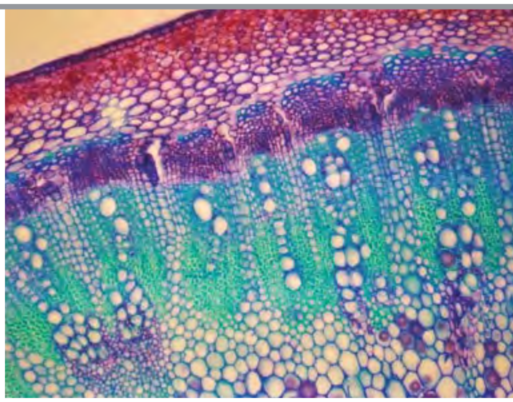
PRINCIPAL INVESTIGATOR: Bao-Luo Ma, AAFC Ottawa

PURPOSE: This project will address four objectives: (1) Assess agronomic and economic responses of canola crop to nitrogen (N) fertilizer management in terms of nitrogen use efficiency (NUE), seed yield and crop standability; (2) improve NUE, crop productivity and lodging resistance of canola plants through best N management practices under different soil and cropping system conditions; (3) identify root architecture traits for efficient N acquisition, high NUE and strong anchorage strength; and (4) investigate the taxonomic and functional response of the soil microbiome to N management in terms of soil sustainability and N cycling.

MAKING OF A MORE SUSTAINABLE CANOLA: USING GENETIC DIVERSITY TO IMPROVE NITROGEN USE EFFICIENCY

PRINCIPAL INVESTIGATOR: Sally Vail, AAFC Saskatoon

PURPOSE: Nitrogen is usually the biggest input cost for canola production, yet very little is known about N uptake and utilization in *Brassica napus* plants, especially for the spring type. This research project will advance the Canadian body of understanding using two main experiments – one under controlled conditions and one with a multi-environment field trials – to characterize whole-plant architectural characteristics and N-partitioning patterns of a diverse collection of *B. napus*. Data generated through these experiments will be used to test potential screening methodology and new rhizosphere N-cycling related traits. Discovery of natural variation within *B. napus* will be linked back to the agronomic management discoveries in Bao-Luo Ma's project noted above.



Bao-Luo Ma with AAFC Ottawa shares this close up photo of a canola stem cross-section. His study on improving nitrogen use efficiency (NUE) includes an objective to identify root architecture traits for nitrogen acquisition, NUE and anchorage strength.

FEASIBILITY OF USING TRICHOMALUS PERFECTUS FOR BIOLOGICAL CONTROL OF CABBAGE SEEDPOD WEEVIL IN THE PRAIRIES

PRINCIPAL INVESTIGATOR: Héctor Cárcamo, AAFC Lethbridge

PURPOSE: This study will test the benefits and risks of introducing the parasitoid wasp *Trichomalus* perfectus to the Prairies. This wasp provides effective parasitism of cabbage seedpod weevil in Europe and it has appeared as an adventive species in Quebec, where it can reach high levels of pest control. Objective one of this study will assess the efficacy of *T. perfectus* for managing seedpod weevil. This will be done in Quebec. This study will also identify potential non-target weevils and parasitoids from insect samples collected on the Prairies and from field sites in Quebec and Ontario. Finally, the study will refine a CLIMEX model to predict whether the Prairie climate will support this new wasp.

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

PRINCIPAL INVESTIGATOR: Alejandro Costamagna, University of Manitoba

PURPOSE: Flea beetles are one of the major pests of canola in Western Canada. Canola growers need strategies to improve the efficiency of seed treatments, and flea beetle management in general. This study will address research gaps that could improve flea beetle management. These include the effect of plant density in flea beetle management, the effect of stem feeding damage on the flea beetle control, the role of natural enemies on flea beetle management, and regional predictive models for flea beetle abundance.

GENETIC RESOURCES FOR FLEA BEETLE RESISTANCE IN CANOLA

PRINCIPAL INVESTIGATOR: Dwayne Hegedus and Chrystel Olivier, AAFC Saskatoon

PURPOSE: Given the regulatory scrutiny of neonicotinoid seed treatments, researchers are looking at alternatives, including natural plant defences. Currently, *Brassica napus* canola varieties have no natural resistance to flea beetles. This project builds on work begun by researchers at Agriculture and Agri-Food Canada and the University of Saskatchewan that identified lines of *B. napus* producing hairs ('trichomes') on their leaves and stems. These hairs deter flea beetles by disrupting their normal feeding behaviour. This project will conduct greenhouse and field trials with naturally-hairy *B. napus* lines, identify genes/loci responsible for hair production in Brassica species, and provide trichome-bearing lines and/or associated markers to the canola breeding community.

IMPROVING THE MANAGEMENT OF SCLEROTINIA STEM ROT OF CANOLA USING FUNGICIDES AND BETTER RISK ASSESSMENT TOOLS

PRINCIPAL INVESTIGATOR: Kelly Turkington, AAFC Lacombe

PURPOSE: Sclerotinia stem rot continues to be the most damaging and difficult-to-manage disease of canola in Canada. Recent research shows that spore DNA assessment of petals (using qPCR) holds promise in stem rot risk assessment. Objectives of this project are to (1) refine the use of qPCR analysis and investigate the potential for using spore traps instead of canola petals, (2) understand the role and impact of relative humidity, rainfall, and temperature on inoculum production and disease development, (3) evaluate the efficacy of very early fungicide applications alone or in conjunction with later applications for management of stem rot, (4) develop a better understanding of factors (e.g. seeding rate) that causes variability in flowering and how this influences fungicide response at various crop growth stages, and (5) and (6) 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 different fungicide application timings.

DEVELOPMENT OF A BIOSENSOR FOR SCLEROTINIA STEM ROT DISEASE FORECASTING IN CANOLA

PRINCIPAL INVESTIGATOR: Susie Li, InnoTech Alberta

PURPOSE: The goal of this project is to develop an in-field real-time sensor to monitor plant disease pathogens, specifically the sclerotinia stem rot pathogens. The sensor would notify the farmer, via cell phone, when a disease outbreak is imminent. Li and the research team have already developed a biosensor that could work, but more research is needed. Objectives of this study are to (1) transition the spore detection technology/device from a large instrument to a portable chip that can be easily applied in the field, (2) establish the correlation between disease severity (per cent petal infection) and inoculum level (number of spores in the air) under controlled and field environments, and (3) verify the technology in the field.

PROTECTION OF CANOLA FROM PATHOGENIC FUNGI USING RIBONUCLEIC ACID (RNA) INTERFERENCE TECHNOLOGIES

PRINCIPAL INVESTIGATOR: Steve Whyard, University of Manitoba

PURPOSE: Whyard and colleagues have found a way to use RNA interference (RNAi), which can reduce gene expression through the application of double-stranded RNA (dsRNA), to reduce sclerotinia stem rot infections. Due to RNAi's high degree of specificity, dsRNA foliar fungicides can target just the pathogenic fungus or related pathogenic fungi, and not affect beneficial species. This would reduce our reliance on broad-spectrum fungicides. The researchers have already identified and nominated sclerotinia-bioactive dsRNA molecules. Next objectives are to synthesize dsRNAs and screen for fungicidal activity and non-target effects, develop and test topical formulations for dsRNA adhesion to leaves and durability under different environmental conditions, and assess the persistence of dsRNAs in the soil.

RESISTANCE TO *SCLEROTINIA SCLEROTIORUM* EFFECTORS IN CANOLA

PRINCIPAL INVESTIGATOR: Dwayne Hegedus, AAFC Saskatoon
PURPOSE: This project will attempt to simplify the identification of *Brassica napus* canola lines with tolerance to sclerotinia stem rot. Researchers will characterize substances produced by the fungus that cause the characteristic brown, necrotic (dead) lesions on the plant or which compromise the ability of the plant to defend itself against attack by the fungus. These substances will be used to identify *B. napus* lines from collections at plant genetic resource centres to find those that are most tolerant or resistant to individual substances. Combining the resistance traits through traditional breeding will accelerate the development of canola varieties with better tolerance or resistance to stem rot.

CANADIAN CANOLA CLUBROOT CLUSTER PILLAR 1: INTEGRATED DISEASE MANAGEMENT

PRINCIPAL INVESTIGATOR: Sheau-Fang Hwang, University of Alberta
PURPOSE: The goal of this project is to develop management practices to reduce clubroot spore populations and prevent their buildup in at-risk areas. These practices are necessary to protect genetic resistance in canola varieties. Project objectives are to (1) characterize soil properties and pathotypes in clusters where resistance has been defeated, (2) test field pre-treatment and amendment techniques, including liming under varying spore concentrations and liming field entrances prior to clubroot introduction, (3) quantify yield loss in relation to disease severity, (4) assess the effect of cultivar rotation on clubroot pathotype structure, and (5) screen clubroot-resistance canola varieties against novel clubroot pathotypes.

CANADIAN CANOLA CLUBROOT CLUSTER PILLAR 2: DEVELOPING NOVEL RESISTANCE RESOURCES AND STRATEGIES TO ADDRESS THE NEW THREAT OF CLUBROOT TO CANOLA PRODUCTION ON THE PRAIRIES

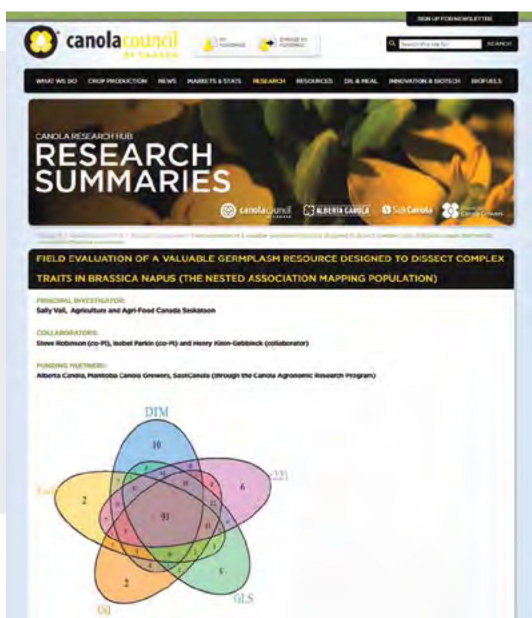
PRINCIPAL INVESTIGATOR: Gary Peng, AAFC Saskatoon
PURPOSE: The rapidly changing clubroot pathogen population presents a challenge to effective use of clubroot resistance (CR) because the single-gene resistance can be overcome quickly. Current canola cultivars have a low diversity in CR, and many newly-identified clubroot pathotypes appear to be virulent on these "resistant" cultivars. New CR genes or gene combinations, especially those with broad-based resistance, may help enhance the efficacy and durability of resistance. For this project, CR genes from existing germplasm as well as new *brassica* sources will be studied for novel CR resistance mechanisms and potential pyramiding/rotation options against a wide range of pathotypes, especially the predominant pathotypes.

CANADIAN CANOLA CLUBROOT CLUSTER PILLAR 3: HOST-PATHOGEN BIOLOGY AND INTERACTION

PRINCIPAL INVESTIGATOR: Bruce Gossen, AAFC Saskatoon
PURPOSE: The explosion of new, virulent pathotypes of *Plasmodiophora brassicae* (the clubroot pathogen) on canola crops in Alberta indicates that producers need management options for situations where no single source of genetic resistance is available to effectively manage all of the pathotypes of clubroot in their field. The goal of this research is to develop and validate best management practices for managing clubroot in canola fields where strong genetic resistance is not available and for slowing the spread of these pathotypes into new areas. The study examines factors that affect resting spore survival, germination and infection. Sources of quantitative (non-pathotype specific or horizontal) resistance, which has not previously been studied in detail, are also being identified and assessed to determine if quantitative resistance might be used to increase the durability of genes that confer strong genetic resistance to clubroot. This study will also evaluate strategies for deployment of clubroot resistance genes, with the aim of identifying approaches that will maximize the durability of resistance.

Explore the Canola Research Hub

The Canola Research Hub at **canolaresearch.ca** is a knowledge-transfer tool – designed to share canola research findings so producers and other industry stakeholders can improve canola production and profitability. The Hub is now funded through CAP. In addition to improvements to the 'advanced search' and updates to the main page, the Hub is planning further improvements and continues to expand the research summary library with recently completed projects, such as this Grower-Funded CARP project led by Sally Vail.



Canola growers fund dozens of research projects with their levy payments to SaskCanola, Alberta Canola and Manitoba Canola Growers. Many of those projects are funded through their joint Canola Agronomic Research Program (CARP). Here are short descriptions and updates for ongoing projects funded by the provincial canola organizations.

UPDATES FOR ONGOING PROJECTS

PLANT ESTABLISHMENT

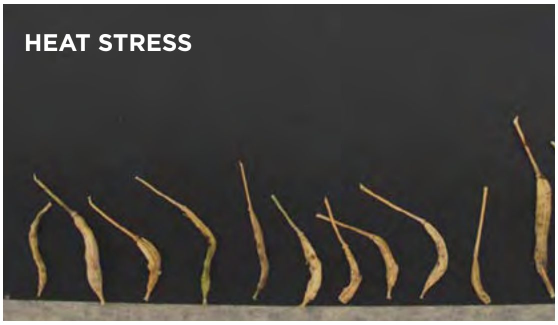
AN ON-FARM APPROACH TO MONITOR AND EVALUATE THE INTERACTION OF MANAGEMENT AND ENVIRONMENT ON CANOLA STAND ESTABLISHMENT AND DISEASE DEVELOPMENT

PRINCIPAL INVESTIGATOR: Christiane Catellier, Indian Head Agricultural Research Foundation (IHARF)

FUNDING: SaskCanola

PURPOSE: This study will use data collected from farm fields to examine how management decisions and environmental conditions interact with each other to affect canola emergence and seedling development, and disease (sclerotinia and blackleg) development in canola. The study started in 2018 and will be conducted in the Indian Head area for three growing seasons.

PROGRESS: Activities since the start of the project have included reviewing literature, planning and developing the methodology, collecting two years of field data and compiling data from third-party sources, organizing the data and creating a data management plan, and conducting preliminary data exploration.



Credit: Raju Soolanayakanahally

Right: Raju Soolanayakanahally with Agriculture and Agri-Food Canada in Saskatoon has a study to see how drought, heat and a combination of the two can affect canola seed yield, oil composition and carbon assimilation. These photos compare canola pods collected under optimal and heat stress conditions.

EFFECT OF CEREAL CROP RESIDUE DISTRIBUTION ON THE FOLLOWING YEAR'S CANOLA EMERGENCE AND YIELD

PRINCIPAL INVESTIGATOR: Lorne Grieger, Prairie Agricultural Machinery Institute (PAMI)

FUNDING: SaskCanola, SaskWheat

PURPOSE: The aim is to compare different residue management systems on a high-residue wheat crop to see how they affect stand establishment for the subsequent canola crop. This is a field-scale project. Treatments include two combine chopper and spreader systems, including one after market chopper designed for improved spread. Each chopper/spreader system was given four treatments: no-till check, fall tillage with a high-speed disc, fall heavy harrow, and fall and spring heavy harrow. Canola stand establishment and yield are compared the follow year for each treatment.

PROGRESS: Results so far indicate limited difference between the treatments, but this may have been due to later canola seeding dates (which possibly reduced any soil temperature effect) and canola harvest delays due to moisture in 2018. It will be interesting to see how the harvest of 2019 influenced residue management and stand establishment in 2020.

IMPACT OF DROUGHT AND HEAT DURING FLOWERING ON CANOLA YIELD

PRINCIPAL INVESTIGATOR: Raju Soolanayakanahally, AAFC Saskatoon

FUNDING: SaskCanola, Saskatchewan's Agriculture Development Fund (ADF)

PURPOSE: The main objective is to see how drought, heat and a combination of the two can affect canola seed yield, oil composition and carbon assimilation.

PROGRESS: Heat clearly altered the reproductive organs and process, leading to a substantial reduction in the seed yield and the number of pods. To a lesser extent, heat impaired the internal CO_2 diffusion and the RuBisCO carboxylation and regeneration. This was most likely the result of thermal damage to the enzymes involved in photosynthetic assimilation. Similarly, heat had a prevailing effect over drought on seed composition, which is greatly influenced by the conversion and transport of photo-assimilates to the seeds, in turn higher levels of saturated fatty oils. Overall, drought affected the carbon assimilation rate mainly through the limitation of CO_2 diffusion through the stomata and the seed yield components.

FERTILITY MANAGEMENT

DEVELOPING A SOIL HEALTH ASSESSMENT PROTOCOL FOR SASKATCHEWAN PRODUCERS

PRINCIPAL INVESTIGATOR: Kate Congreves, Department of Plant Sciences
COLLABORATORS: Rich Farrell and Diane Knight, Department of Soil Science
FUNDING: Saskatchewan Ministry of Agriculture, SaskCanola, SaskWheat, Western Grains Research Foundation (WGRF)
PURPOSE: Maintaining and building soil health is an essential component of long-term sustainable agriculture. Soil health can be defined as the capacity of a soil to function, which reflects sustained biological productivity, environmental quality, and plant health. Farmers need appropriate tools or methods for assessing and interpreting the soil health status of their soils, however, there is no standardized and prairie-based soil health test available. Thus, research is needed to address this gap. We currently have a project underway to assess soil health across Saskatchewan, which will contribute to developing a Saskatchewan Soil Health Assessment Protocol.
PROGRESS: Soil samples from the 0-15, 15-30, and 30-60 cm depth were collected from 55 fields across 26 sites in Sept. and Oct. 2018 (See the map above). The selected sites represented various Agri-Arm sites, producer fields, and AAFC long-term sites. The sites are representative of Saskatchewan agriculture as most sites were previously cropped with wheat or canola; other sites had barley, chickpea, lentil, field pea, soybean, potato, and green manure. Some native prairie samples were also collected. Lab-work is currently underway to characterize soil health attributes, such as organic carbon, total nitrogen, active carbon, nutrient composition, mineralizable nitrogen, microbial carbon substrate use, wet aggregate stability, texture, pH, EC, etc. The dataset will enable descriptive statistics for each soil health attribute, form which soil health scoring functions will be explored (similar to the Cornell Soil Health Assessment, but based on Saskatchewan soils).

REDUCING TOXICITY OF SEED-PLACED PHOSPHORUS FERTILIZER IN OILSEED CROPS

PRINCIPAL INVESTIGATOR: Patrick Mooleki, AAFC Saskatoon
FUNDING: SaskCanola, Alberta Canola
PURPOSE: Objectives are to determine the maximum safe rate of seed-placed phosphorus (P) fertilizer with different opener widths, and to develop guidelines for producers and crop advisors to use.
PROGRESS: This is a two-year field study, 2018 and 2019, with trials conducted at three locations in Saskatchewan (Melfort, Saskatoon and Scott) and two locations in Alberta (Brooks and Lethbridge). The study was designed to look at how increasing seedbed utilization by narrowing row spacing (from 12" to 9") and/or widening opener width (1" to 2" or 4") could reduce the toxicity of seed-placed phosphorus (P) fertilizer on seeds and seedlings, and help improve grain yield of canola. The seed-placed fertilizer was applied at four increasing rates of 20, 35, 50, and 65 lb./ac. of phosphate (P_2O_5). In year one, the effects of row spacing, opener width and phosphorus rate on plant density and plant height were significant at all sampling dates. No significant effect on grain yield and grain quality characteristics were observed for the three factors. Year two data has been collected and is being analyzed.

UNDERSTANDING CANOLA ROOT MORPHOLOGY AND MICROBIOMES IN RESPONSE TO SOIL PHOSPHORUS FERTILITY

PRINCIPAL INVESTIGATOR: Bobbi Helgason, University of Saskatchewan
FUNDING: SaskCanola
PURPOSE: This study will examine root growth and root microbiomes of field-grown canola in response to P rate and placement as part of a larger agronomy research trial by Patrick Mooleki. Because canola exerts genetic control on root growth, examination of different canola genotypes is needed to understand the range of traits involved in root P acquisition and to select for those that are most beneficial in Prairie production systems.
PROGRESS: Plant tissue, root, rhizosphere and bulk soils were collected at early vegetative (June 17) and mid-flowering (July 10) times for canola fertilized at 0, 35 and 65 lb./ac. of P_2O_5, applied with either one-inch or four-inch openers (on a 12 inch row spacing). Plant tissues were dried and ground and will be analyzed for nutrient content to determine the effect of P management on nutrient uptake. Roots, rhizosphere and bulk soil samples were frozen at -80°C and DNA has been extracted. Amplicon libraries are currently being prepared for sequencing.

ENHANCING THE BENEFICIAL ROOT AND RHIZOSPHERIC MICROBIOME IN CANOLA

PRINCIPAL INVESTIGATOR: Chantal Hamel, AAFC Quebec, Mohamed Hijri and Marc St-Arnaud, Universite de Montreal
FUNDING: Alberta Canola, Manitoba Canola Growers, SaskCanola, NSERC
PURPOSE: This project will assess the consistency and variability in the composition of the canola core root microbiome, which could lead to a better understanding of the microbes-plant interactions and could lead to the development of biofertilizers. Researchers also want to determine the crop rotation systems that enhance the beneficial root microbiome of canola and possibly increase canola productivity while allowing the reduction of fertilizer and pesticide use.

PROGRESS: The researchers used four long-term research sites in Saskatchewan and Alberta to test the impact of different cropping systems and previous crop on canola microbiomes. Roots and soil DNA were collected and laboratory work is completed. The four students' projects are at the analysis stage. A manuscript on the fungal core microbiome of canola was submitted, and another on the bacterial core microbiome is in preparation. We have documented the impacts of rotations with different intensity of canola on the productivity and on the arbuscular mycorrhizal fungal (AMF) microbiome of other crops present in the rotation. We also identified rotation systems that optimize N-cycling processes (two manuscripts are in preparation on these results).

EVALUATION OF SAP NITRATE FOR IN-SEASON ASSESSMENT OF CROP NITROGEN STATUS

PRINCIPAL INVESTIGATOR: Dale Tomasiewicz, AAFC Outlook
FUNDING: SaskCanola
PURPOSE: The project evaluates sap nitrate analysis as an in-season test to determine canola and wheat nitrogen (N) status. Sap analysis can be conducted quickly on-farm, so may be a suitable diagnostic tool for guiding in-season N application decisions for topdressing or fertigation.
PROGRESS: All tissue and sap samplings were conducted as planned in each of the three field years (2017, 2018 and 2019). Samples from 2019 still have to be analyzed.

OPTIMIZING PLANT RESILIENCE TO ABIOTIC AND BIOTIC STRESSES THROUGH IMPROVED SILICON ABSORPTION

PRINCIPAL INVESTIGATOR: Richard Bélanger, Université Laval
FUNDING: NSERC, SaskCanola
PURPOSE: The project studies the beneficial effects of silicon (Si) fertilization on canola. Given that canola is naturally a poor Si accumulator, canola plants have to be transformed with Si transporters (Lsi1 and Lsi2) and then evaluated for Si absorption and derived benefits.

Pollen beetle Brassicogethes viridescens

Credit: Christine Noronha

PROGRESS: Canola plants carrying Lsi1 transporters have shown a better ability to uptake Si, particularly in the roots. Optimal material must also contain Lsi2 (efflux) transporters. Inoculation with *Leptosphaeria maculans* will be used on transformed plants to assess the accrued resistance obtained as a results of improved Si accumulation in plants.

INTEGRATED PEST MANAGEMENT

INVESTIGATING THE ROLE OF PLANT HOSTS IN THE OUTBREAKS OF THE ASTER LEAFHOPPER VECTORED ASTER YELLOWS (AY)

PRINCIPAL INVESTIGATOR: Sean Prager, University of Saskatchewan
FUNDING: SaskCanola
PURPOSE: To see if other crops or weeds could harbour the aster yellows pathogen in Western Canada, attract the aster leafhopper to feed on them and thus potentially spread the disease to canola. Currently it is assumed that the pathogen comes up from the United States with leafhoppers that arrive each year.
PROGRESS: Common weeds were surveyed in 2018 and 2019 for the presence of leafhoppers and/or aster yellows phytoplasma. Masters student Berenice Romero has been doing lab bioassays, checking leafhopper preference and performance on wheat (AAC Brandon), oat (CS Candem), barley (CDC Copeland), canola (AC Excel), spiny annual sow thistle, dandelion, fleabane, marigold and Arabidopsis sp (WT Columbia ecotype). Romero has also been looking at the number of probing events and egg numbers, and whether infection with phytoplasmas and the host plant affect females oviposition behaviour and nymph development.

GENERATE KNOWLEDGE AND CONTROL STRATEGIES FOR THE POLLEN BEETLE *BRASSICOGETHES VIRIDESCENS* (COLEOPTERA: NITIDULIDAE), A NEW INVASIVE PEST OF CANOLA.

PRINCIPAL INVESTIGATOR: Christine Noronha, AAFC Charlottetown
FUNDING: Alberta Canola, Manitoba Canola Growers, SaskCanola
PURPOSE: This project proposes to establish economic thresholds for pollen beetle, test the efficacy of insecticides that are less toxic to pollinators, and establish a laboratory colony. It will also establish a surveillance program in Western Canada to monitor the presence/absence of pollen beetles. Surveillance in the Maritimes, where this pest is already established, will try to uncover any naturally occurring biocontrol agents.
PROGRESS: In this study, canola showed a significant decrease in seed weight and total number of pods and an increase in the number of missing pods at the highest

density of nine beetles per plant. Significantly lower oil and higher protein content was also recorded at this density. Three of the four insecticides tested in lab trials showed high toxicity to pollen beetles. A survey of canola fields in Alberta, Saskatchewan and Manitoba revealed no pollen beetles indicating that this pest has not yet moved to Western Canada. Maritime surveys found no natural enemies in the samples collected.

IDENTIFICATION AND ASSESSMENT OF THE ROLE OF NATURAL ENEMIES IN PEST SUPPRESSION IN CANOLA WITH SPECIFIC REFERENCE TO DIAMONDBACK MOTH MANAGEMENT

PRINCIPAL INVESTIGATOR: Maya Evenden, University of Alberta
FUNDING: Alberta Canola, SaskCanola
PURPOSE: This study has four objectives: (1) Monitor natural enemies associated with diamondback moth in canola, with a focus on larval parasitoids. (2) Develop functional response models to understand relationships between DBM and its natural enemies and to develop dynamic action thresholds. (3) Assess predation/parasitism of DBM life stages in the field. (4) Understand factors to enhance foraging and parasitism of parasitoids associated with DBM.
PROGRESS: Despite efforts to conduct extensive population surveys across Alberta, researchers had very low success capturing adult moths and larvae. A similar survey will be conducted in the summer of 2020. Laboratory studies continue to look into the functional response of predators including the carabid beetle, *Pterostichus melanarius* and the seven spotted ladybird beetle, *Coccinella septempunctata*. Field cage studies will be used to determine action thresholds for DBM in canola.

Paul Galpern with the University of Calgary has shown that the insect biodiversity that results from leaving these natural or non-farmed spaces around the farm can actually contribute to yield.

Credit: Gregory Sekulic

SURVEILLANCE NETWORKS FOR BENEFICIAL INSECTS: CAN NATURAL HABITATS SERVE AS INSECT RESERVOIRS, AND DO THEY CONTRIBUTE TO CANOLA YIELD?

PRINCIPAL INVESTIGATOR: Paul Galpern, University of Calgary
FUNDING: Alberta Canola, Manitoba Canola Growers
PURPOSE: This project will examine the relationship between the diversity and abundance of beneficial insects and canola production in Western Canada. Specifically, it will address the role of natural habitats near canola fields as reservoirs for pollinators and natural enemies of canola pests, and to see this effect on canola yield.
PROGRESS: Data from this research indicate that wild bee species visiting wetlands and then traveling into nearby fields may provide an ecosystem service to the crop. Another study suggests that canola plants growing near wetlands have heavier seeds and more seeds per pod. Further work is ongoing to better estimate the magnitude of this yield boost and measure its practical importance to canola growers. Finally, evidence suggests that canola yields are slightly higher in parts of the province where non-crop spaces are more common within fields. The services these spaces can bring to crops (for example, by providing habitat for beneficial insects, limiting soil erosion or improving moisture conditions) may outweigh the possible disservices of retaining them in fields.

VALIDATION OF LYGUS AND OTHER INSECT PEST THRESHOLDS IN COMMERCIAL FARMS THROUGHOUT ALBERTA

PRINCIPAL INVESTIGATOR: Hector Carcamo, AAFC Lethbridge
FUNDING: Alberta Canola, SaskCanola
PURPOSE: Economic thresholds for lygus were developed for open pollinated cultivars. Recent cage and plot data suggest that the threshold should be raised to two or three (rather than one) lygus per sweep for new hybrids. This study will try to validate economic thresholds for lygus using commercial canola fields.
PROGRESS: From 2016–2019, over 20 farm site-year combinations have been studied. Results have been variable but data support increasing the threshold. Data analysis for 2019 and synthesis for all years remains to be done.

CHARACTERIZING TURBULENT SPRAY DEPOSITION FROM SELF-PROPELLED SPRAYERS

PRINCIPAL INVESTIGATOR: Tom Wolf, Agrimetrix
FUNDING: Alberta Canola, SaskCanola
PURPOSE: This study will compare the uniformity of spray deposition for various commercial sprayers.
PROGRESS: In 2019, four experiments were conducted evaluating the effect of travel speed and boom height. Plastic string was used to capture the spray across the boom width, and fluorimetry to quantify the deposit

amounts at 30 cm increments. This technique allows researchers to identify the most aerodynamically turbulent regions behind the sprayer, and shed light on possible remedies.

UNDERSTANDING THE NEW PATHOGEN *VERTICILLIUM LONGISPORUM* AND ITS INTERACTIONS WITH CANOLA

PRINCIPAL INVESTIGATORS: Dilantha Fernando and Mario Tenuta, University of Manitoba
FUNDING: SaskCanola, CAP
PURPOSE: The main objective is to identify and characterize *Verticillium longisporum* isolates from across the Prairies. The researchers will also investigate the longevity of micro-sclerotia produced by this fungus in canola stems, and monitor the pathogen movement in soil or through space, and test canola and rapeseed lines for their resistance to the pathogen and to identify new R-genes.
PROGRESS: Researchers studied two field locations in Manitoba in 2019 and are analysing all field experimental data at the moment.

ASSESSING THE IMPACT OF *CONTARINIA SP.* ON CANOLA PRODUCTION ACROSS THE PRAIRIES.

PRINCIPAL INVESTIGATOR: Meghan Vankosky and Boyd Mori, AAFC Saskatoon
FUNDING: SaskCanola, Alberta Canola
PURPOSE: A new, undescribed species of *Contarinia* midge was found attacking canola flowers in 2016. It is now formally described and named *Contarinia brassicola*. The purpose of this project is to describe the life history, development, timing of adult emergence, distribution and impact of *C. brassicola* on canola crops to determine the pest status of this insect.
PROGRESS: Experiments were repeated in 2017, 2018 and 2019. The timing of adult midge emergence was monitored using emergence cages in northeastern Saskatchewan. Canola plants were dissected weekly during the growing season to determine the timing of midge attack and of midge development. To determine the distribution of this insect, a survey of canola fields in Alberta, Saskatchewan, and Manitoba was completed in late July/early August. Larvae of *C. brassicola* were collected during the survey for population genetic analyses, and tests to determine if larvae were parasitized by natural enemies.

DEVELOPMENT OF A PHEROMONE-BASED MONITORING SYSTEM FOR A NEWLY IDENTIFIED *CONTARINIA* MIDGE ON THE CANADIAN PRAIRIES.

PRINCIPAL INVESTIGATOR: Meghan Vankosky and Boyd Mori, AAFC Saskatoon
FUNDING: SaskCanola, Alberta Canola
PURPOSE: A new species of midge, closely related to swede midge and now formally described and named *Contarina brassicola* is now known to attack canola flowers in fields across the Prairies. This project will see if *C. brassicola* produces pheromones that can be used to develop a pheromone-based monitoring system, similar to the swede midge monitoring system.
PROGRESS: Midge specimens were collected from canola fields across the Prairies and shipped to collaborators in the United Kingdom for refinement of a female-produced pheromone. Lures with different components of the pheromone were placed in traps in northeastern Saskatchewan for testing in field conditions. Additional testing in the lab and the field will refine the pheromone-based monitoring system.

COORDINATED SURVEILLANCE, FORECASTING AND RISK WARNING SYSTEMS FOR FIELD CROP INSECT PESTS OF THE PRAIRIE ECOSYSTEM

PRINCIPAL INVESTIGATOR(S): Meghan Vankosky, Jennifer Otani, Owen Olfert, AAFC
FUNDING: Previously Alberta Canola, SaskCanola, Manitoba Canola Growers and WGRF. Now Canadian Agricultural Partnership
PURPOSE: The aim is to develop and implement insect surveillance programs to identify risks to crop production from pest species and to highlight and conserve their natural enemies.
PROGRESS: As in previous years, surveys were conducted for key field crop pests across the Prairies. Regional forecast and distribution maps for the insects monitored are made available before the growing season. Weekly updates and monitoring protocols for field crop pests of the Prairies are available online on at (**http://prairiepestmonitoring.blogspot.ca/**). Funding is in place to continue surveys and related pest forecasting research until March 2023.

EFFECT OF HAIRINESS IN ON ABUNDANCE, FEEDING AND EGG-LAYING BEHAVIOUR OF FLEA BEETLES, DIAMONDBACK MOTH AND ASTER LEAFHOPPER.

PRINCIPAL INVESTIGATOR: Chrystel Olivier, AAFC Saskatoon
FUNDING: SaskCanola, Alberta Canola
PURPOSE: The project aims to determine the effects of trichomes (hairs) on the feeding and/or egg-laying behaviour of striped flea beetles, diamond back moths and aster leafhoppers.
PROGRESS: Lab bioassays and field trials were conducted with a hairy *Brassica napus* line and a very hairy Brassica species, *B. villosa*. Initial studies demonstrated that striped flea beetles tend to avoid hairy leaves and move to feed on the less hairy stems or petioles. Female diamondback moths prefer to lay eggs on the hairy parts of the plant; however, first instar larvae have difficulty navigating through the trichome mats and are unable to mine and older larvae prefer to feed on glabrous leaves compared to hairy leaves. Lab bioassays with aster

leafhoppers are planned for later in 2019. A new striped flea beetle colony at AAFC Saskatoon will permit year-round laboratory bioassays.

DEVELOPMENT OF A HARMONIZED CLUBROOT MAP

PRINCIPAL INVESTIGATOR: Stephen Strelkov, University of Alberta
FUNDING: Alberta Canola, SaskCanola, Manitoba Canola Growers
PURPOSE: The project will examine the feasibility of a harmonized clubroot map, determine what such a map will look like, and communicate findings and recommendations to stakeholders.
PROGRESS: Various maps have been prepared to determine the clearest and most informative ways to present data on the occurrence and distribution of clubroot. Some maps show the location of fields with confirmed clubroot as red points, while fields where clubroot was not found are shown in green. Other maps have been designed in which clubroot distribution is illustrated based on the total number of confirmed infestations in a municipality. A more recent map expresses infestation as a percentage of total farmed acreage in a county or municipality. Preliminary results have been shared with the Clubroot Steering Committee and other stakeholders. Feedback is being used to further refine the maps.

MANAGING SMALL PATCHES OF CLUBROOT INFESTATION IN CANOLA FIELDS

PRINCIPAL INVESTIGATOR: Bruce Gossen, AAFC Saskatoon
FUNDING: Alberta Canola, Manitoba Canola Growers, SaskCanola
PURPOSE: The main objective is to develop practical recommendations for managing small patches of clubroot in commercial canola fields. The project includes lab studies of rotation crops and grass cover crops, field studies of the efficacy of liming and grasses, and identification of improved techniques for estimating resting spore numbers in soil.
PROGRESS: Four field sites (two in Saskatchewan, two in Manitoba) have been established and initial soil samples collected to assess efficacy of grass crops and liming under field conditions on reducing spore numbers. A new more accurate molecular test for spore concentration is being developed and validated.

INFLUENCE OF PH ON THE CLUBROOT PATHOGEN: ARE THERE PH-INSENSITIVE STRAINS?

PRINCIPAL INVESTIGATOR: Stephen Strelkov, University of Alberta
FUNDING:Alberta Canola, Manitoba Canola Growers, SaskCanola
PURPOSE: Relatively acidic soil is believed to have facilitated the establishment of clubroot in central Alberta, the heart of the outbreak. While liming to increase soil pH represents a potential tool for clubroot management, the effectiveness of increased soil pH in controlling different clubroot strains, and the potential risks of liming as a clubroot management strategy, are not known. This study will try to answer two questions: Does the effectiveness of soil pH amendment for clubroot control depend on the pathotype present? Can liming inadvertently select for pH-insensitive strains of the pathogen?
PROGRESS: A graduate student who was recently recruited who has started experiments to answer these questions.

EVALUATING FUNGICIDE SEED TREATMENT OPTIONS FOR CONTROL OF BLACKLEG IN WESTERN CANADA

PRINCIPAL INVESTIGATOR: Gary Peng, AAFC Saskatoon
FUNDING: Alberta Canola, Manitoba Canola Growers
PURPOSE: In Australia, fungicide seed treatment has been a key component in blackleg management for years. In Canada, there is currently no seed treatment specifically for blackleg. The main goal is to assess whether a seed treatment, either with an existing (Helix, Prosper or Jockey) or a new product (fluopyram, for example), will be of a high value for blackleg control in western Canada.
PROGRESS: A range of new active ingredients/formulations of fungicides were screened in controlled-environment conditions as a seed treatment against foliar infection on Westar (susceptible) that leads to blackleg. While the majority of candidates, including the current industry standard of seed treatment, showed little effect, the new actives containing the succinate dehydrogenase inhibitor (SDHI) appeared highly effective. On resistant canola varieties, the disease level was generally low already, which may overshadow the benefit of this new seed treatment. Field trials will continue.

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, which is happening. Borhan will coordinate efforts with the international blackleg research community to expand the current set of host differentials for new R genes, and apply the pathogen genotyping markers (developed as part of Growing Forward 2 funded research) to define a common set of *Leptosphaeria maculans* differential isolates.
PROGRESS: Blackleg research labs from Australia, U.S., U.K. and France have agreed to join efforts and share

resources with the Canadian research groups working on blackleg disease of canola. Work has been initiated to exchange diverse collections of blackleg (Leptosphaeria maculans) isolates and characterise each isolate based on its virulence on canola and sequence diversity. In addition PCR based markers for *L. maculans*, developed by Borhan's lab, have been shared with the international blackleg research groups.

ECOLOGY OF SWEDE MIDGE – HOST PLANT INTERACTIONS

PRINCIPAL INVESTIGATOR(S): Boyd Mori, AAFC Saskatoon (now University of Alberta)
FUNDING: SaskCanola, ADF, WGRF
PURPOSE: The purpose is to determine the host range of swede midge, *Contarina nasturtii*, for *Brassica sp*. and close relatives, including weeds common on the Prairies. The project will also investigate the susceptibility of *B. napus* cultivars to swede midge.
PROGRESS: All plant species and varieties of *B. napus* tested have been susceptible to swede midge infestation. In addition, experiments were conducted to determine the host plant response following swede midge infestation.

ASSESSING SURFACE WAX CHEMICAL DIVERSITY AS A TOOL TO DEFEND AGAINST ABIOTIC AND BIOTIC STRESS IN CANOLA.

PRINCIPAL INVESTIGATOR: Mark Smith, AAFC Saskatoon
FUNDING: SaskCanola
PURPOSE: The outer surface of a canola plant is covered by a complex mixture of water-repelling organic material referred to as cuticular wax. This layer plays a role in prevention of water loss and is also the first thing an insect or fungal spore encounters when landing on a leaf or petal. The purpose of the project is to characterize the chemical composition of this wax and determine the diversity of composition and amount between different canola cultivars. We are also identifying genes involved in wax biosynthesis to develop markers for use in breeding for wax related traits. The long term goal is to determine if wax composition can be manipulated through breeding to enhance the ability of the plant to protect itself from biotic and abiotic stress.
PROGRESS: The major chemical components have been identified and differences in wax composition have been observed between different plant parts. Chemical diversity between cultivars appears to be limited to changes in the ratios of components, with environment being an important factor in determining wax production. Additional diversity is present in other *Brassica* species. The researchers have identified many genes that appear to have a role in wax biosynthesis, with further validation in progress.

BIOPESTICIDES AS A NOVEL MANAGEMENT STRATEGY FOR SCLEROTINIA IN CANOLA

PRINCIPAL INVESTIGATOR: Susan Boyetchko, AAFC Saskatoon
FUNDING: SaskCanola, Manitoba Canola Growers
PURPOSE: The main objective is 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.
PROGRESS: Five bacterial strains were found to inhibit ascospore germination, mycelial growth and sclerotial formation of S. sclerotiorum. All plants sprayed with bacterial strain PENSV20 in the presence of the pathogen had no symptoms of the disease and plant defense genes were triggered when sprayed 24 hours before and 24 hours after the pathogen. Research on biopesticide evaluation is continuing.

VERTICILLIUM STRIPE MANAGEMENT

PRINCIPAL INVESTIGATORS: Sheau-Fang Hwang and Stephen Strelkov, University of Alberta
FUNDING: SaskCanola
PURPOSE: Objectives are to determine if there is yield loss from verticillium stripe (VS), determine the effects of growth stage and inoculation techniques on infection, and evaluate canola cultivars for resistance.
PROGRESS: The effects of inoculum density on disease severity was assessed. Two canola cultivars were grown in outdoor microplots inoculated with a virulent isolate of verticillium at various densities. Treatments will be assessed for VS symptoms, rated for disease severity and seed yield per plant will be recorded. Regression analysis will be performed to estimate the yield loss resulting per unit increase of disease severity.

HARVEST MANAGEMENT

PRE-HARVEST HERBICIDE AND DESICCATION OPTIONS FOR STRAIGHT-COMBINING CANOLA: EFFECTS ON PLANT AND SEED DRY-DOWN, YIELD AND SEED QUALITY

PRINCIPAL INVESTIGATOR: Chris Holzapfel, IHARF
FUNDING: Manitoba Canola Growers, SaskCanola
PURPOSE: The three-year study will evaluate the potential benefits of a pre-harvest application of herbicide or desiccant to standing canola prior to straight combining. Visual stem dry-down, seed moisture at harvest, total plant moisture at harvest, dockage, seed yield, green seed, lodging and visual shatter ratings will be measured for each treatment.
PROGRESS: Field trials were completed at four locations for 2017, 2018 and 2019. The study compared Liberty Link and Roundup Ready varieties, starting with InVigor L233P and Pioneer Hi-Bred 45M35 in year one. In years two and three, InVigor 233P was replaced with InVigor L255PC

which had an estimated maturity that was closer to 45M35. A total of 10 treatments were completed, five for each variety. Pre-harvest treatments were untreated, glyphosate, saflufenacil, glyphosate plus saflufenacil, and diquat.

ON-FARM SURVEY OF COMBINE GRAIN LOSS IN CANOLA ACROSS WESTERN CANADA

PRINCIPAL INVESTIGATOR: Amie Harrison, PAMI
FUNDING: Alberta Canola, Manitoba Canola Growers, SaskCanola
PURPOSE: This project conducted in-field combine loss surveys at farms across Western Canada in 2019. Previous studies have measured average total harvest loss in canola in Western Canada at 5.9 per cent of yield. Total loss includes environmental loss, header loss and combine loss. This project aims to determine how much canola loss is attributed to combine loss.
PROGRESS: Surveys were completed and data is being compiled and analyzed to quantify the relationships between grain loss and other variables. Results of this survey will educate and inform producers about which factors are most likely to contribute to higher losses.

Two drop-pan companies were cooperators in the PAMI harvest loss study, which will quantity actual in-field canola combine losses and factors that tend to contribute to higher losses. The ScherGain drop pan is on the left, Bushel Plus on the right.

DEFINING BEST MANAGEMENT PRACTICES FOR USING SUPPLEMENTAL HEATING WITH NATURAL AIR DRYING

PRINCIPAL INVESTIGATOR: Lorne Grieger, PAMI
FUNDING: SaskCanola, SaskWheat
PURPOSE: Many producers use natural air drying (NAD) systems to minimize the capital and operating costs of grain drying, but very little practical information is available to help producers make management and operational decisions related to using supplemental heating. The objective of this project was to conduct bench-scale drying trials to determine how the use of supplemental heat affects the drying rate and storage conditions of wheat and canola.
PROGRESS: In year one, which was the fall of 2018, damp canola (13 per cent moisture content) was dried down to 10 per cent within four days with an applied airflow rate of 2.0 cubic feet per minute per bushel and a 10°C increase in inlet air temperature, or within five days without heat. It took eight days to dry canola at 1.0 cfm/bu with heat. Both trials suggest that over-drying at the bottom of the bin may not be avoidable, and that an average dry moisture should be targeted and then the grain should be mixed.

GENETICS

INTROGRESSION OF CLUBROOT RESISTANCE FROM *B.RAPA* INTO *B.NAPUS* CANOLA AND IDENTIFICATION OF MOLECULAR MARKERS FOR RESISTANCE, AND PYRAMIDING OF THIS RESISTANCE WITH OTHER RESISTANCE GENES.

PRINCIPAL INVESTIGATOR: Habibur Rahman, University of Alberta
FUNDING: Alberta Canola, SaskCanola
PURPOSE: This study will introgress clubroot resistance from two subspecies of *B. rapa* to canola. These rapa sources carry resistance to pathotypes 3 and 3A. This could be a new source of resistance because they are not strongly associated with the genetic markers for two well-known sources, the CR genes of A3 and A8 of Mendel and rutabaga, respectively.
PROGRESS: Resistance to clubroot pathotype 3 was transferred from *B. rapa var. rapifera* (radish) and *B. rapa var. chinensis* (Chinese cabbage) to *B. napus* canola. Transfer of resistance to 3A is in progress. Marker screening continues.

DEFINING POPULATIONS OF *PLASMODIOPHORA BRASSICAE* WITH NEAR ISOGENIC *BRASSICA NAPUS* LINES

PRINCIPAL INVESTIGATOR: Fengqun Yu, AAFC Saskatoon
FUNDING: SaskCanola, Saskatchewan's Agriculture Development Fund
PURPOSE: This study aims to develop a set of near isogenic *B. napus* lines containing single clubroot-resistance genes, and to define the populations of *P. brassicae* with the newly developed near isogenic lines.
PROGRESS: Four near isogenic lines have been obtained, and further selection from 800 other double-haploid lines is in progress.

GENOME WIDE FUNCTIONAL ANALYSIS OF *PLASMODIOPHORA BRASSICAE* EFFECTORS AND THE MANAGEMENT OF CLUBROOT DISEASE.

PRINCIPAL INVESTIGATOR: Peta Bonham-Smith, University of Saskatchewan
FUNDING: Saskatchewan Ministry of Agriculture, SaskCanola
PURPOSE: The main objective of the project is to profile *Plasmodiophora brassicae* candidate effector proteins. Using the RNA-Seq data from clubroot-infected Arabidopsis, previously generated by the same research group,

they will identify a subset of candidate effector proteins secreted by the clubroot pathogen during secondary infection. Each effector protein will be characterised and their target plant protein identified in order to explore potential sources of resistance to clubroot disease.
PROGRESS: The group has identified 32 candidate effector proteins (small secreted *P. brassicae* proteins - SSPbPs). One candidate is important in plant effector-triggered immunity. Characterization of effector proteins continues.

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 help canola growers with management of clubroot disease, researchers propose to develop a sensitive and rapid diagnostic tool to detect the presence of pathogen and determine the pathotypes present and the relative abundance.
PROGRESS: Researchers have improved the pathotype 3 genome to almost chromosome level assembly. This improved genome will be used as a reference for sequence based diagnostic of clubroot isolates from canola fields.

IDENTIFICATION AND GENETIC MAPPING OF NOVEL GENES FOR RESISTANCE TO BLACKLEG IN CHINESE AND CANADIAN *BRASSICA NAPUS* VARIETIES/LINES/GERMPLASM

PRINCIPAL INVESTIGATOR: Dilantha Fernando, University of Manitoba
FUNDING: Alberta Canola, SaskCanola
PURPOSE: This study will evaluate disease incidence and severity in selected commercial fields with different R-gene rotations and within a small plot trial looking at rotating major resistance gene groups. This project will help to understand how blackleg major resistance genes should be stewarded to protect cultivar longevity and to minimize blackleg incidence and severity.
PROGRESS: Recent data from the small plot trial showed that canola cultivars carrying a single *Rlm4* gene or *Rlm3/Rlm4* genes displayed lower disease incidence and disease severity. This indicates that canola cultivar carrying *Rlm4* gene could be introduced as an effective rotation material in Western Canada canola fields. Over 50 fields have been surveyed across the Prairies from 2018 and 2019. Differences have been noted in blackleg disease incidence and severity with cultivars containing different resistance genes.

OVERCOMING BLACKLEG DISEASE IN CANOLA THROUGH ESTABLISHMENT OF QUANTITATIVE RESISTANCE

PRINCIPAL INVESTIGATOR: Hossein Borhan, AAFC Saskatoon
FUNDING: SaskCanola
PURPOSE: Quantitative resistance to blackleg disease, also known as adult plant resistance (APR), is a highly desirable trait for mitigation of risk to production and export of canola posed by the blackleg pathogen *Leptosphaeria maculans* (*Lm*). However the nature of APR genes and their function in providing protection is not known. The goal of this project is to combine gene expression profile and mapping data to identify genes providing immunity to blackleg of canola.
PROGRESS: Three genes with reported roles in plant defence and predicted function as receptors, detoxifying enzymes and cell wall reinforcement proteins were identified. One has been transferred to the *B. napus* cultivars to determine its function in APR.

MAPPING AND INTROGRESSION OF THE HIGHLY EFFECTIVE *BRASSICA RAPA* BLACKLEG RESISTANCE GENE *RLM11* INTO SPRING-TYPE *BRASSICA NAPUS.*

PRINCIPAL INVESTIGATOR: Hossein Borhan, AAFC Saskatoon
FUNDING: SaskCanola, Western Grains Research Foundation, Saskatchewan's Agriculture Development Fund
PURPOSE: In previous projects, the researchers identified Rlm11 as an important gene for canola resistance to blackleg in Western Canada. This study will identify markers for the gene and then use introgression to cross the gene into into *B. napus* germplasm.
PROGRESS: Currently *Rlm11* has been introgressed into a *B. napus* line with plants showing normal spring-type growth habit and good seed set.

A FIELD-BASED PROTOCOL FOR THE ASSESSMENT OF QUANTITATIVE RESISTANCE (QR) AGAINST BLACKLEG OF CANOLA AND CRITICAL WINDOW OF INFECTION IN WESTERN CANADA

PRINCIPAL INVESTIGATOR: Gary Peng, AAFC Saskatoon
FUNDING: SaskCanola, CAP
PURPOSE: This project aims to show the relative importance of cotyledon vs. lower true-leaf infection linked to blackleg incidence and severity. Additionally, the impact of race non-specific resistance on blackleg development via leaf infection will also be studied to provide key information for fungicide strategy based on seed or foliar treatment.
PROGRESS: In 2019, two greenhouse trials on Westar (susceptible) and two inoculated field trials on five canola varieties were carried out. Data are being analysed.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