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Science Edition 2016

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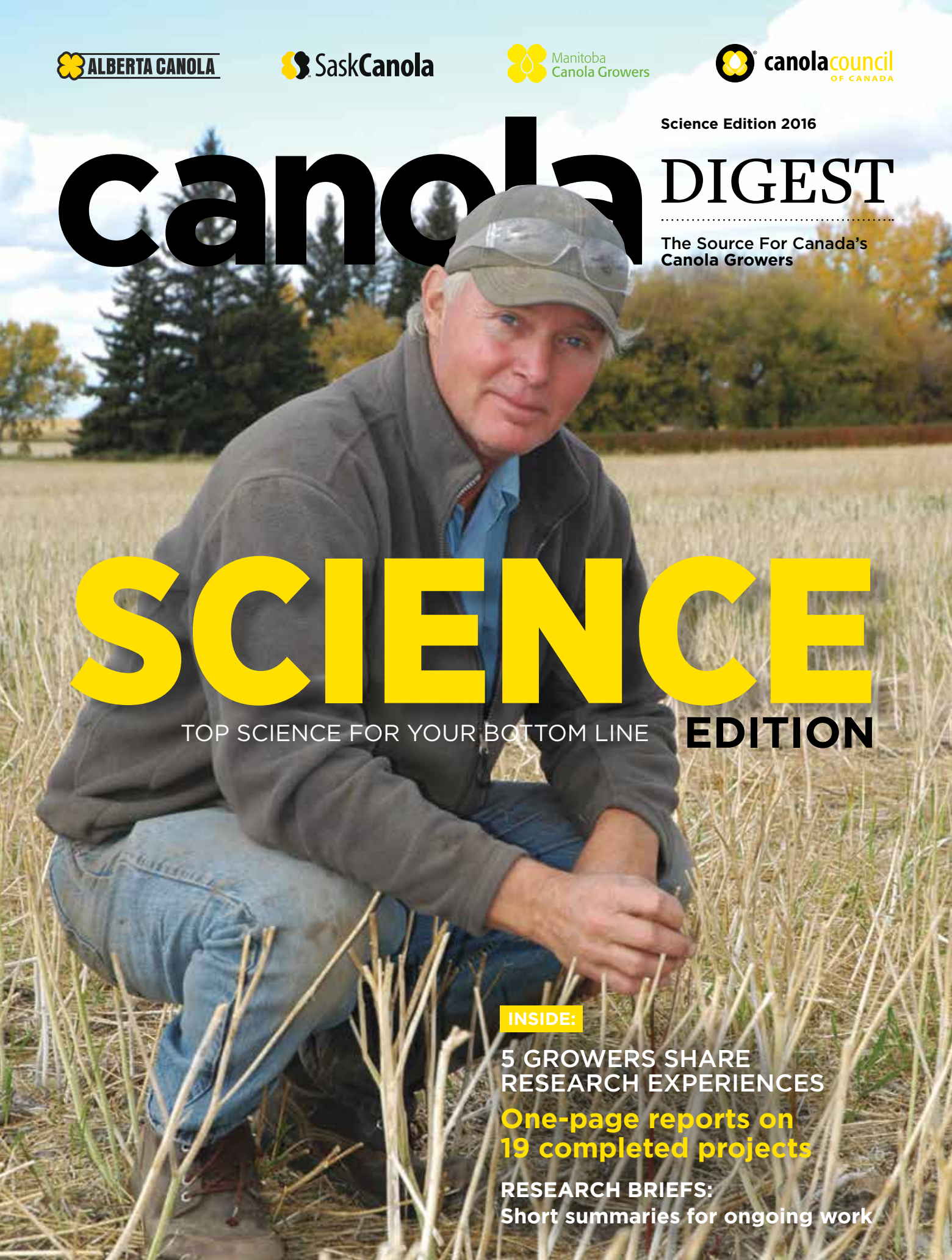
The Source For Canada's Canola Growers



SCIENCE EDITION

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5 GROWERS SHARE RESEARCH EXPERIENCES

One-page reports on 19 completed projects

RESEARCH BRIEFS:
Short summaries for ongoing work

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THE CANOLA DIGEST
is a joint publication of the Alberta Canola Producers Commission (ACPC), SaskCanola, the Manitoba Canola Growers Association (MCGA) and the Canola Council of Canada.

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CANADIAN POSTMASTER
Send address changes and undeliverable copies (covers only) to:
400 – 167 Lombard Avenue
Winnipeg, MB R3B 0T6

PRINTED IN CANADA
ISSN 0715-3651
Postage paid in Winnipeg, MB
Publication Mail Sales Agreement
#40027283

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Putting results to work

Canola growers invest in research. Canola growers steer research objectives. Canola growers also do research and use research, through on-farm trials and application of results to improve their practices and profitability.

This year's Canola Digest Science Edition features five growers who have offered their fields for important research projects or put recent research results into practice. These growers understand the value of research and they support research investment – as we do and likely you, too.

This edition also features one-page summaries of 20 recently completed studies, and short updates on many other ongoing studies. All of these are categorized into the five major segments that, with the application of improved practices, can help growers move toward the goal of 52 bu./ac. average Canadian canola yield by 2025, as outlined in the Canola Council of Canada's Keep It Coming strategic plan. The five segments are plant establishment, fertility management, integrated pest management, harvest management and genetics. By adopting the latest genetics and making incremental improvement in each of the four agronomy segments, we can achieve the goal to increase canola productivity and expand Canadian canola sales into the growing global oilseed market.

As research chairs for our respective provincial canola farmer organizations, we have a responsibility to recognize on-farm challenges and advance research that can help solve these challenges to meet the productivity goal. As growers ourselves, we also require a clear description of how these results can increase profitability and sustainability on the farm.

We don't take this responsibility lightly.

SaskCanola invested $1.94 million in research projects and investments in 2015-16 and has a research budget of $2.1 million for 2016-17. It has funded 341 projects to date. SaskCanola, through Growing Forward 2 and in partnership with Alberta Canola, also leads "Canola Disease Management Tools for the Prairies – Blackleg and Sclerotinia," which funds a team of researchers from universities and Agriculture and Agri-Food Canada (AAFC) looking for solutions to these two major diseases. This magazine has a progress report on those projects.

Alberta Canola invested $1.4 million towards 11 new agronomic projects and two new product-development projects in 2015-16. In total, Alberta Canola has $3.5 million committed toward 28 active projects. These investments leverage partnership dollars at a three-to-one ratio.

Manitoba Canola Growers invested over $480,000 in new and continuing research projects in 2015-16. These funds were leveraged through Growing Forward 2 and in partnership with Agriculture and Agri-Food Canada at a ratio of four to one.

When growers invest in research, industry and other funders, including AAFC, get a clear signal showing which projects growers value. This drives the collaboration and leverages more funding that multiplies the grower investment. Updates on these collaborative projects are featured throughout this magazine.

With the federal government's Growing Forward 2 funding, growers also have a say in funding decisions through their involvement in the Canola Council of Canada. Many completed and ongoing studies featured in this magazine are GF2 funded. With Growing Forward 3 anticipated in 2018, this co-operation should continue.

As is clear from this Canola Digest Science Edition, many good people are involved in canola research across Canada. Through active involvement and investment from the Canola Council of Canada and your canola grower organizations, growers influence what projects get done. The next step is to look at the results and promote how growers can benefit from all that work. The Canola Research Hub at research.canolacouncil.org is one great resource to help growers apply research. This magazine is another.

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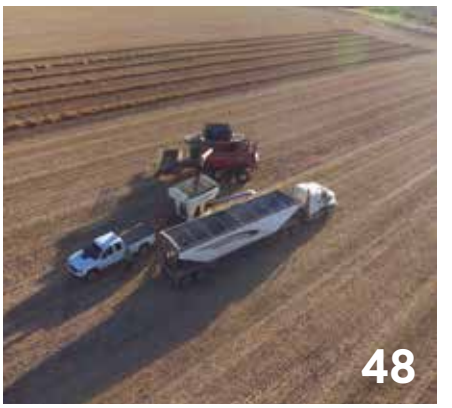


GLOSSARY OF ABBREVIATIONS

Alberta Canola/ACPC — Alberta Canola Producers Commission
MCGA — Manitoba Canola Growers Association
SaskCanola — Saskatchewan Canola Development Commission
CCC — Canola Council of Canada
AAFC — Agriculture and Agri-Food Canada
ABC — Alberta Barley Commission
ACIDF — Alberta Crop Industry Development Fund
ADF — Agriculture Development Fund (a Saskatchewan program)
AF — Alberta Agriculture and Forestry
AFC — Agriculture Funding Coalition
AIBIO — Alberta Innovates Bio Solutions
AIP — Agri-Innovation Program (AAFC matching initiative for Growing Forward 2)
AITF — Alberta Innovates Technology Futures
APG — Alberta Pulse Growers
ARDI — Agri-Food Research and Development Initiative
ASCA — Alfalfa Seed Commission of Alberta
AWC — Alberta Wheat Commission
CARP — Canola Agronomic Research Program (grower organization funded)
CGDP — Canola Germplasm Development Project (SaskCanola funded)
GF2 — Growing Forward 2 (federal funding program)
NSERC — Natural Sciences and Engineering Research Council of Canada
PAMI — Prairie Agricultural Machinery Institute
SPG — Saskatchewan Pulse Growers
SWDC — Saskatchewan Wheat Development Commission
WGRF — Western Grains Research Foundation

PLANT ESTABLISHMENT

Ideal seeding speed depends on drill, conditions

An even seeding depth across all rows will improve canola uniformity and seed survival, but the seeding speed to achieve this consistency will depend on the drill, soil type and field conditions. It helps to run your own tests.

For a summary of Bob Blackshaw's study, search for "Management practices for optimum canola emergence" at **research.canolacouncil.org**.

Rob Florence participated in an Agriculture and Agri-Food Canada (AAFC) study to see how seeding tools and seeding speeds affect canola emergence. Florence learned that with his drill and his black soil, he could actually seed a little faster and still hit his canola plant establishment targets.

Florence, who farms at North Battleford, Sask., with his son Drew, participated in both years – 2011 and 2012 – of the field-scale part of the study. A coordinator came out to take soil tests and help choose a relatively even area to run the comparison. Florence then seeded at six different speeds between three and six mph using his John Deere 1870 ConservaPak drill with paired-row openers.

Rob Florence participated in an AAFC field-scale study into canola seeding speed. He learned that with his drill in his conditions, he could seed faster if he wanted to.

As expected, seed depth was most consistent at the slowest speed and varied most widely – from surface to 1.5" – at six mph.

What surprised Florence was that he could actually speed up his standard seeding speed and still achieve reasonably good seed depth and plant emergence across all runs.

"On average, we had good plant counts up to five mph in the trial," he says.

Florence says they try to seed at 4.2 mph, but "it's nice to know we can go faster if we're stressed for time." Their target population is eight to 12 canola plants per square foot. "We like to have lots in case of frost or insects," he says. "Our emergence in 2016 was 60 to 70 per cent, which is slightly above our usual average, due to good conditions at seeding."

Florence says having trials done on his own farm in his conditions makes the results a little more relevant. "I know on-farm trials can be a hassle, but the results make it worthwhile," he says.

SMALL PLOT COMPONENT

Bob Blackshaw, the AAFC research scientist who led the study, also ran small-plot trials at five locations across the Prairies. The study compared six openers from a 0.5-inch knife to a 4.5-inch paired row. Canola was seeded at 12-inch row spacing into cereal stubble at two speeds – four and six mph.

Across all opener types, an increase in seeding speed from four to six mph in the small-plot study resulted in reduced canola emergence in 20 per cent of comparisons in 2011 and 33 per cent of comparisons in 2012. The results found little difference in performance between the six openers. All openers usually performed well.

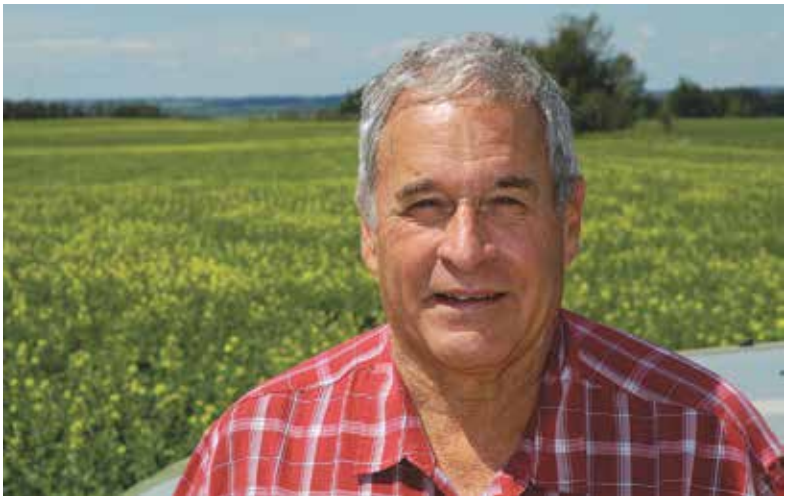
This study also confirmed results from previous studies indicating that canola emergence is highly variable and often in the range of 50 to 70 per cent.

Aim for consistent seed depth

Planters are the ultimate tool for precise and consistent seed placement, which benefits canola stand establishment. But are they worth it?

You want to seed canola at up to one inch deep. What you might not realize, says Craig Shaw, is that seeding tools are rarely that precise, often varying from a quarter inch to two inches when set for one inch.

Shaw, who farms at Lacombe, Alta., wanted to see if planters could reduce that variability. He has worked with Agriculture and Agri-Food Canada (AAFC) research scientists at Lacombe on various projects, and recently co-operated with them on a planter project for canola seeding.



Craig Shaw, who farms at Lacombe, Alta., helped with a three-year planter study with AAFC. The study didn't make any conclusions, but Shaw learned a lot about the good and bad when using a planter to seed canola.

Shaw and AAFC with input from Murray Hartman, oilseed specialist with Alberta Agriculture and Forestry, and the Canola Council of Canada, put together a three-year project to compare results for a ConservaPak drill and a Monosem planter. Both were configured for two row spacings – 12" and 24" – and various seeding rates, including rates as low as two seeds per square foot.

The project didn't come to any sound conclusions. "We did not get a strong data set from this experiment," says Neil Harker, AAFC research scientist and lead on the project. Weather and equipment settings were factors. "The data are too preliminary and limited to make any solid conclusions or recommendations."

By participating in the study, Shaw did learn a lot about planters. For one thing, they are not well-suited to a one-pass system. Planters are more likely to reach their precise seed placement potential in a tilled field, and they are not designed to carry much fertilizer. Modifications are available to make them one-pass possible, "But how much money do you want to tie up in the planter?" Shaw asks. "It is not hard to double the cost of a planter by adding features."

Planters also have a lot more moving parts than a regular drill, which means more maintenance, he adds.

That said, if Shaw wasn't ready to retire, he might make the switch. "A planter would work in our system," he says. Shaw puts fertilizer down in the fall, which works the soil and also eliminates the need to carry a lot of fertilizer with the seeding tool – both of which benefit the planter option.

He says six or seven farms in his area already use planters for canola. "The huge plus," he says, "is the ability to back off seeding rates quite a bit and still be able to maintain yields."

"The huge plus is the ability to back off seeding rates quite a bit and still be able to maintain yields."

— Craig Shaw

But planters aren't the only path to higher seed survival and achieving target yields at lower seeding rates. Shaw uses a Salford 522 double-disc drill with air delivery and 10-inch spacing between openers. He seeds canola at 3.5 lb./ac. To limit seed bounce, he added SeedVu vents at the top of each manifold to bleed off air pressure so seed and fertilizer just drop to the opener. This is one step that can improve consistency of seed placement with an air drill.

Others are Individual depth control on each row and improved seed metering.

Beyond that, canola seed survival depends a lot on soil temperature, soil moisture, residue conditions and many other factors that have little to do with the seeding tool.

"The bottom line is that high canola seeding rates will offset variability in the seedbed environment," Shaw says. "When you do things right to reduce variability in the seedbed environment, you can lower seeding rates." While a planter can help in some respects, many other factors influence the results.

Consider seed size when targeting optimum plant stand

KEY RESULT: Seeding rates should be established based on 1,000-seed weight, using an on-line seeding rate calculator or on-line apps.

PROJECT TITLE, PRINCIPAL INVESTIGATOR: "Seed size and seeding rate effects on canola yield and quality," Neil Harker, Agriculture and Agri-Food Canada Lacombe

FUNDING: Alberta Canola, MCGA, SaskCanola, CCC, AAFC, GF2

Recent surveys indicate that approximately half of all western Canadian canola growers have crop densities of less than 40 plants per square metre (about 4 plants per square foot), yet optimal, consistent yields require a minimum of 50 plants per square metre.

Adding to stand establishment challenges is that, in recent years, canola seed size has increased substantially. Seed weights greater than 6 g per 1,000 seeds are not uncommon. Large seed means a lower number of seeds per square metre are planted if seeding rate is based just on pounds per acre, and this approach could run the risk of less than 50 plants per square metre.

A three-year study investigated the influence of seed size on seedling emergence, and canola yield and quality. In 2013, direct-seeded experiments were conducted at nine western Canada locations. Four canola seed sizes (1,000-seed weights ranging from 4.0 to 5.7 g) and one un-sized treatment (4.4 g average) were seeded at two rates (75 and 150 seeds per square metre).

At the time of research, the largest seed available wasn't representative of the largest seed size available in the marketplace. In 2014 and 2015, two seed sizes were compared at sixteen western Canadian sites; averaging 3.4 g for small seed and 5.2 g for the large seed and five seeding rates (50, 75, 100, 125 or 150 seeds per square metre).

IMPROVED CROP GROWTH

In 2013, higher seeding rates led to better canola emergence and stubble density at harvest, but did not result in higher yield. Higher seeding rates also increased early crop biomass, increased weights and seed oil content of harvested seed, and reduced days to start of flowering and days to crop maturity.

In 2014 and 2015, smaller seed had improved canola yield at higher seeding rates, but the same response did not occur for the larger seed lot. Increasing seeding rates also increased crop density, plant mortality, crop biomass and seed oil content and decreased days to start of flowering, days to end of flowering, days to maturity, per cent green seed and seed protein content.

Using the larger seed lot resulted in increased early crop growth and 1,000-seed weights but did not have an effect on canola emergence, yield or seed quality in 2013. In 2014 and 2015, the larger canola seeds increased crop density and crop growth and decreased plant mortality, days to start of flowering, days to end of flowering, days to maturity and per cent green seed. Seed size did not influence yield, seed oil content or seed protein content.

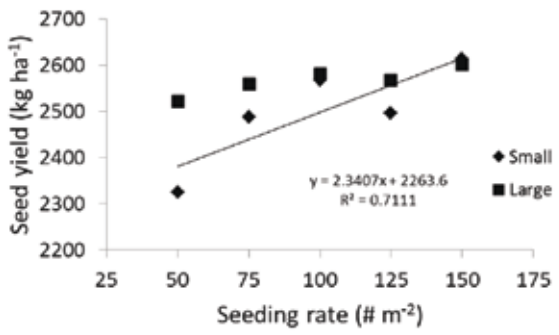
CONCLUSIONS

Given current trends for increased seed size, and the fact that canola seed costs are traditionally based on weight rather than seed number, it is useful to know that, in this trial, larger versus smaller seed could increase crop density and decrease plant mortality, days to flowering, days to end of flowering and days to maturity. In western Canada, earlier flowering and maturity are advantageous for optimum canola yields because high temperature yield reductions are less likely earlier in the growing season.

The larger seed also increased early season growth, which favours crop competition with weeds and less reliance on herbicides. Furthermore, planting the larger seed lot led to lower levels of green seed than small seed, and therefore created opportunities for higher canola grades and profits.

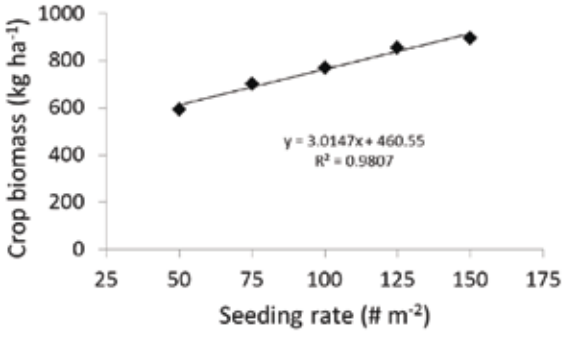
Growers should note that the largest seed lot available at the time of research wasn't as large as is available in the marketplace. When choosing a canola seeding rate, growers should continue to focus on their target plant density which is affected by seed size, seeding rate and seed survival.

Graph 1. Seeding rate bigger influence on yield for small seed



Increasing the seeding rate of small canola seed improved canola yield (2014-15 results). For large seed, seeding rate regression effect was not significant.

Graph 2. Higher seeding rate improved crop biomass



When it comes to crop biomass, there was no interaction for seed size and seeding rate, so results are averaged over seed size. (2014-15 data)

Identification of superior crop rotations

KEY RESULT: The southeast Peace region has the highest intensity of canola acres and short canola rotations in the western Canadian Prairies. However, this study suggests that this may not be the best choice for growers in terms of long term yield, cropping system sustainability, soil moisture use, root health and economics.

PROJECT TITLE, PRINCIPAL INVESTIGATOR: "Identification of superior crop rotations to minimize inputs, optimize crop production and maximize contribution margin," Kabal S. Gill, Smoky Applied Research & Demonstration Association (SARDA)

FUNDING: Alberta Canola APG, ABC, AF, local municipalities, SARDA

Short canola rotations in the southeast Peace region bring up concerns of yield losses, long-term economics and sustainability. However, despite the advantages of crop diversity found in other areas (including reducing the risk from crop failure or price fluctuations, minimizing pest issue, optimizing yield, and spreading the workload), there was a lack of local information on this topic.

This seven-year study conducted by Dr. Kabal S. Gill at SARDA compared canola and wheat monocultures to 10 different crop rotations including pea (P), barley (B), flax (F), canola (C) and wheat (W) crops, i.e. WC, PWW, CWW, CCW, PCW, CPW, WBC, BWC, FWC, and FCW. One crop from each of the 12 treatments was grown from 2009 to 2015. Crops were fertilized to 45, 60, 60, 35 and 90 bu/ac of canola, wheat, peas, flax and barley, respectively. Recommended agronomic practices were used for each crop.

There were a few weather challenges throughout the study. Four of the years were drier than average (2009, 2010, 2014 and 2015) and the other three years (2011-2013) were normal or wetter than average (including flooding in June of 2013 which resulted in a few plots being discontinued). The variations in precipitation levels and the distribution of rain throughout the growing season were linked to the huge range in canola yields (especially in the crop following a dry year), regardless of the rotation they were a part of. Frost damage in 2010 may have also affected the canola yields.

RESULTS

Crop rotations were generally superior to continuous canola and continuous wheat systems. Interestingly, this is the result of improvements in several areas, including soil moisture uptake, fertilizer use, root health and yield, which together impacted economic returns.

YIELD. Although the yield benefits of canola grown in a crop rotation varied from year to year, the average yield benefit was 11.6 bu./ac. (19.9 per cent) over continuous canola. (See the table.) While canola generally yielded lower on canola stubble than other crop stubble, the difference between a variety of crop stubbles was not consistent. Continuous wheat system also tended to have lower yields than wheat in a rotation.

FERTILITY. Compared to the continuous canola system, which received the maximum amount of N, P, K and S fertilizers, all other rotations required lower total inputs and therefore had lower total fertility costs.

SOIL MOISTURE. Soil water data in 2013, 2014 and 2015 indicated that cereals, especially barley, used more water and peas and flax used the least. Therefore a rotation which included peas or flax would reduce total water depletion compared to one without, while a rotation with only cereal crops would increase water depletion.

ROOTS. Canola root length, surface area, projected area, volume and number of tips were higher when grown on wheat stubble compared to canola grown on canola stubble. Flax root growth in 2015 was better on wheat stubble than canola stubble but wheat root growth wasn't significantly different when grown on the canola or wheat stubble.

ECONOMICS

The canola-pea-wheat rotation provided the highest gross returns and contribution margins, followed by the wheat-barley-canola rotation and then continuous canola. The continuous wheat rotation came in with the lowest contribution margin out of all 12 treatments.

However, while these values include crop expenses, they don't account for the increased risk of pest pressure or impact on soil quality that come with long-term continuous rotations. Similarly, revenues do not account for the potential increase in stability and robustness that may come from improved soil quality and reduced soil moisture depletion.

Canola and wheat yield benefit from the crop rotations over the continuous canola (CC) and continuous wheat (WW) systems.

	CANOLA YIELD BENEFIT		WHEAT YIELD BENEFIT	
Year	Range, bu/ac	Mean, bu/ac	Range, bu/ac	Mean, bu/ac
2010	8.5 to 13.7	11.6	-1.0 to 6.7	2.3
2011	1.1 to 8.5	4.6	5.5 to 16.3	12.8
2012	3.8 to 11.6	8.0	4.3	4.3
2013	12.6 to 20.6	16.9	5.8 to 14.1	10.0
2014	9.1 to 19.3	15.2	-2.3 to 1.1	-0.7
2015	9.3 to 18.8	13.6	10.4 to 11.5	10.9
Average		**11.6**		**6.6**

Aster yellows: Seed treatment benefit; rating damage

KEY RESULT: The study found that seed treatment can reduce leafhopper feeding and therefore suppress aster yellows (AY). It also produced a five-point rating scale to score canola plants for AY damage and help predict yield loss.

PROJECT TITLE, PRINCIPAL INVESTIGATORS: "Seed treatments as an alternative method of controlling leafhoppers and aster yellows disease in canola," Bob Elliott and Chrystel Olivier, Agriculture and Agri-Food Canada, Saskatoon

FUNDING: GF2, ACIDF (WGRF and Alberta Canola) and private industry

Aster yellows (AY) is caused by a phytoplasma that infects vascular tissue in the leaves, stems and roots of *B. napus*. Leafhoppers feeding on canola transmit this disease-causing phytoplasma. AY caused major production losses to canola in western Canada in 2000, 2007 and 2012. In 2012, the disease was found in 77 per cent of the canola fields surveyed, with yield losses estimated to average 10 per cent.

The experience in 2012 inspired this project, which had two parts: (1) Study the influence of leafhopper feeding densities on phytoplasma levels and symptoms in hybrid canola plants, as well as yield and 1,000-seed weight in dry and wet soil. (2) Evaluate seed treatments for control of aster leafhoppers, which transmit disease-causing phytoplasma.

PART 1 RESULTS

Investigators compared infection in dry and wet soil conditions, and under a wide range of leafhopper population densities. They also observed a wide range of symptoms. With their results, investigators came up with two valuable management recommendations.

(1) Not all leafhoppers are feeding, and the percentage not feeding tends to be higher in dry conditions. Therefore plant inspections to estimate leafhopper feeding densities will provide a more accurate indication of potential AY infection than estimates based on sweep nets.

(2) Investigators produced a five-point rating scale to identify AY symptoms more accurately in the field. (See the table.) The scale shows a wide range of symptoms associated with AY. As the study found, plants with AY ratings of three to five produced little or no seed. Also, if plants are showing just some bladder-like pods, AY will likely cause yield loss in all pods – even ones that look normal. Assessments done eight weeks after initial infection seem to provide the most accurate correlation between damage and yield loss.

PART 2 RESULTS

Since early infection seems to cause the most significant damage, part 2 of the project studied whether seed treatments provided some protection from leafhopper feeding and the resulting transmission of phytoplasma.

Laboratory and field tests from 2013-15 evaluated untreated seed, fungicide-treated seed, four neonicotinoid seed treatments, two diamide seed treatments, three diamide/neonicotinoid mixtures and two experimental seed treatments. Laboratory bioassays in 2013-14 focused on the effect of soil moisture on efficacy.

In laboratory and field tests, it was found that a number of seed treatments already on the market can manage leafhoppers enough to suppress the AY phytoplasma and AY symptoms.

Results were sent to chemical companies to support the registration of the treatments for leafhopper control and AY suppression. However, given that leafhopper and AY infestations are sporadic and unpredictable, canola growers are unlikely to select seed treatments based on their efficacy against leafhoppers and AY. Instead, they will continue to select seed treatments based on their efficacy against crucifer and striped flea beetles.

This five-point rating scale developed by Bob Elliott and Chrystel Olivier was published in the Canadian Plant Disease Survey. It will assist producers, pathologists and agronomists in identifying AY symptoms more accurately in the field.

AY rating	Plant stature and height	Presence of swollen buds	Pale green or purple flowers	Presence of normal or bladder-like pods
1	Normal height	None to a few swollen buds on lateral branches (<10% of all buds)	None	None at bolting or flowering (<10% bladder-like pods at tips of a few branches at plant maturity; >90% normal pods)
2	Normal height Erect plant/pods	Swollen buds on lateral branches and some main stems (<50% of all buds)	None	Few bladder-like pods on main stem and lateral branches at bolting (<50% bladder-like pods; >50% normal pods)
3	Normal to slightly shorter height Erect plant/pods	Swollen buds on all lateral branches and some main stems (<80% all buds). Condensed inflorescence	Many pale green flowers at tips of all branches	Many bladder-like pods on lateral branches at bolting (<20% normal pods; usually on main stem)
4	Short erect plant Limited bolting	All buds swollen Condensed inflorescence	All flowers green or purple	100% bladder-like pods at maturity No normal pods. No seeds
5	Bonsai-like plant No bolting	All buds swollen Swollen buds emerging directly from growing point	Only small green flowers	Few bladder-like pods at maturity No normal pods. No seeds

Less seed-placed fertilizer means more seed survival

Lee Erickson discovered that high rates of fertilizer in the seed row were having a devastating effect on his canola seed survival.

Cynthia Grant's research summary for, "Improving nutrient management in canola and canola-based cropping systems," is available at **research.canolacouncil.org**.

Steve Shirtliffe's report, *"Determining the economic plant density in canola,"* is posted in the Research section at saskcanola.com and was featured in the 2015 Canola Digest Science Edition, available at **canoladigest.ca**

Right: Lee Erickson found that limiting seed-placed fertilizer and seeding at less than five mph make a big difference to canola seed survival on his farm at Donalda, Alta.

Lee Erickson wanted to lower his canola seeding rate but his agronomist put the brakes on that idea.

"You're only getting 50-60 per cent seed survival," his agronomist said, factoring in seeding rate, thousand seed weight and the emerged stands. "You can't lower the seeding rate without reducing plant stand below eight per square foot."

This target aligns with Canola Council of Canada's recommended stand of seven to 10 plants per square foot, a practice driven in large part by Steve Shirtliffe's 2009 meta-analysis. The University of Saskatchewan researcher analyzed results from 35 canola seeding rate studies, and concluded that stands of fewer than five plants per square foot cannot reach the crop's yield potential. Stands above this threshold have the plants needed to reach their yield potential.

Eight plants per square foot established in the spring allows for some plant loss to frost, insects or disease while still achieving the five plant minimum by harvest.

Driven by his low seed survival, Erickson, who farms at Donalda, Alta., discussed with his agronomist what could be done to fix this issue. They went through possible causes, including herbicide carryover damage, seed depth, seeding date and fertilizer rates, to see which was most likely on Erickson's farm.

They finally identified the problem: Too much fertilizer in the seed row.

He had been putting 70 lb./ac. of monoammonium phosphate (MAP), equivalent to 30-35 lb./ac. of actual phosphate, and up to 70 lb./ac. of ammonium sulphate (AS) in the canola seed row. "It turns out this was really damaging our seed survival," Erickson says.

Now he puts an "absolute maximum" of 20 lb./ac. of actual phosphate in the seed row and no sulphur. "We have seen a dramatic change in seed survival since we made this change three years ago," he says. "We're now getting 70-80 per cent seed survival on average, and maybe more this year."

In her recent study showing how seed-placed fertilizer will reduce canola seed survival, Cynthia Grant, now retired from Agriculture and Agri-Food Canada, found that while MAP alone can decrease canola stand density, the effect is much greater when AS is added in the seed row. Canola stand density at a base rate of 20 lb./ac. of phosphate (40 lb./ac. MAP) drops by around 30 per cent when AS is added at 70 lb./ac. Even MAP alone can reduce seed survival. In Grant's study, stand density with 40 lb./ac. of phosphate in the seed row was 20 per cent lower than with no fertilizer in the seed row.

Erickson currently has two different drills. He has a Bourgault Model 3320 QDA (quick depth adjustment) with mid row banders bought so he could apply dry fertilizer at the time of seeding. And he has a John Deere 1910 with ConservaPak paired-row openers that can apply NH3. He bought the John Deere for its sectional control. In his area, he calculated that 11.8 per cent of area he covers with his seeders each year are overlaps. He wanted to stop this waste of inputs. Both drills do a good job of seeding canola, he says.

He aims for one-inch average seed depth for canola, and to ensure this, he will not seed faster than 4.8 mph. "As soon as we hit 5 mph, the drill starts throwing more soil," he says. "We're no-tillers, so we have lots of residue coverage to work through, and at speeds over five mph, things don't work the way they should."

These steps, including reduced seed-placed fertilizer, are all part of his goal to get canola off to a good start. "If your canola doesn't start well, you're not getting the 50-60 bu./ac. yields," he says.

EC cannot help make VR strategies more consistent

KEY RESULT: While soil electrical conductivity (EC) measurement is a strong indicator of soil clay and moisture content, it cannot help to make variable rate (VR) fertilizer programs more consistent. Producers using VR should be prepared to use a specific strategy for each field each year.

PROJECT TITLE, PRINCIPAL INVESTIGATORS: "Understanding soil variability for effective zone management in precision agriculture – an evaluation of sensor based soil mapping tools," Ken Coles, Farming Smarter

FUNDING: Alberta Canola ABC

Satellite images, historical yield maps, terrain analysis and representative soil samples are often used in various combinations to characterize different zones. Farming Smarter initiated this study to see if soil electrical conductivity (EC) measurements could improve the accuracy and effectiveness of these zones and the crop response predictions and prescriptions used on these zones.

The study compared two EC sensors: EM38-MK2 (EM38) and Veris MSP3 (Veris). Soil EC maps from both sensors were found to be strong and consistent indicators of the presence of clay and soil moisture. However, the study revealed that mapped EC data could not be used for a direct estimation of the spatial distribution of macronutrients in the soil.

The project then tested five different zone delineation methods in each of the 10 fields studied. They were:

SURFACE GEOGRAPHY: Zones were created using a subjective assessment of visual spatial differences in terrain, moisture, salinity, etc.

GRID SOIL SAMPLING: Soil sample nitrogen measurements were spatially interpolated using the kriging method. Resulting values were divided equally into three zones.

HISTORIC YIELD: All available yield maps were normalized, then pooled to create an average normalized yield map. Resulting values were divided into three zones equally.

EC: A single EM38 deep EC map was put through a cluster analysis procedure to objectively determine zone boundaries and number of zones.

COMPOSITE: A single representative EM38 deep EC layer and a single representative yield layer were pooled and put through a cluster analysis procedure to objectively determine zone boundaries and number of zones.

All five methods had some level of success at identifying regions that yielded differently from one another. However, the study could not consistently identify an effective variable nitrogen management strategy for these zones.

Among the zone delineation methods, there was reasonable success identifying regions that yielded differently from one another, as the study did so in about 50 per cent of instances. These results varied across delineation methods, with the grid soil sampling method being notably less effective than the others. However, the project was unable to consistently identify unique yield responses to nitrogen, indicating that grain yields in the zones identified did not respond differently to nitrogen.

Yield correlated with EC data in roughly 20 per cent of instances, on average, but this fluctuated significantly by year. Correlation exceeded 30 per cent of instances for 2010 and 2013 yield data but was as low as zero per cent for 2012. This shows how variable yield patterns can be from year to year. In fact, yield maps from various years only had strong correlations to one another in 10 per cent of instances project-wide. Elevation correlated strongly with yield data in 26 per cent of instances. This places significant limits on the capability of soil sensor or elevation data to predict grain yield in a given field in a given year.

The study found that universal strategies for zone delineation were largely ineffective, which begs for close scrutiny of VR strategies. It is unlikely that the strategies tested would help a producer reduce nitrogen inputs and associated costs.

In conclusion, this study questions the viability of a formulaic approach to zone delineation and management. Producers should be prepared to develop a specific variable-rate strategy for each field each year.

MOMENT

A significant "aha!" moment for me came nearly 25 years ago when I came across some anion exchange membrane material in sheet form. I decided to place some of it in direct contact with the surface soil in various farm fields in my area that I knew had different abilities to supply nutrients to crops. When we measured the nutrients on the membranes, they revealed differences in absorbed nutrients that reflected very closely the different growth and nutrient uptake patterns of crops I could see on the fields. This ultimately led to the development and patenting of the Plant Root Simulator probe and technology for its use. Western Ag Innovations of Saskatoon commercialized it and it has been used since as a tool for research into soil nutrient dynamics as well as a basis for fertilizer recommendations for Prairie farmers.

—Jeff Schoenau, professor of soil science, University of Saskatchewan

The fate of sulphur fertilizers in the soil

KEY RESULT: Choosing the most suitable sulphur (S) fertilizer for the conditions can be difficult. This study found that soluble sulphates, thiosulphate and gypsum are effective at providing early supplies of plant-available sulphate in the seed row. An early supply of sulphate appears to be important for plant S uptake and yield.

PROJECT TITLE, PRINCIPAL INVESTIGATORS:
"Transformations and fate of seed-placed sulfur fertilizers in Saskatchewan soils," Jeff J. Schoenau, University of Saskatchewan

FUNDING: GF2, ADF, SaskCanola, SPG, WGRF, NSERC

Sulphur (S) is recommended for many crops grown in Saskatchewan, including canola. With the fertilizer options available to farmers, choosing the most suitable for the conditions can be difficult, especially since the form of S fertilizer can influence its behaviour and the crop response.

Sources of S include completely soluble ammonium and potassium sulphate, insoluble elemental S (that must be oxidized to sulphate to be plant available), liquid ammonium thiosulphate, and gypsum (calcium sulphate) which is slightly soluble. Although there have been studies that apply various forms of S fertilizer then measure the crop yields, further investigation is required to reveal the specific transformations that different S fertilizers undergo in the soil from the time of application to crop uptake. By understanding the fate of the S fertilizer applied, attempts to predict the relative performance of different S fertilizers for a number of crops under varying application conditions may be improved. This could benefit growers trying to select the fertilizer best suited to their conditions.

End station of the SXRMB at Canadian Light Source, Saskatoon, SK used to measure soil S speciation in the collected samples

Field studies were conducted in 2013 and 2014 along with a growth chamber study to evaluate five S fertilizer forms (ammonium-sulphate, ammonium-thiosulphate, gypsum, potassium-sulphate and elemental sulphur). These five forms were applied alone and in combination with monoammonium phosphate (MAP) in the seed row with wheat, canola and yellow peas. This was carried out in Brown and Black Chernozem and Gray Luvisol soils (all of which were marginally deficient in sulphur) in Saskatchewan. The fate of fertilizer was evaluated by measuring soil-available sulphate and phosphate in the seed row, crop S and phosphorus uptake, and grain yields.

This study also aimed to develop and employ new techniques for using the Canadian Light Source synchrotron to study the fate of fertilizer in soil.

RESULTS

Most of the crop uptake of S occurred one to four weeks after seeding and fertilizing, so early supply of sulphate appears to be important for plant S uptake and yield. Among crop types, canola responded most consistently and to the greatest extent to S fertilizer. It was also determined that S fertilizer products that supply sulphate and/or acidify the soil may slightly enhance the supply of plant-available phosphorus from fertilizer phosphorus placed in the seed row with the sulphur fertilizer.

With regards to the different forms of S, sulphate and thiosulphate were effective in enhancing short-term soil-available sulphate supplies in the seed row, along with crop S uptake and yield compared to the elemental S fertilizer form (which releases sulphate slowly by oxidation). Gypsum maintained the highest seed row sulphate concentrations over time (a consequence of its slightly soluble nature, which reduced the sulphate leaching) and elemental S was found to be the least effective in increasing seed row sulphate supply and providing plant-available sulphur to plants over the short term (first weeks after application). Therefore, soluble sulphates, thiosulphate and gypsum are effective in providing early supplies of plant-available sulphate in the seed row for use by crops. However, for sensitive crops like canola and yellow pea, ammonium thiosulphate and ammonium

Sulphur uptake by canola

In a controlled environment chamber, different S fertilizer forms were applied in the seed row at a rate of 20 kg S per ha.

Treatments	Total S uptake (mg/pot) Brown Chernozem soil
Control	15.4 d
AS	25.2 b
ATS	29.0 bc
Gypsum	29.2 bc
PS	27.3 bc
ES	16.7 d
P × S Fertilizer effect†	
P Value (0.05)	0.042
SEM††	2.66

AS = Ammonium Sulphate; ATS = Ammonium Thiosulphate; PS = Potassium Sulphate and ES = Elemental sulphur
# Means with the same letter in the same column are not significantly different (LSD, p <0.05)

sulphate can cause injury when placed in close proximity to seed and are best placed separate from the seed. Results also showed that while combinations of S fertilizer with MAP may provide some enhancement of phosphate availability, the effects were typically small.

Limited yield response with the addition of S fertilizers may be anticipated in the Brown soil zone when the subsoil has adequate supplies of sulphate S. However, under conditions of unusually high moisture, responses to S fertilization may be observed even in soils with subsoil sulphates. Soils of high organic matter and with good mineralization capacity for S, such as Black Chernozems, also show reduced response.

The Canadian Light Source (CLS) synchrotron was successfully used to identify different S species formed in the soil from addition of S fertilizers, and to follow their transformations in the soil in the growing season following application. Using the CLS, thiols and ester sulphates were identified as short-term products formed from seed-row placed sulphur fertilizers in our Prairie soils that likely originate from microbial immobilization of fertilizer sulphur.

Fungal endophyte could improve canola yield

KEY RESULT: Fertilizer applications are a significant cost to growers and unpredictable environmental temperatures and precipitation events can make it tough to predict the proper fertilization regimes. This study investigates an alternative solution for canola growers: the potential benefit of endophytic fungus *Piriformospora indica* on canola growth and yield. Results from the controlled-environment experiment look very promising.

PROJECT TITLE, PRINCIPAL INVESTIGATORS:
"Improving growth and yield of canola with a novel fungal endophyte *Piriformospora indica*," Janusz Zwiazek, University of Alberta

FUNDING:
Alberta Canola, AFC, AIBIO, SaskCanola, WGRF

Canola is a very resilient plant, but it has high nutrient requirements and is negatively impacted by unpredictable moisture and temperature stresses. Nitrogen (N) and phosphorus (P) fertilizer are also a large part of total crop expenses. New alternatives that could improve plant productivity and robustness while reducing input costs are worth investigating.

Janusz Zwiazek at the University of Alberta studied the effect of fungal endophyte *Piriformospora indica* on canola growth, yield, nutrient (nitrogen and phosphorus) uptake and resistance to stress from drought, oxygen-deficiency and low soil temperatures. Although no fungi has been able to successfully colonize a Brassicaceae plant until recently, the potential for this fungus to have a positive impact on canola was considered due to earlier studies of *P. indica* with other agricultural plants, including *Arabidopsis*.

P. indica is an endophyte that was first discovered in northwest India. It is able to grow in a variety of plant media and has been reported to improve plant survival in unfavourable conditions. While it has shown benefits to some plants, it has also been found to parasitize certain crops in phosphorus-rich soils.

Inoculated canola seedlings (by *P. indica* fungal plugs or liquid media) were used in the series of studies testing the growth and yield of plants under different N and P levels and levels of drought, flooding and soil temperature.

RESULTS

Inoculating canola plants with *P. indica* had a number of positive impacts on growth and yield as well as reducing the negative impacts of environmental stresses and reducing demands for nitrogen and phosphorus.

Despite the lack of benefit found when inoculated plants were grown under controlled-environment conditions in sand culture, the fungus did increase the growth and yield of canola by over 50 per cent and reduce demand for N and P when grown in a medium with sufficient carbon. In addition, while the inoculation of canola plants had no impact on drought resistance at N rates of 50 per cent and 100 per cent during the flowering stage, an improvement in drought resistance was reported at five per cent and 25 per cent N rates. Inoculation of canola was not found to impact the fatty acid composition of the seed, except for C18:3 (alpha-linolenic acid), which was lower in the inoculated plants.

With regards to temperature stress, canola inoculated with *P. indica* was able to tolerate lower temperatures than non-inoculated plants, with growth at 12°C comparable to the growth at 20°C. Presence of the fungal endophyte also reduced the impact of drought, depending on the growth stage. Furthermore, root and shoot biomass was greater in canola plants inoculated with *P. indica* compared with non-inoculated plants.

Furthermore, the storage of coated seeds for six to 12 months at 4°C had beneficial effects on plant growth. Effectiveness of this inoculation treatment lasted for up to one year for seeds in cold storage, suggesting this inoculation protocol is promising for commercial scale applications and needs to be further tested.

These findings provide some justification for further investigation into *P. indica* for the growth and yield of canola while providing environmental benefits at the same time.

Assessing current soil-test based fertilizer recommendations

KEY RESULT: Soil-test-based fertilizer applications can be a sustainable and economical technique to optimize crop production and profit margin, but aren't always used due to questions of effectiveness. This study found that soil test recommendations are fairly accurate and provide good information to growers in both direct seeding and conventional tillage systems.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Assessing current soil test based fertilizer recommendations for direct seeding systems to optimize crop production and contribution margin," Kabal S. Gill, Smoky Applied Research & Demonstration Association (SARDA)

FUNDING: Alberta Canola, ABC, AAF, local municipalities, SARDA

While soil tests are recommended to determine the amount of nutrients available for the upcoming crop, growers often question their effectiveness and the economics of the recommendations. Some also wonder if tests are accurate for a zero tillage system and for farms that no longer use summerfallow.

This study investigated the effects of different soil-test-based fertilizer rates and seeding systems (direct seeding, DS and conventional tillage, CT) on canola and cereals (wheat or barley). The study ran for six growing seasons and compared four fertilizer rates – 0, 60, 100 and 140 per cent of the soil-tests-based recommendation – in a canola-cereal rotation. Both canola and a cereal crop were grown each year on adjacent areas. Fertilizer recommendations were based on annual soil tests for depths of 0-6 inches and 6-12 inches. The amounts of nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) nutrients were calculated for each treatment.

Low spring soil moisture and very low June and July precipitation in 2010 were suspected to reduce wheat yield and canola was damaged by frost, which was then mowed down. The site received adequate moisture during 2011 to 2013. The 2014 was very dry and 2015 was dry in the early growing season.

RESULTS

Results suggest that soil test recommendations are fairly accurate and provide good information to growers in both direct seeding and conventional tillage systems. In addition, nutrient availability data from the Plant Root Simulator soil probes supported the accuracy of soil test results. A fertilizer rate near 100 per cent of the recommendation was able to achieve optimum canola yield.

Soil tests were found to be responsive to the changes in growing conditions and yield of the preceding crop. For example, lower fertility rates were recommended for canola crops that followed a dry year and a low-yielding cereal crop, especially for the higher fertilizer rate treatments of 100 per cent and 140 per cent. Then despite the low fertilitizer rates applied to some of the of 100 per cent and 140 per cent fertilizer rate treatments, higher crop yields than the lower fertilizer rates resulted. These results indicated that the crops effectively used the residual nutrients detected by soil test results (and that using soil tests can save on fertilizer costs due to avoiding excess applications).

The relatively small changes to the P, K and S recommendations may indicate the lower sensitivity of soil tests for these nutrients as well as the relatively large amounts of total P and K in the soil compared to the amounts applied using fertilizers.

Use of direct seeding was shown to improve aggregate stability compared to conventional tillage. From 2011 to 2015, the differences between DS and CT were not consistent across all years, but an overall increase of 0.022 tonnes per hectare per year in canola yields was observed for the DS over the CT system.

As expected, increased fertilization correlated to increased canola yield and there was a diminishing response to fertilization at higher rates. Fertilization also improved canola root growth in early growing season, water uptake from soil during growing season and stability of soil aggregates.

Interestingly, the canola seed yield response to fertilizer did become larger with the passage of years. Compared to the zero per cent fertilizer rate treatment, canola seed yields at the 140 per cent fertilizer rate were 1.35, 2.34 3.00 2.20 and 3.25 times in 2011, 2012, 2013, 2014 and 2015, respectively. Apparently, repeated use of fertilizer enhanced the response of canola yield to fertilization.

Table 1. Canola seed yield (tonnes/ha) based on fertilizer rate (% of recommended)

Treat	2011	2012	2013	2014	2015
Mean direct seeding	3.95	2.58	2.88	1.81	2.79
Mean conventional tillage	3.85	2.57	3.48	1.21	2.49
LSD A	0.260	0.280	0.69	0.352	1.54
Significance	NS	NS	†	*	NS
Mean 0%	3.19	1.41	1.42	0.83	1.04
Mean 60%	4.08	2.56	3.34	1.58	3.01
Mean 100%	4.02	3.02	3.73	1.79	3.14
Mean 140%	4.31	3.30	4.27	1.83	3.39
LSD B	0.31	0.178	0.46	0.166	0.341
Significance	**	***	***	**	***

Profitability and sustainability can go hand-in-hand

KEY RESULT: BMPs can improve canola production while simultaneously advancing environmental stewardship. This study identifies factors that contribute to improved canola production efficiency on the Canadian Prairies. It also examines the relationship between production efficiency and adoption of select environmental stewardship practices. These results may be of use for policy makers in identifying areas of focus for extension and/or support aimed at increasing canola production and competitiveness.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Economic profitability and sustainability of canola production systems in Western Canada,"
Scott Jeffrey, University of Alberta, Edmonton, Alta.

FUNDING: Alberta Canola, SaskCanola, MCGA, CCC, AAFC, GF2

Adoption of best management practices (BMPs) has been encouraged as a means of mitigating the impact of agricultural production on environmental quality. However, the resulting effects of BMP adoption on farm performance are uncertain. Limited evidence suggests that some BMPs might contribute to lower returns. One way in which BMP adoption may affect financial performance is through changes (positive or negative) in the efficiency of production.

BMPs may include development of environmental farm plans, soil testing, reduced- or zero-tillage systems, application of precision farming techniques and various nutrient management practices. Understanding the relationship between BMP adoption and production efficiency levels can provide insights into the likelihood of BMPs being economically viable for producers.

Data for this study was obtained from a 2011 survey of canola producers in the four Western Canadian provinces. Survey data included information on canola area and yield, nutrient use, production practices, as well as farm- and farmer-specific characteristics.

Higher than normal growing season precipitation in 2011 resulted in significant production problems, and contributed to unexpected negative correlation between rainfall and yield. Model results indicate that BMP variables for soil tests, nutrient management planning, use of cropping plans, and precision farming are positively related to production efficiency while other BMP indicators are not significant. There was no significant evidence indicating whether fertilizer inputs were risk increasing or risk decreasing, which may have been due to the high rainfall in 2011.

In terms of environmental stewardship and BMP adoption, the impact on canola production efficiency appeared to be either positive or neutral. However, only a limited number of practices were addressed in the current study. In particular, the survey did not ask producers about their use of environmental stewardship practices that are not directly related to canola production decisions; for example, land use change BMPs such as restoration of wetlands or implementation of buffer strips. If these types of BMPs were considered, the effects might have been different. If wetlands in canola fields were restored for example, there may be an impact on efficiency of field operations due to nuisance costs that would negatively affect overall efficiency of production.

PUBLISHED RESULTS

Results from the efficiency study were presented in a selected paper session at the joint conference of the Agricultural & Applied Economics Association and the Canadian Agricultural Economics Society. An accompanying paper, discussing the potential of improving technical efficiency in Western Canadian canola production while simultaneously advancing environmental stewardship, was subsequently published in the *Canadian Journal of Agricultural Economics**.

To build upon this study, it would be useful to assess environmental efficiency. This would require estimates of not only canola yield but also environmental outputs such as nitrogen that may have been lost due to leaching or run off. This type of assessment would permit a more complete picture of the impact of environmental stewardship, including potential tradeoffs between production and environmental efficiency. Further analysis of this type would help farmers and industry develop profitable and sustainable canola production policies.

Cagdas, Ali D., Jeffrey, Scott R., Smith, Elwin G., Boxall, Peter C. 2016. Environmental stewardship and technical efficiency in Canadian Prairie canola production. Canadian Journal of Agricultural Economics 64(3): 455-477.

aha! MOMENT

I have experienced many moments in my work when I was amazed at the complexity yet simplicity of our natural world. One of those occurred on a blustery fall day just before the first snowfall when we were harvesting rutabaga to monitor and rate root maggot damage. In an old root maggot feeding tunnel around the perimeter of a rutabaga I discovered a "train" of crucifer flea beetles, positioned head to tail, that had selected the tunnel in which to hibernate for the winter. (See the photo.) Not only did it reinforce my belief that flea beetles can and do overwinter in as well as outside crucifer fields, it also highlighted the adaptability and resourcefulness of organisms in their quest for survival.

—Julie Soroka, research scientist, Agriculture and Agri-Food Canada, Saskatoon

What better way to learn about blackleg?

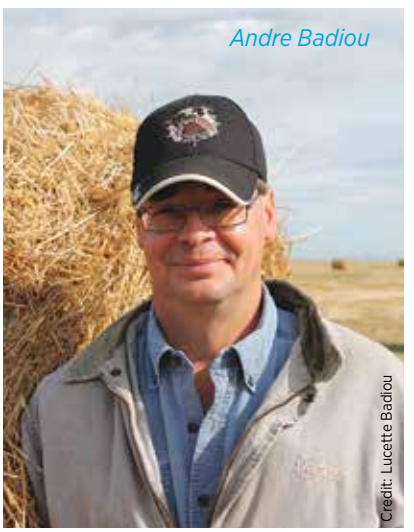
Manitoba canola grower Andre Badiou took part in a study to find out more about the blackleg on his farm and pick up a few management tips. He helped with the study, and the study helped him.

Gary Peng's study into fungicides for blackleg was featured on page 13 of the 2015 Canola Digest Science Edition. Find it at **canoladigest.ca**.

University of Manitoba professor and plant pathologist Dilantha Fernando was telling his agriculture class three years ago about a blackleg project he was about to start. It included a survey of fields across the Prairies to see what blackleg pathotypes were present and how pathotypes changed over time.

After class, a student came up to him and said her dad may be interested. The student was Lucette Badiou from Notre Dame de Lourdes, Man., and her dad, Andre, was starting to see more blackleg on their canola.

"A couple of decades ago my dad and I had to quit growing canola because of severe blackleg in Westar," Andre says. When blackleg-resistant varieties came along, they got back into canola. In 2014, when he saw blackleg return in a big way, Andre thought, "Oh no, here it comes again."


Andre Badiou

Credit: Lucette Badiou

Fernando sent out two assistants on the project, including a doctoral student who collected the samples and gave Andre and Lucette a few pointers on blackleg management.

The Badious usually rotated canola varieties, but in one field they had grown a Roundup Ready variety in 2012 and the same variety again in 2014. The canola also lodged fairly badly. It seemed to have blackleg anywhere stems cracked from lodging, Andre says. A survey found blackleg on 95 per cent of the plants.

The following year, the assistants surveyed a Badiou canola field seeded to a different herbicide system. Andre had also sprayed it with a fungicide. Blackleg incidence on that field was only five per cent.

Badiou is one of 75 or so farmers involved in the five-year project funded through the federal government's Growing Forward 2. Fernando is working with Gary Peng, research scientist with Agriculture and Agri-Food Canada (AAFC) in Saskatoon, and Ralph Lange, plant pathologist with Alberta Innovates, to investigate changes in blackleg populations and how that affects genetic resistance in canola varieties. The goal is to develop a durable blackleg resistance stewardship plan.

So far, the researchers have seen changes in the virulence of *L. maculans*, the more common blackleg-causing pathogen in Western Canada. Specifically, changes in the pathogen population AvrLm3 have led to the breakdown of the canola resistance gene Rlm3 in some fields. Rlm3 is the most common resistance gene in Canadian canola varieties.

The study should show how crop rotation and other agronomic practices affect the rate of pathogen adaptation as well as the relative durability of different resistant sources. Increased knowledge of *L. maculans* pathotype diversity could allow seed breeders to improve their disease resistance package and allow farmers to select varieties with resistance to suit the pathotypes present in their fields.

A system where growers can test which pathotypes are present in a field and then choose a variety that will be resistant to those pathotypes is close, and would be a big step forward for blackleg stewardship in Canada, Fernando says.

Meanwhile, the project has already inspired some important management changes on the Badiou farm. They will now use a consistent three-year rotation, growing canola, soybeans and wheat. And they will apply a blackleg-targeted fungicide at the two- to four-leaf stage of the crop. It will go on in a tank mix with the first in-crop herbicide application.

Fernando notes that the value of fungicides remains questionable in most situations. Recent research led by Gary Peng with AAFC concluded that fungicide applications may help only when the variety is susceptible to blackleg and disease risk is high.

New threats: Aster yellows and swede midge

KEY RESULT: This study revealed new information about yield losses from aster yellows, tentative economic thresholds for leafhoppers, and the lifecycle patterns and host preference of swede midge. Growers should scout crops for swede midge and leafhoppers and consult with agronomists if either pest or aster yellows are identified.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Aster yellows and swede midge – new threats to prairie canola production," Juliana Soroka and Chrystel Olivier, AAFC Saskatoon Research and Development Centre.

FUNDING:
AAFC, GF2

The objectives of this project were to determine the extent of infestation, evaluate yield losses, develop forecast warnings and identify resistant canola lines for two Prairie pests – aster yellows and swede midge.

Aster yellows is an insect-vectored disease that affects many crops, including significant canola yield loss observed in 2012 with incidence as high as 80 per cent in some fields.

Swede midge *Contarinia nasturtii* (Keiffer), native to Europe, is an insect pest of crucifer crops. While some damage has been seen in canola in Ontario since 2000, it was only in 2012 that damage was found in commercial spring canola on the Prairies.

SWEDE MIDGE

Plots were established at Agriculture and Agri-Food Canada in Melfort, Sask., in 2014 and 2015 to study swede midge in the field. In both years, the first midges to appear in the pheromone traps and in the emergence cages were in early July when most plants were starting to flower. Data indicated the presence of two generations of swede midge occurring in the canola plots annually; the first with larvae in the crop and the second, in August, with larvae feeding on volunteer canola and other weeds.

Results showed no differences among lines of glyphosate-tolerant *Brassica napus* in terms of insect injury. In comparing six different species of Cruciferae, plants of *Camelina sativa* (camelina) and *Sinapis alba* (white mustard) were less injured than the others by swede midge and *C. sativa* appeared to be resistant. These more-resistant crucifers may provide a source of resistance.

Swede midge survey results found that populations are increasing and have spread westward across Saskatchewan.

ASTER YELLOWS

Aster yellows is a phytoplasma organism that causes misshapen pods and flower buds and is mainly transmitted by the six-spotted leafhopper (*Macrosteles quadrilineatus*) in canola. The six-spotted leafhopper is a migratory insect whose populations tend to be higher in years when suitable wind currents arrive early in the growing season from southern USA. Field surveys conducted across Saskatchewan from 2013–2015 found very low aster yellows incidence: 1.4 per cent of samples analyzed in 2013, nil in 2014 and less than one per cent in 2015.

The research also compared *B. napus* germplasm to look for tolerant/resistant lines in plots at Saskatoon. In 2012, visual observations identified several lines that did not show aster yellows symptoms. However, many of the observations on tolerant/resistant germplasms observed in the 2012 canola nursery could not be confirmed in subsequent years. Similarly, no difference in aster yellows incidence was found between commercially available cultivars, mostly because of the low aster yellows incidence that did not allow comparison.

Three assays were developed to provide highly efficient, selective and fast identification of aster yellows.* Field testing is also underway for a new rapid molecular technique (LAMP) to determine the infectivity of leafhoppers and the aster yellows incidence in the field. A rating scale for aster yellows symptoms was developed.

Swede midge damage rating scale

Up to stage 3.3 (vegetative):

0 = no damage
1 = mild twisting of foliage or slight crumpling of leaves, or up to 1/3 of buds on primary raceme misshaped, small, not developing normally
2 = severe twisting and/or crumpling of leaves, or more than 1/3 of buds on primary raceme misshaped, small, not developing normally
3 = death of meristem; including bud clusters that were initiated, but did not develop; may see swelling of buds, rot of bud cluster, bouquet of leaves, but no elongation of stem, no signs of flowers opening, no pod formation

For stages 4 and 5 (reproductive):

0 = no damage; includes racemes where stem is elongated with flower stalks, even if no flowers left and no pods have formed.
1 = stem of raceme may be slightly twisted, but still elongated; up to 1/3 of flowers fused; or, up to 1/3 of buds swollen and closed
2 = **either** i.) stem of raceme may be slightly twisted, but still elongated; more than 1/3 of flowers fused; **or**, more than 1/3 of buds swollen and closed; or, ii.) distorted pod bunches - ie. stem not elongated, pods in a bunch on a short length of stem (umbrella or bouquet effect)
3 = death of meristem; including bud clusters that were initiated, but did not develop; may see swelling of buds, rot of bud cluster, bouquet of leaves, but no elongation of stem, no signs of flowers opening, no pod formation

*Dumonceaux, T., Green, M., Hammond, C., Perez, E., and Olivier, C. (2015) "Molecular Diagnostic Tools for Detection and Differentiation of Phytoplasmas Based on Chaperonin-60 Reveal Differences in Host Plant Infection Patterns." PLoS ONE 9(12): e116039. doi:10.1371/journal.pone.0116039.

High rates of parasitism on diamondback moth larvae

KEY RESULT: This study continued work initiated by earlier research which showed that parasitism of diamondback moth larvae and pupae can be relatively high early in the season. Canola producers are encouraged to carefully monitor populations, waiting a few days after nominal thresholds are reached to provide beneficial insects an opportunity to control larvae and to determine whether insecticide applications are necessary.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Improved integrated crop management with beneficial insects," Juliana Soroka, AAFC Saskatoon Research and Development Centre.

FUNDING: Alberta Canola, MCGA, SaskCanola, CCC, AAFC, GF2

This project successfully investigated the phenology of diamondback moth larvae and its parasitoids in four eco-regions of Saskatchewan at three different times of the canola-growing season during 2012, 2013 and 2014. Larvae of the moth were most numerous in the most southerly eco-region surveyed, and parasitism was highest in the Boreal Transition Eco-region running along the Black and Dark Gray soil zones early in the season (June).

Two parasitoid species were found to regularly parasitize diamondback moth larvae in the field, on occasion at levels high enough to exert considerable control of pest numbers. The parasitoid to emerge from diamondback moth larvae in the greatest number was a parasitic wasp, *Diadegma insulare* in the ichneumonid family, followed by the braconid wasp *Microplitis plutellae*. Another parasitoid was also present, later identified with the help of the National Identification Service as *Diolcogaster claribita*, which is the first report of this wasp in Saskatchewan.

Parasitism levels reached 45 per cent at some sampling times, indicating that biological control can have a considerable effect on diamondback moth populations on the Prairies. High rates of natural parasitism of diamondback moth found in this study were a surprise to researchers and producers.

Although not definitive, variation in DNA profiles of early and late-collected moths suggest that overwintering of diamondback moth may be occurring, but further research is necessary to confirm this.

PUBLISHED RESULTS

Considerable information obtained on the effects of temperature on the development of both diamondback moth and *D. insulare* was reported in the *Environmental Entomology* journal*. Laboratory studies quantified, for the first time, low and high temperature developmental parameters of the principal parasitoid *D. insulare* at 2.1 and 34.0°C, respectively.

Parasitism by beneficial insects such as Diadegma insulare, shown here along with one diamondback moth larvae, were surprisingly high.
Credit: Lloyd Dosdall

The research found that the low temperature threshold for diamondback moth development was lower than previously determined. The low temperature threshold was therefore lowered by several degrees to 2.1°C.

Other laboratory studies found that fluctuating temperatures, more representative of actual field conditions, affected diamondback moth and beneficial insect development differently than did constant temperatures of the same average value as the fluctuating temperatures. This points out the importance of natural conditions in determination of insect development.
In addition, the discovery that expression of a heat shock protein in both diamondback moth and *D. insulare* suggest that this is a viable means of tracking arthropod response to changing climates.

The project has generated information that will have both practical and theoretical utility. Identification of the natural enemies of diamondback moth present in Prairie canola fields will aid in finding ways to increase their efficacy. The research will aid in the development of a Dymex model to predict the responses of both insects to irregular patterns of global climatic change.

**New Threshold Temperatures for the Development of a North American Diamondback Moth (Lepidoptera: Plutellidae) Population and Its Larval Parasitoid, Diadegma insulare (Hymenoptera: Ichneumonidae); M. H. Bahar, J. J. Soroka, L. Grenkow, L. M. Dosdall; Environmental Entomology Oct 2014, 43 (5) 1443-1452; DOI: 10.1603/EN14055*

MOMENT

One of my "aha!" moments was when post-emergence herbicides were widespread and everyone was delaying their application so they could kill more weeds and because crops would tolerate late herbicide applications. I remember thinking that the weeds were taking too much light, moisture and nutrients before they were removed. The thought, followed by much research, led to our current early weed removal recommendations that preserve crop yield capacity.

—Neil Harker, research scientist, Agriculture and Agri-Food Canada, Lacombe, Alta.

Real-time diagnosis in the field

KEY RESULT: Researchers were able to develop and validate nine real-time qPCR assays targeting eight different phytoplasma (aster yellows) species along with *P. brassicae* (clubroot) and *L. maculans* (blackleg). This project provides tools for producers and regulators to obtain timely information on plant disease prevalence and spread, which will aid efforts to contain and control these diseases.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Development and application of rapidly deployable in-field molecular diagnostics for plant diseases," Tim Dumonceaux, Agriculture and Agri-Food Canada Saskatoon

FUNDING:
SaskCanola, Saskatchewan Ministry of Agriculture, ADF

**Dumonceaux TJ, Green M, Hammond C, Perez E, Olivier C (2014) Molecular Diagnostic Tools for Detection and Differentiation of Phytoplasmas Based on Chaperonin-60 Reveal Differences in Host Plant Infection Patterns. PLoS ONE 9(12): e116039. doi:10.1371/journal.pone.0116039*

Disease management in canola production relies on timely and precise identification. Molecular diagnostics can play an important role by providing relatively rapid, accurate data that often includes disease strain information. However, this type of diagnosis normally requires complex DNA extraction, polymerase chain reaction (PCR) amplification steps and DNA sequencing, which can require several days at a time when fast action is critical.

Dumonceaux led a team of researchers in this project which exploited the unique features of the loop-mediated isothermal DNA amplification (LAMP) method originally developed for monitoring disease outbreaks in human populations (Notomi et al. 2000).

Quick LAMP tests done in the field can identify whether the blackleg pathogen L. maculans is present on these diseased stems.

LAMP is an inexpensive, highly-specific tool that can yield results in as little as one hour, including strain-level data. The enzyme used for LAMP makes it an ideal tool for in-field diagnostics as DNA samples pulled from soil and certain plant species can be very crude compared to those used for PCR testing. A second aspect of this project involved the development of in-field DNA extraction for application of the newly developed diagnostic tools.

Certain particularly problematic diseases are in immediate need of diagnostic improvements. This project focused on clubroot, caused by the soil-borne pathogen *Plasmodiophora brassicae*, aster yellows, caused by the parasitic bacterial pathogen *Ca.* Phytoplasma spp. and spread by infected leafhopper insects, and blackleg, caused by *Leptosphaeria maculans*.

Dumonceaux and his team employed genomic and molecular barcode sequence data that they had generated in other projects to develop a panel of LAMP assays to specifically detect *P. brassicae* and *L. maculans* by focusing on one readily available LAMP target gene, chaperonin-60 (cpn60, groEL, hsp60). They also developed a method for accessing the *cpn*60 sequence from a diverse array of phytoplasma, and showed that two host plants, *Brassica napus* and *Camelina sativa*, display different phytoplasma infection patterns.

A total of nine real-time qPCR assays targeting these diseases have been developed and validated. Several assays have also been adapted to the droplet digital PCR format, which facilitates the quantification of low copy numbers of target DNA samples (which is often the case when testing for pathogens such as clubroot in soil).

A LAMP assay targeting *P. brassicae cpn*60 was among those developed and validated. Using soil samples spiked with known numbers of spores, researchers were able to use these assays to detect the minimum spore number that can cause clubroot galls on plants.

DNA samples were also provided from the first Canadian isolate of Verticillum stripe, discovered in a Manitoba canola field in 2014. Researchers quickly isolated the cpn60 gene from this potentially devastating fungus and successfully developed a LAMP assay targeting this organism as well. This highlights the capability this project has provided to respond rapidly to producer needs and to provide protection from the emergence of novel or previously undetected pathogens in their crops.

PUBLISHED RESULTS

Dumonceaux describes the method developed for generating *cpn60* UT sequences for *Ca.* Phytoplasma spp. in an article published in PLoS ONE journal*.

A progress update on this study included in the 2014 special science edition of *Canola Digest* also attracted industry attention. Researchers are now working with both Winnipeg-based Pest Surveillance Initiative and the City of Saskatoon on the development of mobile molecular diagnostics targeting other pathogens of interest.

Bertha armyworm monitoring system still works

KEY RESULT: The current system for monitoring potential bertha armyworm outbreaks is based on a pheromone trap network developed in the 1970s (Steck et al. 1979) and improved in the 1980s (Struble et al. 1984). This study tested the efficiency of this system in the context of current canola production and determined the monitoring and forecasting system in place is serving the canola industry well.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Improving crop risk assessment tools for bertha armyworm," Scott Meers, Alberta Agriculture and Forestry

FUNDING: ACIDF, Alberta Canola, SaskCanola, MCGA

The canola industry has changed dramatically since research was originally conducted on bertha armyworm pheromone trap catches in relation to the subsequent larval density in nearby fields (Turnock 1987). With increased production of hybrid canola and improvements made to the monitoring system, Scott Meers and his team conducted this three-year study to evaluate the current process and revalidate the original research.

The objectives of this study were to: (1) determine the optimum density of pheromone traps; (2) determine the association of larvae numbers and trap counts to improve forecasting through larval sampling; (3) test the impact of trap height and location on moth catch numbers; and (4) develop and test a trap system that would reduce bumblebee catch without affecting bertha armyworm moth catch for forecasting purposes.

From 2012 through 2014, canola fields were identified in a block of 35 townships east of Edmonton, Alta., in an area predicted to have a bertha armyworm outbreak based on increasing pheromone trap moth catches in 2011. Two traps were established in each field and bertha armyworm moths were removed and counted weekly from mid-June throughout July. Moth counts were added to the bertha armyworm map as part of the already established Alberta Insect Pest Monitoring Network.

A larval survey was also conducted on fields with the pheromone traps and nine fields surrounding each of those fields in all directions. An additional 48 fields were sampled in Saskatchewan. In August of each year, larval density was measured using the 'Manitoba' method – shaking small sections of canola plants and searching the ground for larvae.

The location of current outbreaks were identified using the Alberta Agriculture bertha armyworm monitoring system. Each field was surveyed at six sites – two each at either end and two in the middle.

Bertha armyworm, Mamestra configurata Walker, is an economically significant pest of canola in Western Canada.

Similar to the results recorded by Steck et al. in 1979, traps with a cumulative total of 900 or more moths had the highest proportions of nearby fields with larval counts above the economic threshold. However, over the duration of this study there was a large variation between fields.

Earlier studies found no significant relationship between moth catch and proximity of current-year canola. Meers found a positive correlation, however, with canola grown in the previous year, which suggests that localized outbreaks can develop where populations build up year to year. This is especially true where canola is grown continuously in close proximity, which is now common practice across the entire canola growing region. Monitoring these population increases can be used to determine where more intensive trapping can be deployed to catch potential outbreaks.

To reduce bumblebee bycatch, two distinct prototype traps were developed in partnership with University of Alberta engineering students and the Agriculture Technology Centre of Alberta Agriculture and Forestry. Both prototypes were designed to be closed during the day, excluding bumblebees, and open at night to catch moths. Although these tests did provide advancement towards reducing bumblebee mortality due to moth traps, more work is needed to avoid decreases in number of moths caught and the resulting negative impact on forecast accuracy.

RESULTS

The existing model of bertha armyworm forecasting in Western Canada stood up well to the studies applied during this project. Meers and his team were able to validate that the current methods for trap height, placement in the field and thresholds based on moth catches are serving canola growers well.

Results suggest that placing traps in areas of higher concentration of canola from the previous year are more likely to catch potential outbreaks. Also, while more traps will always give a better indication of bertha armyworm populations, the current trap density rate of approximately five per county is adequate, as long as they are well distributed. Producers should also continue to verify larval density of each field prior to proceeding with control measures because even during outbreaks larval counts can vary greatly from field to field.

Table 1. Larval densities all 3 years of study

	Trap fields						All fields					
Moths/ Traps	**Larvae/m²**			**P***			**Larvae/m²**			**P***		
	N	**X̄**	**max**	**>10**	**>20**	**>30**	**N**	**X̄**	**max**	**>10**	**>20**	**>30**
0-299	8	2.00	8.7	0	0	0	54	3.35	18.0	0.07	0	0
300-899	19	4.90	25.3	0.11	0.05	0	165	4.71	34.0	0.12	0.06	0.01
900-1199	5	1.17	2.7	0	0	0	59	11.21	116.0	0.37	0.15	0.09
>1200	5	10.22	22.0	0.20	0.20	0	56	7.00	26.0	0.25	0.07	0

P = proportion of fields with larval densities above 10, 20, and 30 larvae per square metre.
N = number of fields
X = mean number of larvae/m² per field

Economize on fungicide through rapid detection of sclerotinia

KEY RESULT: Sclerotinia stem rot, caused by *Sclerotinia sclerotiorum*, is commonly managed by routine application of fungicides, typically without any indication of disease risk. Through this study, a quantitative polymerase chain reaction (qPCR)-based assay was developed to measure *S. sclerotiorum* DNA in canola petals, enabling rapid and accurate estimates of infestation levels when timely fungicide application decisions need to be made.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Development of a rapid quantitative detection method for sclerotinia stem rot inoculum to aid risk assessments and fungicide spray decisions," Stephen Strelkov, University of Alberta

FUNDING: ACIDF, Alberta Canola, WGRF, AAFC

Right: Quantitative PCR analysis can provide a more rapid and accurate assessment of petal infestation levels.

The effectiveness of many sclerotinia stem rot management strategies is limited by the wide host range of the *S. sclerotiorum* pathogen, production of wind-borne ascospores and the sporadic nature of disease development. Previously developed risk assessment methods have focused on petal infestation since this is an important stage of the disease cycle in canola. Quantitative PCR analysis can provide a more rapid and accurate assessment of petal infestation levels.

Stephen Strelkov at the University of Alberta led this two-year study with the objectives to: (1) develop and refine a rapid quantitative method for pathogen detection in canola flowers; (2) understand the relationship between the amount of pathogen on canola petals and final stem rot levels in commercial fields; and (3) assess correlations between pathogen detection, weather-based forecasts and final stem rot levels.

A hydrolysis probe-based qPCR assay was developed that could detect as little as 8.0×10^{-4} nanograms (ng) of *S. sclerotiorum* DNA with a high degree of specificity. Evaluation of petals collected at five sampling points in each of 10 commercial canola fields on each of two sampling dates (corresponding to 20-30 per cent flower and 40-50 per cent flower) revealed infestation levels ranging from zero to 3.3×10^{1} ng *S. sclerotiorum* DNA per petal.

Strelkov and his team explored the relationship between petal infestation levels and final stem rot incidence in canola further in two additional studies. In the first study, conducted over two years, petal infestation was compared with disease incidence in 34-35 commercial canola fields across the Prairies. In the second study, these parameters were compared over three years in nine to 11 fields located in central Alberta.

Petal infestation level, as determined with the qPCR assay at 40-50 per cent flower, accounted for 60-92 per cent of the variation in sclerotinia stem rot incidence under field conditions in Western Canada. Petal infestation level was influenced by petal age and by the time of day when samples were collected. A diurnal fluctuation in infestation levels was found in young, but not old petals, with significantly higher infestation in afternoon- versus morning-collected samples. Sclerotinia stem rot development also was influenced by environmental conditions, with relative humidity playing a more significant role in disease development than temperature.

Extensive knowledge transfer of these findings has included publication of abstracts in the Canadian *Journal of Plant Pathology** and the publication of a full-length, peer-reviewed article in *Plant Disease***, as well as presentations in various industry and scientific meetings. The qPCR assay developed as part of this project is highly sensitive and specific for *S. sclerotiorum*, and in addition to its utility as a potential risk-assessment tool, it also may prove useful in studies of the epidemiology of sclerotinia stem rot.

The published refereed paper also discusses the considerable variation observed in the amount of petal infestation in different fields and at different crop stages, indicating the importance of assessing petal infestation and risk potential for a particular field as opposed to an assessment of risk based on regional conditions.

The qPCR assay may serve as the basis for a risk assessment system as well as representing a useful tool for the study of the incidence, distribution and possible control of Sclerotinia stem rot of canola. It is important to emphasize, however, that this forecasting system should be linked to environmental indicators as well as cropping history, seeding date and crop canopy conditions, which may influence stem rot development and the need to spray a fungicide.

*Ziesman, B.R., Turkington, T.K., Basu, U., and Strelkov, S.E. 2014. Initial validation of a quantitative PCR-based system for detection of Sclerotinia sclerotiorum on canola. Can. J. Plant Pathol. 36: 132. (Abstr.).
**Ziesman, B.R., Turkington, T.K., Basu, U., and Strelkov, S.E. 2016. A quantitative PCR system for measuring Sclerotinia sclerotiorum in canola (Brassica napus). Plant Dis. 100: 984-990.

Identifying and controlling cutworms

KEY RESULT:
A pest complex of economically significant cutworm species can be found on the Prairies, and outbreaks seem to be occurring with greater frequency. This study has resulted in a DNA protocol for quick, accurate identification of cutworm species; identification of natural enemies and evaluation of their ability to develop on different cutworm species; assessment of the effects of seed cultivar, seed treatment and fertilizer regime on cutworm development; and the production of a cutworm identification guide.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Detection, identification and control strategies for management of cutworms (Noctuidae) on the Prairie provinces," Kevin Floate, AAFC Lethbridge

FUNDING: Alberta Canola, SaskCanola, MCGA


Credit: Beth Hoar

During cutworm outbreaks, accurate and rapid identification is required to maximize control methods. As some species of cutworm feed below ground and other species are nocturnal foliage feeders, the decision if and when to apply contact insecticides is determined by the type of cutworm to be controlled. Molecular methods allow for accurate species identification of the cutworm at any stage of development.

To accelerate species identification, Dr. Martin Erlandson (AAFC Saskatoon), a collaborator on the project, developed a multiplex polymerase chain reaction (PCR) tool to detect and identify five key cutworm species: the redbacked cutworm (*Euxoa ochrogaster*), army cutworm (*Euxoa auxilaris*), pale western cutworm (*Agrotis orthogonia*), dingy cutworm (*Feltia jaculifera*) and bristly cutworm (*Lacinipolia renigera*).

Each of these species has unique genetic markers and the PCR method uses the length of these markers to provide species identification within one or two days. This is a significant reduction from the week or more that the process of genetic sequencing requires, during which time the crop would continue to be damaged by cutworm feeding. Results of this study confirm the accuracy of the PCR method with only a low level of error.

NATURAL ENEMIES

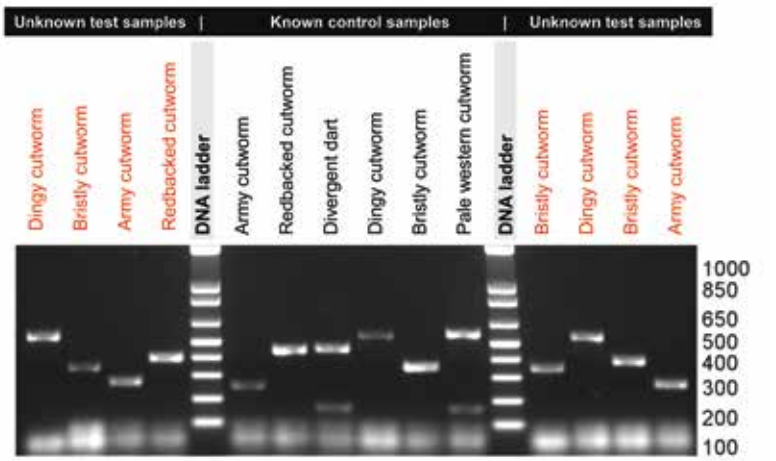
Parasitoids can provide a natural reduction in the severity and duration of cutworm outbreaks. Cutworm larvae were collected throughout Alberta in 2012, 2013 and 2014. Parasitoids reared from these larvae included at least three species of flies and 13 species of wasps. For the three years of this study, parasitism averaged about 20 per cent but was sometimes much higher, based on year and collection site.

During this study, a European species of parasitic wasp (*Cotesia vanessae*) was discovered in North America for the first time. In laboratory tests, this wasp proved able to develop on 34 (of 47 tested) species of caterpillars, including many of the cutworm species that affect

MOMENT

One "aha!" happened when we realized that the real causal agent of Fusarium wilt of canola was *Fusarium oxysporum.* It was actually my colleague Dr. Jian Yang who made the identification. We then went back to the basics and were able to satisfy Koch's postulates and easily replicate symptoms. Before that we had been running around in circles trying to pin the cause down to other pathogens (like *Verticillium longisporum* or other Fusaria) or drought. With a correct ID, everything we had been observing suddenly fell into place because different forms of *F. oxysporum* cause nearly identical diseases in many other plant species. It even suggested a way to control the disease in canola. As in other similar diseases caused by *F. oxysporum*, only certain cultivars were affected, while others were completely immune. This information allowed the industry to control the problem, eliminating the sometimes massive yield losses we were seeing, and turning Fusarium wilt into the non-issue it is today.

—Ralph Lange, crop pathology and biotechnology team lead, Alberta Innovates Technology Futures



Known control samples show the number and size of genetic markers associated with six species of cutworms (black font). The identity of unknown test samples (red font) is determined by comparing the number and length of genetic markers with those of the known control samples. DNA ladders contain DNA that forms genetic markers of known length. They are used to 'measure' the length of the genetic markers obtained from the cutworm samples.

Canadian crops. *C. vanessae* could be distributed to regions where it does not already occur to increase parasitism and delay or reduce the severity of future cutworm outbreaks.

FERTILIZER USE AND PLANT HEALTH

Experiments focused on cutworm biology showed that fertilizer use was associated with increased oviposition by bertha armyworm on canola and also increased larval development time and weight. Larval development of both redbacked and pale western cutworms was quicker on fertilized versus non-fertilized plants, regardless of the host crop.

Bertha armyworm moths also laid more eggs on plants grown with increasingly higher levels of fertilizer. This was assessed using a Clearfield hybrid, a Roundup Ready hybrid and a Q2 variety with fertilizer treatments of zero, 1.0, 3.0 and 5.0 g/L. The Q2 variety, however, had an increased number of eggs with fertilizer treatment only until the 3 g/L treatment, after which egg number decreased.

PUBLISHED RESULTS

The North American discovery of *Cotesia vanessae* was published in 2014 in the scientific journal *The Canadian Entomologist**.

Floate, working in collaboration with Erl Svendsen (AAFC Saskatoon), is in the final stages of completing the 100-page *Cutworm Pests of Crops on the Canadian Prairie: Identification and Management Field Guide*. This richly-illustrated guide specifically targets farmers and producer groups to provide information on the identification and control of 20 cutworm pest species.

Additional information arising from this project has been presented through field tours, meetings, workshops, interviews and in a series of weekly web documents through the Prairie Pest Monitoring Network.

**Hervet, V.A., H. Murillo, J.L. Fernández-Triana, M.R. Shaw, R.A. Laird and K.D. Floate. 2014. First report of Cotesia vanessae (Hymenoptera: Braconidae) in North America. The Canadian Entomologist 146(5):560-566. doi: 10.4039/tce.2014.9*

Cotesia vanessae larvae emerge from a cutworm

Army cutworm

Redbacked cutworm

Pale western cutworm

Glassy cutworm

Herbicides that could improve cleavers control

KEY RESULT: In Western Canada, field surveys show an increased presence of cleavers. This two-year study showed that clomazone and quinclorac herbicides significantly reduced both cleaver biomass and seed contamination, and improved cleavers control in canola.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Emergence timing and management of cleavers in Saskatchewan canola crops," Christian Willenborg, University of Saskatchewan

FUNDING:
SaskCanola, Saskatchewan Ministry of Agriculture, GF2

Find Willenborg's report in the Research section at **saskcanola.com**

It is important to note that, as of October 2016, clomazone is not yet registered and quinclorac should not be used on canola due to maximum residue limit (MRL) issues. *Until exporters and processors are confident that they can ship quinclorac-treated canola without trade concerns, growers are advised to avoid this marketing risk by using other cleavers control methods.* ***Learn more at keepingitclean.ca/canola.***

In Western Canada, it has been believed that galium (cleavers) populations consisted of two species, *G. aparine* and *G. spurium*. These species are difficult to control and can cause downgrading and reduce crop quality. Proper identification and improved control can lead to better management practices for cleavers in canola.

Willenborg led this two-year study to determine the emergence and morphological characteristics of cleavers populations in Western Canada and to assess which species are present. A third objective was to characterize their response to both new herbicides, such as quinclorac and clomazone, and to common canola herbicides such as glufosinate-ammonium and glyphosate.

Field experiments were conducted in 2013 and 2014 at the Scott Research Farm and the Saskatchewan Pulse Growers research site (SPG) near Saskatoon. An additional site was added at Rosthern in 2014. Herbicide efficacy on cleavers was evaluated using eight treatments in which the herbicide standard for each canola system was used alone and with the addition of quinclorac and/or clomazone. At all sites, canola varieties resistant to their respective herbicide system were seeded into cereal stubble. Cleavers were seeded to target a plant stand of 75-100 plants/m^2. Greenhouse dose-response experiments were also conducted to assess variability between populations in their herbicide response.

Results of the field trials consistently showed that tank-mixing quinclorac with any of the herbicide standards improved cleavers control in canola. Applying clomazone prior to seeding canola followed by an in-crop application of a herbicide standard also provided acceptable control. Clomazone and quinclorac significantly reduced both cleavers biomass and seed contamination.

Cleavers resistance to Group-2 herbicides is already noted throughout Alberta and Saskatchewan, and cleavers rank second among weeds likely to develop glyphosate resistance in the Black Soil Zone. Better control of cleavers is key for resistance management as smaller population size means weeds are less likely to have resistant individuals present.

Willenborg and his team also developed molecular analyses to characterize the genetic differences among cleavers populations, and have identified a molecular marker that can be used to differentiate between galium species. All samples processed from across western Canada were *Galium spurium L.*, or false cleavers, which suggests either *G. aparine* is not present in western Canada, or it was not present in the samples used in the study.

Molecular analysis showed that the galium populations generally exhibited little variation in morphological traits, with the exception of ermergence timing and start and end of the flowering period. Emergence timing was significantly different between years with all of the populations exhibiting emergence in both spring and fall.

These differences suggest growers will need to pay close attention to emergence timing of this weed to ensure the small window for control is not missed. As a significant proportion of cleaver populations emerged in the fall, and with those that over-winter being very difficult to control in the spring, Willenborg reports that fall management is key to the sustainable long-term control of cleavers in Western Canada.

Speed one factor in lower harvest losses

Brent Lensen offered two canola fields for a study measuring canola harvest loss. His losses were lower than study's average – possibly due to his 3-mph combine ground speed.

Rob Gulden and Andrea Cavalieri's report, "Evaluation of the causes of on-farm harvest losses in canola in the Northern Great Plains," was published in *Crop Science* 2016 Vol 56

Teketel Haile's report, "On-farm seed loss does not differ between windrowed and direct-harvested canola," was published in *Canadian Journal of Plant Science* 2014 Vol 94

Brent Lensen combines canola at no more than three miles per hour, and it seems to work for him and his Case IH rotary. The farmer from Vanscoy, Sask., participated in a canola harvest loss survey in 2010 and his results were better than average.

"Lensen's losses were small compared to the average yield loss reported from all fields," says Teketel Haile, the University of Saskatchewan researcher who helped with a harvest loss study by Rob Gulden and Andrea Cavalieri at the University of Manitoba. The survey measured harvest losses for 310 fields in four regions from 2010 to 2012.

Haile literally vacuumed up all loose material from six quarter-square-metre "quadrats" at three locations in each field. "It took a long time to separate shattered seeds from dirt, weed seeds and chaff," he says.

Lensen had two fields measured for harvest losses in 2010. Field one yielded 32 bu./ac. with an average loss of 0.8 bu./ac., or 2.4 per cent. Field two yielded 29 bu./ac. with an average loss of 2.0 bu./ac., or 6.5 per cent. His average loss over both fields was 4.4 per cent.

Average loss for all 26 Saskatoon region fields surveyed in 2010 was 5.7 per cent.

For the whole study, the lowest average loss was 4.0 per cent for fields around Lacombe, Alta., in 2012 and the highest was 8.5 per cent for the Saskatoon region, also in 2012.

Participating growers also completed a questionnaire to collect agronomic data for each field. Wind data from the nearest local weather station was used to determine wind speed during the harvest season. As Gulden and Cavalieri's published report noted, "total on-farm harvest losses in canola are a complex phenomenon."

They concluded that growers can reduce harvest losses with earlier harvest (which is often a result of seeding decisions and conditions), fungicide application at flowering, lower combine ground speed and reduced swather width.

Interestingly, the study found that combine manufacturer and *B. napus* variety did not contribute significantly to total harvest losses in canola.

Brent Lensen of Vanscoy, Sask., permitted harvest loss researchers to check his canola fields for canola seeds left behind. His losses, at 4.4 per cent on average for two fields, were lower than average.

Harvest method did not make a difference either. Haile published his own report based on 16 straight combined and 19 swathed canola fields he surveyed over the three years. "There were no differences in seed yield, loss or seedbank addition of canola between windrowing and direct-harvesting operations," he wrote. "This may suggest that direct-harvesting can be considered a viable option to harvest canola in Western Canada."

Lensen swaths his canola and when it comes time to combine, he uses a drop pan to check for losses. "We always pay close attention to how we set the combine," he says. "But while we set it the best we can, losses can occur in the swath or at the header when you pick up the swath."

Growers have steps they can take to reduce risk – such as combining slower – but the study found that spring conditions preventing rapid and even stand establishment and harvest wind and weather delays are often key factors determining the overall level of canola harvest losses.

Storage bags work best with dry canola

KEY RESULT: This research looked at the feasibility of bag storage for canola and the effects on seed quality based on moisture content and length of storage time. Dry canola seeds can be safely stored for six to eight months in bags, but canola at 12 per cent moisture should be stored only temporarily.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Feasibility of bag storage system for canola under prairie conditions," Digvir S. Jayas, University of Manitoba

FUNDING: Alberta Canola, SaskCanola, MCGA, CCC, AAFC, GF2

** Fuji Jian, Vellaichamy Chelladurai, Digvir S. Jayas, Noel D. G. White. "Three-Dimensional Transient Heat, Mass, and Momentum Transfer Model to Predict Conditions of Canola Stored inside Silo Bags under Canadian Prairie Conditions: Part I. Soil Temperature Model." Transactions of the ASABE.58(4): 1127-1134. (doi: 10.13031/trans.58.11052) 2015*

In the first year of study, canola seed at three different moisture contents – 8.9 per cent (or "dry" based on grading standards), 10.5 per cent ("tough") and 14.4 per cent ("damp") – were stored in silo bags from autumn 2010 to summer 2011 in Winnipeg, Manitoba. Seed germination, free fatty acid value (FAV) and moisture content of canola were analyzed at seven locations in each silo bag every two weeks, along with carbon dioxide concentrations of intergranular air and temperature of canola.

For the dry canola, germination was maintained above 90 per cent and FAV stayed within 1.5 times the initial value during the 40-week storage. Tough canola maintained its initial germination value in most parts of the silo bags, except at the top layer. However, germination of damp canola dropped to below 80 per cent and FAV doubled its initial value within eight weeks of storage. High levels of CO_2 and localized hotspots in damp canola indicated intense biological activity and degradation of seed quality.

Canola put into a bag at 14 per cent moisture looked like this after 40 weeks. This is from the 2010-11 experiment.

Canola which graded No.1 at the beginning of the storage remained No.1 for dry canola, became No.2 for tough canola and dropped to Feed grade for damp canola. Results from this study indicate that dry canola can be stored in silo bags for up to 40 weeks without seed quality loss, but tough and damp canola could not be safely stored for very long.

Another study was conducted for two storage years (2011-12 and 2013-14) to determine the changes in grain quality for canola stored at around 12 per cent moisture. Canola was stored in three silo bags (67 tonnes /bag). One was unloaded after 20 weeks (the middle of winter), one at 28 weeks (the end of winter) and one at 40 weeks (in summer).

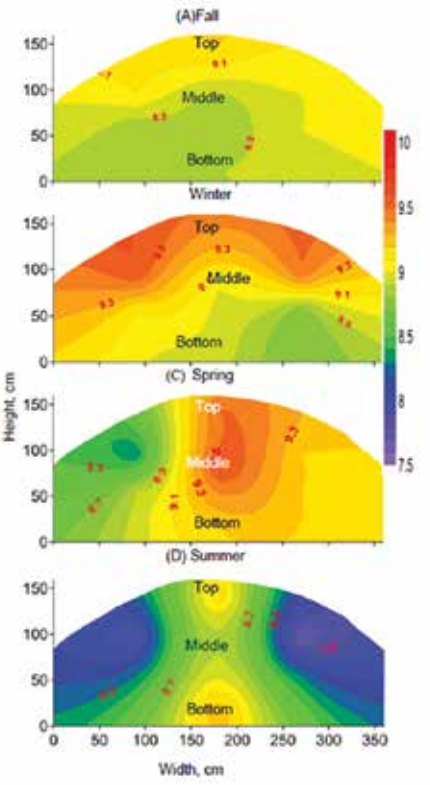
The canola showed no significant change in quality parameters up to 16 weeks of storage. Germination of canola at most parts of the silo bags stayed above a safe level up to the end of the winter season (20 weeks of storage). After 40 weeks, germination of canola decreased to below 30 per cent at the top layer.

The commercial grades after first, second and third unloading were No.1, No.2 and No. 2, respectively, in year 1. In the second year, these were No.1, No.1 and No.2, respectively.

Findings from this study were published in two parts in the transactions of the American Society of Agricultural and Biological Engineers*.

MOISTURE MIGRATION

These images show how the moisture profile in a silo bag of "dry" canola changes throughout the four seasons.



Moisture profile of silo bag with dry moisture content canola in (A) Fall, (B) Winter, (C) Spring, and (D) Summer seasons.

These experiments show that storing dry canola seeds for short duration was the best way of using harvest bags under Prairie conditions. To avoid quality and quantity losses, dry canola seeds can be stored for up to six to eight months, but tough moisture canola should be stored no more than five months, and damp canola should be stored only for three to four weeks.

Investigation into pod drop and pod retention resistance

KEY RESULT: Seed losses at harvest can be significant. This study provides insight into pod drop and the factors impacting it. The pod retention measurement method developed and validated in this study can be used in future studies. Results from this study also suggest that pod retention is a heritable trait and could be exploited by breeders to reduce seed losses.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Developing a rapid method to evaluate pod-drop in canola," Rob Gulden, University of Manitoba

FUNDING: Alberta Canola, SaskCanola, MCGA, GF2

Seed losses before and at harvest are due to pod shatter and pod drop, and they could be more substantial than expected. Pod shatter is when the siliques (pods) open up while still attached to the plant. Pod drop is when the whole silique breaks off and falls to the ground. They both result in seed losses.

Pod drop is difficult to measure and less research has been done on it, so there was a need for more understanding on this topic. Before pod drop could be accurately examined, this project aimed to develop an accurate pod drop measuring method.

More specifically, the project objectives were to determine the details (number of measurements and rachis type and position) needed to collect meaningful pod-retention resistance measurements and then to use the developed method to create and validate a relationship between pod-retention resistance and pod drop across several varieties and a range in environments.

This tool measures the pod attachment strength.
Credit: Dr. Rob Gulden, University of Manitoba

For the method development part of the study, two years of field studies (2013 and 2014) were carried out in Carman, Man., and Saskatoon, Sask. Two seeding dates were used for the Carman location and one seeding date was used in Saskatoon for each year of the study, but the early-seeded trial was cancelled in 2013 due to a late-season hail and in 2014 due to a sclerotinia outbreak (likely influenced by high precipitation early in the season). The relationship validation part of the project utilized the Canola Performance Trials and was carried out in 2014 (at Carman, Man., and Outlook, Sask.) and 2015 (at Thornhill and Elm Creek, Man., and in Saskatoon, Wakaw and Melfort, Sask.).

In 2013 and 2014, six canola varieties (73-15RR, 73-45RR, 74-44BL, 74-54RR, and InVigor L130, InVigor L140P) were grown at two different target densities (120 and 30 plants/m^2). This was done in order to see if pod-retention resistance was affected by phenotypic plasticity (i.e. increased branching).

RESULTS

While working on the method development, it was noted that about 12-15 pod-retention resistance (PRR) measurements per rachis type or rachis position were necessary to minimize the variation within treatment and to provide a fairly accurate estimate of PRR. (A rachis is the stem holding the cluster of pods.)

It was determined that there was a clear relationship between weight-adjusted (specific) pod-retention resistance and absolute pod drop.

Canola genotypes with low pod drop (and therefore lower seed losses from pod drop) required greater force per gram to dislodge their pods than those with high pod drop (and therefore greater seed losses from pod drop).

While many parameters contributed to the variation in pod drop results (location, rachis position and genotype), they were not ranked in the same order of importance as the parameters affecting pod-retention resistance (rachis position, cultivar and location). However, there was a very significant relationship between pod drop and weight-adjusted pod-retention resistance.

Although the findings suggest that pedicel attachment strength may affect pod drop, further research is needed on this subject. (A pedicel is the little stem that attaches individual pods to the rachis.) Such future studies could include examining how environmental factors during seed maturation contribute to pod drop and understanding the relationship between plasticity in pod size and pod-retention resistance.

Finally, these results imply that (after environment and position on the plant) heritability is another major contributor to pod drop, which could be utilized by breeders to help growers reduce canola harvest losses.

Lots of diversity in clubroot resistance

KEY RESULT: Clubroot resistance in Canadian canola varieties relies almost entirely on one source, "Mendel". This study identified many other genes, found genetic markers for them and then crossed some of them into *B. napus* lines that could be used for breeding. Canola seed breeders can use the results of this work to broaden and possibly stack the resistance sources they offer.

PROJECT TITLE, PRINCIPAL INVESTIGATOR:
"Identification and mapping of clubroot resistance genes in Brassica and development of SNP markers tightly linked to resistance genes," Fengqun Yu, Agriculture and Agri-Food Canada, Saskatoon

FUNDING: GF2, ACIDF, WGRF, Alberta Canola, AAFC

In 24 clubroot-resistant Brassica lines collected from around the world, the type of resistance could be grouped into 16 clusters. The "Mendel" clubroot-resistance gene, the source resistance for most clubroot cultivars available on the Canadian market, was just one of them.

This is good news given that the effectiveness of Mendel in clubroot-infested parts of Alberta seems to be eroding. Pyramiding of resistance genes or rotating to other sources of resistance could improve clubroot management through genetic resistance.

A previous GF1-funded study by Gary Peng and Kevin Falk at AAFC's Saskatoon Research Centre identified several *B. rapa* cultivars/breeding lines and one *B. oleracea* cultivar highly resistant to five pathotypes of clubroot-causing *P. brassicae* previously identified in western Canada.

In this project, which ran from 2013-16, Yu and her team mapped the genes then identified molecular markers tightly linked to the CR genes in the cultivars that Peng and Falk identified. These DNA markers associated with the target genes, allow breeders to confirm the presence of a desired gene early in the breeding process.

Five resistance genes were mapped in *B. rapa: Rcr1* was identified from bok choy cultivar "Flower Nabana", *Rcr2* from Chinese cabbage cultivar "Jazz", *Rcr3* from canola *B. rapa* breeding line 6992, *Rcr4* from canola breeding line T19 and *Rcr5* from turnip cultivar "Purple Top White Globe". As well, *Rcr6* was identified in *B. nigra* line PI and *Rcr7* was identified in *B. oleracea* cabbage cultivar "Tekila".

PUBLISHED RESULTS

Yu published part of the work – work on *Rcr1* – in PLoS ONE journal*. The article describes how Yu and her team found 776,200 single nucleotide polymorphisms (SNPs) and 122,200 insertion/deletion (InDels) in resistant cultivars. SNPs and InDels are patterns that could possibly become "markers". Through time-consuming lab work using well-established tools, fourteen SNP markers in the target region were confirmed to associate with *Rcr1*. The team then employed nine of these SNP markers for marker-assisted introgression of *Rcr1* into *B. napus* canola from *B. rapa*, with 100 per cent accuracy.

Similar work was done for each of the other six clubroot-resistant Brassica lines that Peng and Falk had earlier identified.

The next step was to insert these newly-discovery CR genes into commercial species for breeding purposes. They successfully "re-synthesized" a *B. napus* canola line to contain *Rcr3* and *Rcr7* genes, which could greatly broaden the genetic base of clubroot resistance in *B. napus*. The project also re-synthesized both *B. juncea* and *B. carinata* with highly resistant genes. This re-synthesis will enable both canola and mustard breeders to rapidly incorporate clubroot resistance into their cultivars.

Yu F, Zhang, X, Huang Z, Chu M, Song S, Chang A., Deora A, Chen Q, Zhang Y, McGregor L, Falk KC, Gossen BD, McDonald MR, Peng G. Identification of SNP Markers Associated with Clubroot Resistance Gene Rcr1 through Bulked Segregant RNA Sequencing PLoS ONE 11(4): e0153218. doi:10.1371/journal.pone.0153218.

aha! MOMENT

I can think of 2 distinct moments – one was "aha!" and another one was "oh no". I remember when canola hybrids first hit our market and experts thought that the higher yield potential would only be reached under good to excellent growing conditions. Then some trial results indicated high relative yield compared to open-pollinated (OP) types even under poor, low-yielding environments. When I analyzed hybrid yield data from variety trials over different yielding environments (low, medium, high), I could see that the relative yield benefit was similar, and thus the original thinking was wrong.

The other situation that led to a big "oh no" was after the discovery of clubroot in canola in 2003. I remember how this bad feeling crystallized in late fall after finding 12 cases of clubroot in a quick survey of 70 fields in the Edmonton area. I had made a brief review of research papers that educated me on the serious challenge of this disease. The discovery of 12 cases meant the disease couldn't be easily contained, and thus we were going to have to deal with it from that point on.

—Murray Hartman, oilseed specialist, Alberta Agriculture & Forestry

One step closer to sclerotinia control

KEY RESULT: Sclerotinia stem rot-tolerant varieties are available and efforts continue to improve varietal resistance, in both the public and private sectors. Researchers on this project have identified previously undiscovered genes associated with the plant defense response, providing valuable resources for researchers interested in developing sclerotinia-resistant canola lines.

PROJECT TITLE, PRINCIPAL INVESTIGATORS: "Getting one step closer to Sclerotinia control through cultivar resistance and biological applications," Dilantha Fernando, Mark Belmonte and Teresa de Kievit, University of Manitoba

FUNDING: Alberta Canola, SaskCanola, MCGA

**Girard Ian J., Mcloughlin Austein G., de Kievit Teresa R., Fernando Dilantha W. G., Belmonte Mark F. Integrating large-scale data and RNA technology to protect crops from fungal pathogens. Front. Plant Sci., 31 May 2016. Available: http://dx.doi.org/10.3389/fpls.2016.00631*

This three-year study was launched to identify novel defense genes and the molecular framework underlying canola's defense response to sclerotinia stem rot, and to answer three main biological questions:

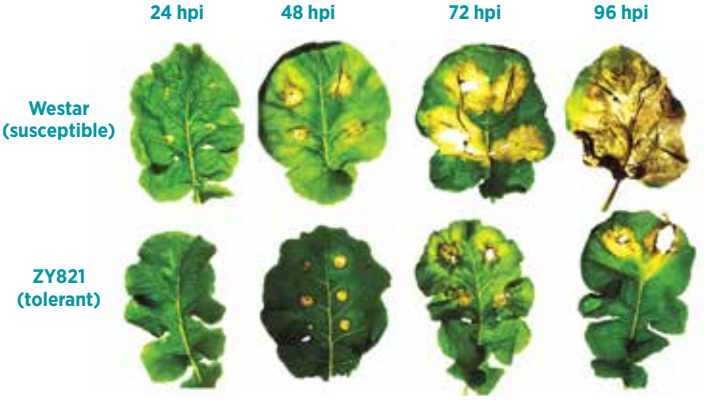
1. How does global gene expression change during whole-leaf infection in susceptible versus tolerant canola cultivars?
2. What are the tissue-specific defense responses that occur in susceptible versus tolerant cultivars?
3. What changes in gene expression and physiology occur in response to the biocontrol bacterium *Pseudomonas chlororaphis* (PA23), with and without the presence of the *S. sclerotiorum* pathogen?

Field conditions of sclerotinia infection were accurately mimicked using a petal inoculation technique on both a tolerant *B. napus* genotype and a susceptible variety. Using next generation RNA sequencing and a robust bioinformatics pipeline, novel defense molecules were functionally characterized.

The team discovered over 1,200 previously undefined transcripts, including genes involved with plant defense processes and cell signaling. They also identified novel regulators of the plant defense response and found biological processes, including protein modification and non-genetic influences, which may contribute to tolerance of *S. sclerotiorum*.

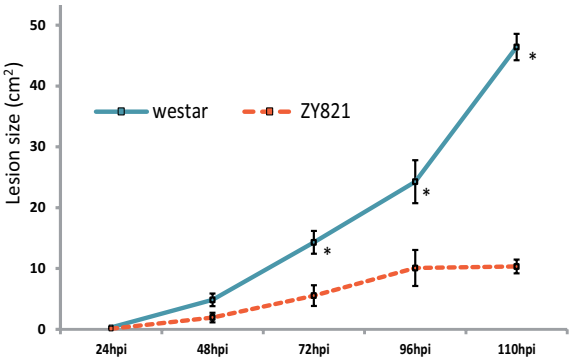
To identify tissue-specific defense responses, three types of infected and non-infected leaf tissues were collected, 24 hours after inoculation, from both the susceptible and tolerant cultivars. RNA isolation and sequencing led to the identification and functional analysis of cell-specific genes and transcription factor regulators.

Results indicate that *Sclerotinia* infection induces tissue-specific defense responses in susceptible leaves of *B. napus* plants. This data will provide a high-resolution map of the immediate plant defense response to infection.



To measure changes in response to the biocontrol bacterium PA23, *B. napus* plants were sprayed with solutions of PA23 alone, *S. sclerotiorum* ascospores only, or PA23 followed by ascospores 24 hours later. All treatments were incubated under humid conditions for 72 hours to confirm PA23's efficacy in preventing fungal infection.

Application of PA23 reduced the number of lesions present on plant leaves by more than 91 per cent, when comparing the rate of infection to total petals in the plant canopy. Plants treated with both PA23 and *S. sclerotiorum* also had the fewest unique gene expression changes as a biological response, at 515 genes. This is approximately 16 times less than the 8,237 up-regulated differentially expressed genes activated in those treated with *S. sclerotiorum* alone.



Sclerotinia lesions grow much faster on susceptible Westar than they do on resistant Chinese variety ZY821. hpi = hours post inoculation

These findings reveal that PA23 has a significant effect on the interaction between *B. napus* and *S. sclerotiorum*, likely through modulation of defense responses in the plant and activation of unique gene expression patterns at the point of infection. This is significantly relevant for the use of PA23 as a biocontrol agent in the field and in commercial applications.

A mini review article recently published in *Frontiers in Plant Science** illustrates the application of this research. With fungal pathogens capable of destroying 60 per cent of all crops in a severe epidemic, innovative plant protection solutions are an immediate priority. Integration of these cutting-edge molecular tools represents one more step for plant scientists, breeders and canola growers towards finding new and translatable solutions to protect global food systems.

The federal government's $15 million investment in canola research through *Growing Forward 2* (GF2) combined with the canola industry's $5 million contribution is funding 23 research projects for five years. Some of those are complete and featured in the first half of this magazine. Here are short descriptions and progress reports for the 11 ongoing agronomy projects.

GROWING FORWARD 2 **UPDATES**

Growing Forward 2
A federal-provincial-territorial initiative

PLANT ESTABLISHMENT

INVESTIGATING TOLERANCE OF CANOLA GENOTYPES TO HEAT AND DROUGHT STRESSES, AND ROOT TRAITS ESTIMATION BY ELECTRICAL CAPACITANCE

PRINCIPAL INVESTIGATOR: Bao-Luo Ma, AAFC Ottawa
PURPOSE: To better understand the physiological mechanisms of tolerance to heat and drought stresses in canola genotypes.
PROGRESS: Results from three field trials and greenhouse experiments show that measurements of pollen fertility can be used for quantifying flower abortions. Also, electrical measurements, especially root capacitance, have potential to be used as a non–invasive and rapid method for the *in situ* assessment of lodging resistance among various agronomic practices or for selecting genotypes with high yield potentials and strong anchorage strength in canola breeding programs. Under the controlled greenhouse growth conditions, measurements of the gas exchange characteristics (such as net photosynthetic rate, stomatal conductance, intercellular CO_2 concentration and intrinsic water-use efficiency), and chlorophyll fluorescence parameters have provided insightful understanding of physiological mechanisms in the responses of canola plants to heat and drought stresses.

Below: Weather Innovations uses data from these weather stations for its project on sclerotinia stem rot risk. (See the summary on page 31.)

CANOLA SUSTAINABILITY – RISK MITIGATION

PRINCIPAL INVESTIGATOR: Neil Harker, AAFC Lacombe
PURPOSE: To determine if the risks of growing canola more frequently in rotations can be mitigated by inputs that are either higher than normal (fertilizer, seed) or unusual practices (enhanced seed treatment or chaff removal).
PROGRESS: Preliminary results indicate that some agronomic treatments (higher fertilizer rates, fungicide and chaff removal) may partially mitigate the impacts of continuous canola when they are applied sequentially over two years. However, none of these mitigation measures in continuous canola appear to be as consistently effective as simply rotating canola with other crops.

CANOLA ROTATION STUDIES FOR EASTERN CANADA

PRINCIPAL INVESTIGATOR: Claude Caldwell, Dalhousie University
PURPOSE: To gain better understanding of how canola will fit into existing cropping systems in Eastern Canada. (This project is built on an established rotation experiment.)
PROGRESS: Clubroot infection was determined to be the cause of crop decline and eventual death of a large percentage of plants in continuous canola plots at the Canning site in 2015. The continuous soybean rotation and soybean following wheat showed significantly lower yield than the other two rotations at the Canning site, while continuous wheat yielded significantly lower than the other rotations and the continuous corn yielded significantly lower than corn following soybean rotations at the Ottawa site. Yield of wheat, soybean and corn was not significantly affected by the rotations at the McGill site. This suggests continuous crop rotations have a tendency of yielding lower than the other rotations.

FERTILITY MANAGEMENT

VARIABLE N FERTILITY MANAGEMENT OF CANOLA AT THE FIELD SCALE, BASED ON ANALYSIS OF YIELD MAPS AND SPATIAL AND STATISTICAL VARIABILITY OF SOIL TEST N AND P

PRINCIPAL INVESTIGATOR: Alan Moulin, AAFC Brandon
PURPOSE: To examine the impact of variable-rate nitrogen (N) fertility programs on canola yield in areas with consistently high production, of the economic return and efficiency of fertilizer use, of the relationship between the variability of canola yield and soil test N and phosphorus (P), of variability related to soil test recommendations and of the correlation of digital elevation, landform and remote sensing data with canola yield.
PROGRESS: Soil and crop data were collected for nine sites in 2015-16 along with some satellite images. Laboratory analysis and preliminary statistical analyses for 2015 are underway. Yield response of canola hybrids to N fertilizer varied considerably between farms. Nitrogen fertilizer resulted in increased yields in comparison with the controls, but the response varied by farm between 50, 100 and 150% of recommended rates for the producers target yield.

INTEGRATED PEST MANAGEMENT

CHARACTERIZATION AND DEVELOPMENT OF NEW RESISTANT SOURCES FOR SUSTAINABLE MANAGEMENT OF CLUBROOT IN CANOLA

PRINCIPAL INVESTIGATOR: Gary Peng, AAFC Saskatoon
PURPOSE: This project, which builds on previously identified clubroot resistance (CR) genotypes, maps out the CR genes in the selected materials and develops markers that are tightly linked to these CR genes, in order to facilitate the introgression of clubroot resistance into canola. Additionally, the study investigates resistance mechanisms by different CR genes to help determine whether the CR genes can be judiciously used, based on their modes of action.
PROGRESS: A total of nine CR genes have been characterized based on the genetic mapping of *Brassica rapa, B. nigra* and *B. oleracea* and molecular markers have been developed for most of these CR genes. Five of the CR genes from AAFC and one CR gene from U of A have been transferred to seed companies in western Canada, along with effective markers, for the development of new resistant canola cultivars.

THE HOST-PATHOGEN INTERACTION OF *PLASMODIOPHORA BRASSICAE* AND CANOLA

PRINCIPAL INVESTIGATORS: Sheau-Fang Hwang, AF, and Stephen Strelkov, University of Alberta
PURPOSE: To investigate the host-pathogen interactions in the clubroot pathosystem in order to guide the industry, management options and resistance-breeding decisions, including providing some insights into the timing of the interaction between effectors from *P. brassicae* and the host.
PROGRESS: After studying one gene that appeared to be present exclusively in pathotype 5 of *P. brassicae*, findings suggest that it is involved in clubroot pathogenesis, and that it also might serve as a molecular marker for differentiation of pathotype 5 from other pathotypes. Other work has provided insights into the timing of interaction between effectors from *P. brassicae* and the host. As well, a suite of putative differential host cultivars was identified. This will be further evaluated to finalize a Canadian clubroot differential set to more effectively classify pathotypes of *P. brassicae*.

MANAGEMENT OF CLUBROOT IN A DYNAMIC ENVIRONMENT

PRINCIPAL INVESTIGATOR: Sheau-Fang Hwang, AF, and Stephen Strelkov, University of Alberta
PURPOSE: This study aims to provide the tools and information necessary to successfully manage clubroot in western Canada (by developing economical and effective techniques to eradicate localized clubroot infestations using soil fumigants), to assess the impact of cropping rotations and to optimize practices for disinfesting agricultural and industrial equipment.
PROGRESS: Soil fumigation study results strongly suggested the utility of these chemicals in eradicating or containing localized clubroot infestations. Crop rotation studies revealed that large numbers of resting spores die or disappear in the first year or two after a susceptible crop, but some resting spores are persistent and may survive many years. Rotation studies examining the impact of including host, non-host bait crops and fallow periods found that clubroot severity on canola following *B. rapa*–fallow or *B. rapa*–ryegrass in any sequence was lower than following ryegrass–fallow or fallow–fallow sequences.

CLUBROOT SURVEILLANCE AND EPIDEMIOLOGY

PRINCIPAL INVESTIGATOR: Stephen Strelkov, University of Alberta

PURPOSE: This study aims to use clubroot surveillance to track incidence and predict the spread of clubroot, identify potential issues, monitor populations for pathotype shifts, and evaluate clubroot resistance in fields.

PROGRESS: Further surveillance identified another 229 new records of the disease, for a total of 287 new clubroot-infested fields in 2015. Clubroot severity ranged from mild to moderate, but no severe infestations (ID > 60 per cent) were identified in 2015, possibly due to the very dry conditions in many parts of the province in 2015. Surveillance activities have been ongoing in 2016 with data and samples currently under analysis. PCR-based testing of soil collected in Manitoba revealed the presence of low levels of *P. brassicae* DNA in three of 36 samples analyzed from that province.

DEVELOPMENT OF PEST MANAGEMENT DECISION-MAKING PROTOCOLS FOR SWEDE MIDGE IN CANOLA

PRINCIPAL INVESTIGATOR: Rebecca H. Hallett, University of Guelph

PURPOSE: The aim is to evaluate insecticide efficacy and timing of insecticide applications, evaluate the use of pheromone-based action thresholds and develop decision-making protocols for the timing of insecticide applications for reducing swede midge damage in spring canola.

PROGRESS: Results from field trials and lab experiments suggest that multiple insecticide applications are often required to reduce swede midge damage. Single applications of insecticide at the early or mid-plant stage timings can be effective under some circumstances, but late timing alone is not an effective treatment. An interim action threshold of 5 midges per trap per day (based on four pheromone traps per field) is recommended. However, prior to the 4-leaf stage, growers should wait until they have reached a total of 20 midges captured before making an insecticide application (beginning swede midge counts at the cotyledon stage).

THE ENVIRONMENTAL FOOTPRINT OF CANOLA AND CANOLA-BASED PRODUCTS

PRINCIPAL INVESTIGATOR: Vern Baron, AAFC Lacombe

PURPOSE: The aim is to study farm-gate canola carbon footprints in each soil zone and determine the greenhouse gas intensity for canola production using best management practices in a high-yielding, high-input region.

PROGRESS: In addition to the findings reported last year, the carbon balance study comparing barley and canola portion of the life cycle assessment of canola production practices between 1990 and 2010 on the Canadian Prairies found that early planted canola was a sink for Net Ecosystem C-Exchange (NEE) in five out of five years while early planted barley was only a sink in four out of five years. However when NEE was adjusted for C-loss due to grain harvest, in four out of five years both early-planted crops were biome carbon sources (the fields on which they were grown had a net loss in carbon).

OPERATIONAL MODELS TO FORECAST CANOLA GROWTH STAGE, SCLEROTINIA RISK, AND YIELD IN WESTERN CANADA

PRINCIPAL INVESTIGATOR: Rishi Burlakoti, Weather Innovations

PURPOSE: The aim is to develop models and deploy forecasting tools for canola growth stage, sclerotinia stem rot risk and canola yield on a near real-time basis.

PROGRESS: Field trials were conducted in Manitoba (11), Saskatchewan (2) and in Alberta (3) in 2015. After comparing accumulated heat units from three thermal models, accumulated physiological-day (P-day) thresholds were selected for predicting the growth stages. When growth stages prediction thresholds for short-, mid- and long-season cultivars were compared, differences among cultivar groups were determined. The newly developed sclerotinia stem rot (SSR) score card has both weather and agronomic variables as input variables and will be refined using 2016 and 2017 cropping season field data. The sclerotinia risk calculation index was also deployed at http://canoladst.ca for the 2016 field season in Manitoba, Saskatchewan and Alberta (and will also be refined using field data from 2016 and 2017).

MOMENT

An early non-canola related "aha!" moment happened when I went to the annual big Christmas craft sale at the U of A at the "Butterdome". I stopped at a booth set up by a big Alberta Saskatoon Orchard. I got chatting with the person manning the booth about the Saskatoon business, and he told me that until recently they'd had terrible problems with a disease called Entomosporium leaf and berry spot, but new fungicide registrations had become available and they could now control the problem. I didn't comment on this to the vendor, but walked away pretty happy because I had conducted the project that secured those minor use registrations. This wasn't rocket science, but it made me realize that our projects, even the small ones, matter to people.

—Ralph Lange, crop pathology and biotechnology team lead, Alberta Innovates Technology Futures

Researchers across western Canada are working towards developing new tools to help producers manage two serious diseases in canola – blackleg and sclerotinia stem rot. This project, led by SaskCanola, partners with the Alberta Canola and the Federal Government under *Growing Forward 2* (GF2). This Agri-Science Project, which is still in progress, has multiple activities focused on new discoveries and solutions for managing these diseases.

DISEASE MANAGEMENT TOOLS FOR BLACKLEG AND SCLEROTINIA

BY DONNA FLEURY

IMPROVING CANOLA RESISTANCE AGAINST BLACKLEG DISEASE THROUGH INCORPORATION OF NOVEL RESISTANCE GENES SOURCED FROM *B. NAPUS, B. RAPA* AND *B. OLERACEA*

PRINCIPAL INVESTIGATOR: M. Hossein Borhan, AAFC, Saskatoon

PURPOSE: To identify new major resistance genes for blackleg disease through the phenotypic screening of 500 accessions of *Brassica napus, B. rapa* and *B. oleracea* with a differential set of *Leptosphaeria maculans* isolates.

PROGRESS: New sources of resistance genes are needed to protect the commercial canola cultivars against constantly evolving blackleg pathogen populations. Researchers have screened *B. napus* and *B. rapa* germplasm available at the Plant Gene Resources of Canada (PGRC) with a set of six blackleg isolates to determine their genotype for known Rlm (Resistance to *L. maculans*) genes and to identify novel R genes. In addition *L. maculans* transgenic lines containing individual avirulence (Avr) genes were produced to help with genotyping. After screening the entire collection of *B. napus* lines (466 accessions), three lines (AF229-1 N1, AF272-1 N1 and AF 328-4 N2) were identified with potential novel R genes. These lines have been crossed to the susceptible *B. napus* cv Topas to produce F2 and BC1 populations. A subpopulation of F2 plants is being grown to confirm the presence and map the position of potential novel R genes. For the 538 *B. rapa* lines screened, 21 lines were selected for another round of testing.

IDENTIFYING NOVEL RESISTANCE GENES FROM CANOLA RELATIVES AND DEVELOPING CANOLA GERMPLASM WITH MULTIPLE RESISTANCE GENES SOURCED FROM *B. NIGRA, B. JUNCEA,* AND *B. CARINATA*

PRINCIPAL INVESTIGATORS: Genyi Li and Dilantha Fernando, University of Manitoba

PURPOSE: To use cloned blackleg resistance genes (1) to identify the effective resistance genes, (2) to monitor the changing of pathogen isolates in canola fields, (3) to guide pyramiding effective resistance genes in the development of canola cultivars, (4) to guide the deployment of canola cultivars with various blackleg resistance genes and (5) to identify novel blackleg resistance genes in canola relative species.

PROGRESS: Researchers cloned all six published avirulence genes from 20 blackleg fungal isolates frequently used in the project. They also collected RNA sequencing data using samples from transgenes and near isogenic lines that were challenged with different blackleg pathogen isolates. The results of RNA-seq showed that the cloned resistance genes can induce those genes involved in defense and suppress other genes that may produce metabolites for fungal growth. In field trials, researchers identified a horizontal blackleg resistance gene that proved to confer good resistance to all field fungal isolates and performed well under severe blackleg disease pressure. The results suggested that this resistance locus has excellent potential in blackleg management in western Canadian canola production regions. Researchers also identified novel resistance genes from canola relatives including *B. carinata*, *B. nigra* and *B. juncea*. In one trial, the introduction of a novel resistance gene introduced from *B. carinata* into *B. napus* proved to be highly resistant to highly virulent blackleg fungal isolates. Researchers will provide all resistance gene-specific molecular markers and their effectiveness information to Canadian canola seed companies so they will be able to pyramid several resistance genes in newly released canola cultivars through marker assisted selection.

Above: Dilantha Fernando's study into resistance (R-gene) durability of canola cultivars and emergence of virulent blackleg isolates in farmers' fields used plots to test the difference in performance between resistant (left) and susceptible (right) varieties.
Credit: Hossein Borhan

GENOME-WIDE ASSOCIATION MAPPING OF QUANTITATIVE RESISTANCE AGAINST BLACKLEG IN *BRASSICA NAPUS*

PRINCIPAL INVESTIGATOR: M. Hossein Borhan, AAFC Saskatoon

PURPOSE: (1) To identify tightly-associated genetic markers for controlling adult plant resistance to blackleg; and (2) to define the underlying genetic architecture of this durable resistance to blackleg in *B. napus*.

PROGRESS: Blackleg disease of canola caused by the fungus *Leptosphaeria maculans* continues to be a major disease affecting canola yield. Qualitative (monogenic) disease resistance (R) provides full immunity against *L. maculans*, but becomes ineffective when new races of the pathogen emerge. Quantitative resistance (multigenic) provides durable resistance to various *L. maculans* isolates and has been shown to be effective in preventing blackleg disease of canola at the adult plant stage (Adult plant resistance (APR)). In this project, researchers screened *B. napus* germplasm (467 accessions) at the Plant Gene Resources of Canada (PGRC) for APR against two criteria: (i) lack of race specific resistance and (ii) spring type growth morphology. Two hundred *B. napus* lines were screened twice for APR; 85 lines were confirmed to contain quantitative resistance, resulting in 69 lines being self-pollinated to form the association mapping population. As well, researchers successfully developed and confirmed the methodology for detecting APR response and identifying associated genetic markers.

TRANSCRIPTOMIC ANALYSIS OF THE *LEPTOSPHAERIA MACULANS* (BLACKLEG)-CANOLA INTERACTION TO IDENTIFY RESISTANCE GENES IN CANOLA AND AVIRULENCE FACTORS IN *L. MACULANS.*

PRINCIPAL INVESTIGATOR: Richard Bélanger, Laval University

PURPOSE: (1) To identify effectors and evaluate the comparative transcriptomic response of susceptible and resistant canola lines to virulent isolates of *Leptosphaeria maculans* (blackleg); and (2) identify specific resistant genes in canola involved in the expression of an incompatible interaction with *L. maculans*

PROGRESS: The infection process of blackleg disease in canola is highly dependent on host recognition and molecular cross talk between the host and the pathogen where pathogenicity-related genes play an important role. However, any given host-pathogen interaction is a very complex phenomenon, which makes it difficult to understand the factors dictating compatibility or incompatibility. In this study, transcriptome profiling of *L. maculans* was performed in an effort to understand and define the pathogenicity genes that govern both the biotrophic and the necrotrophic phase of the fungus, as well as those that separate a compatible from an incompatible interaction. Researchers analyzed the RNA-seq transcriptome profiling of *L. maculans* inoculated on susceptible and resistant canola lines at five developmental stages with five biological replications. Sequence characterization and expression profiling of pathogenesis-related genes along with the novel transcripts were performed. From the comparative transcriptome analyses, key genes were highlighted that dictate the interaction between canola and *L. maculans*, resulting in the identification of key pathogenicity genes that regulate not only the fate of the interaction but also lifestyle transitions of the fungus.

DURABLE BLACKLEG RESISTANCE STEWARDSHIP THROUGH KNOWLEDGE OF BLACKLEG PATHOGEN POPULATION, RESISTANCE GENES AND CROP SEQUENCE TOWARDS THE DEVELOPMENT OF A CULTIVAR ROTATION PROGRAM IN THE PRAIRIE PROVINCES

PRINCIPAL INVESTIGATOR: Dilantha Fernando, University of Manitoba

PURPOSE: To analyze blackleg avirulence (Avr) gene diversity and frequency of different Avr genes in different farms.

PROGRESS: Changes in the virulence of *L. maculans* populations had been reported a lot in western Canada, such as changes in AvrLm3, which subsequently leads to breakdown of Rlm3. In this project, 50 representative grower

sites were selected from each of Alberta, Saskatchewan and Manitoba from fields that have had blackleg to various degrees. This five-year study provides a unique opportunity to study the long-term effects of crop rotation and other agronomic practices on the rate of pathogen adaptation as well as the relative durability of different resistant sources. In addition, one test plot will be set up in each Prairie province to compare the effect of sowing cultivars in their own residue, rotating cultivars with different sources of resistance, and also gauge the rate of change in *L. maculans* populations with respect to the avirulence genes analyzed. Knowledge of the Avr genes diversity will be helpful for mastering changes in structure of Avr genes and providing a guide for seed breeders as well as farmers for variety selection. The Avr profile information has already prompted seed companies to incorporate effective R genes into new canola hybrids against the current pathogen population on the Prairies. Some varieties may be made available commercially in 2016, adding new management tools to the fight against blackleg.

INVESTIGATING THE RESISTANCE (R-GENE) DURABILITY OF CANOLA CULTIVARS AND EMERGENCE OF VIRULENT BLACKLEG ISOLATES IN FARMERS' FIELDS

PRINCIPAL INVESTIGATOR: Dilantha Fernando, University of Manitoba

PURPOSE: (1) To assess which cultivar resistance genes are most durable to disease pressure and make recommendations on when and how often to rotate cultivars studied; and (2) to examine the potential of emergence of virulent isolates when a new cultivar without corresponding virulent isolates is introduced.

PROGRESS: For this study, plots were established with near isogenic lines (NILs) carrying different single dominant genes for resistance for *L. maculans* (Rlm) and inoculated with 100 per cent avirulent isolates to the corresponding resistant gene. The cultivar Topas (no-R genes) and its isogenic lines with single R-genes, developed by AAFC to compare the durability of different blackleg resistance genes without the influence of host variation, and single Rlm carrying Topas lines will also be seeded in each of these fields for five years (canola on canola) and as a rotation (canola-wheat-canola). The pathogen isolates spores will be collected and tested to identify changes in the populations to an increasing virulence, followed by differential testing in the greenhouse and PCR analysis in the lab. Each year, the changes will be recorded in the two systems (canola on canola; and canola-wheat-canola) to understand the changes and how a rotation may help in reducing the increase in virulence isolates. Establishing a timeframe for the majority of isolates to gain virulence will help compare the relative durability of different resistance genes and make recommendations on when to rotate each cultivar depending on its resistance gene.

RAPID FIELD DIAGNOSTICS OF THE BLACKLEG PATHOGEN RACES THROUGH THE IDENTIFICATION OF PATHOGEN AVIRULENCE (AVR) GENES AND THE DEVELOPMENT OF AVR-SPECIFIC MARKERS

PRINCIPAL INVESTIGATOR: M. Hossein Borhan, AAFC Saskatoon

PURPOSE: To develop molecular markers as an efficient tool for genotyping and monitoring *L. maculans* populations in canola fields across Western Canada.

PROGRESS: For effective management of blackleg disease, it is important to know the genotype of blackleg isolates within a field population. To date 16 resistance (R) genes (Rlm1-11, Rlms; LepR1-4) from Brassica have been identified that provide full immunity against *L. maculans* isolates with matching Avr genes (AvrLm1-11, AvrLms; AvrLepR1-4). Researchers cloned AvrLm2 and AvrLepR2 using map-based cloning in combination with genome sequence comparison. In addition KASP molecular markers for these two genes and all other known *L. maculans* Avr genes were designed and successfully applied to determining the genotype of close to 200 *L. maculans* isolates collected from canola fields across western Canada. By knowing the prevalence of these Avr genes in the field populations of *L. maculans*, breeders will be able to develop appropriate cultivars with resistance genes targeted against prevalent pathogen races (based on Avr genes) on a regional basis.

As part of Lone Buchwaldt's project to identify markers for sclerotinia-resistance genes, sclerotinia mycelium is grown on nutrient agar in petri dishes. In this photo, summer student Semi Mulic cuts mycelium plugs and places them on pieces of para film (plastic) to be used for inoculation of canola stems in the field.
Credit: Lone Buchwaldt

DEVELOPMENT OF A BLACKLEG YIELD LOSS MODEL AND ASSESSMENT OF FUNGICIDE RESISTANCE IN WESTERN CANADIAN POPULATIONS OF *LEPTOSPHAERIA MACULANS*

PRINCIPAL INVESTIGATOR: Stephen Strelkov, University of Alberta

PURPOSE: (1) To develop a yield loss model to relate the severity of blackleg on canola with the corresponding yield losses; and (2) to evaluate representative populations of *L. maculans* from western Canada for the occurrence of fungicide resistance.

PROGRESS: In field experiments across western Canada, researchers are studying the relationship between blackleg severity and yield. Results show blackleg severity was lower, and seed yield was 120-128 per cent greater, in moderately-resistant to resistant hybrids compared with the susceptible cultivar. In all canola varieties, the analysis showed that pod number and seed yield declined linearly as blackleg severity increased. The yield loss model and associated recommendations being finalized will help producers make informed crop management decisions and estimate economic disease impacts. Researchers are also evaluating the sensitivity of a representative collection of *L. maculans* isolates from western Canada to the fungicide pyraclostrobin in agar plate and microtiter plate assays. No pyraclostrobin insensitive isolates have been identified so far. In field experiments, results show pyraclostrobin fungicide reduced disease severity in all site years, and increased yield in two site-years. This fungicide could be an effective and sustainable blackleg management tool for canola growers, as long as fungicide stewardship is practiced and included as a component of an integrated pest management plan.

CHARACTERIZATION OF DEFENSE GENES UNDERLYING QUANTITATIVE RESISTANCE LOCI (QRL) TO SCLEROTINIA STEM ROT IN ASIAN *BRASSICA NAPUS* AND TRANSFER OF RESISTANCE TO CANADIAN SPRING TYPE CANOLA

PRINCIPAL INVESTIGATOR: Lone Buchwaldt, AAFC Saskatoon

PURPOSE: (1) To identify molecular markers linked to sclerotinia resistance and identification of underlying defense genes; and (2) to transfer of sclerotinia resistance to elite open-pollinated spring-type canola.

PROGRESS: Researchers are working to identify genes underlying sclerotinia resistance and to develop molecular markers linked to resistance. Even though sclerotinia resistance is a very rare trait, researchers were able to generate *B. napus* lines with high level of sclerotinia resistance. A set of 17 *S. sclerotiorum* isolates representing the genetic and pathogentic variablity of the sclerotinia population in western Canada have been identified. One *B. napus* line from Pakistan with the highest level of resistance to these isolates was crossed with one of AAFC's open-pollinated elite canola lines to transfer sclerotinia resistance into a spring-type canola quality background using traditional backcrossing. A population of ~500 doubled haploid backcross lines was phenotyped for sclerotinia resistance in the 2016 growing season and resulted in identification of about 30 lines (six per cent) as resistant as the Pakistani line. Canola breeders can already request seed from AAFC of resistant lines from Pakistan, South Korea and Japan, molecular markers linked to resistance in the Pakistani material and sclerotinia isolates for development of canola cultivars. Open pollinated canola lines with improved sclerotinia resistance will be available for non-exclusive licensing at the end of the current project.

RESISTANCE TO *SCLEROTINIA SCLEROTIORUM* NECROSIS INDUCING PROTEINS IN CANOLA

PRINCIPAL INVESTIGATOR: Dwayne Hegedus, AAFC Saskatoon

PURPOSE: (1) To identify proteins secreted by *S. sclerotiorum* that cause or contribute to necrosis; and (2) to develop a method to screen *B. napus* lines for resistance to their effects.

PROGRESS: Researchers want to determine how *S. sclerotiorum* causes the most noticeable and damaging aspect of disease in *B. napus*, i.e. the necrotic lesions on the stem that lead to lodging and crop loss. So far they have identified a small number of proteins that are secreted by *S. sclerotiorum* that have the ability to cause necrosis. The next step is to characterize the proteins and then the most important of these will be used to screen a diverse, global collection of *Brassica napus* for lines that are more tolerant or resistant to the protein effects. This targeted approach will help to characterize the resistance in lines already identified in the AAFC collection and identify new lines with resistance to the main pathogenicity factors. This trait can then be incorporated into canola breeding programs to develop spring-type varieties with one or a few highly effective and robust stem-rot resistance genes.

—Donna Fleury, P.Ag., is an agricultural freelance writer from Millarville, Alta.

Canola growers across the Prairies fund dozens of research projects with their levy payments to Alberta Canola, SaskCanola and Manitoba Canola Growers Association. Many of those projects are funded through their joint Canola Agronomic Research Program (CARP), which has been going for almost 30 years. Other projects are funded through arrangements with other organizations listed in these summaries. Here are short descriptions and updates for ongoing projects directly funded by provincial canola grower organizations. **See page 2 for an explanation of all abbreviations.**

GROWER-FUNDED RESEARCH PROJECTS

PLANT ESTABLISHMENT

INVESTIGATING WIDER ROW SPACING IN NO-TILL CANOLA: IMPLICATIONS FOR WEED COMPETITION, RESPONSE TO NITROGEN FERTILIZER AND SEEDING RATE RECOMMENDATIONS

PRINCIPAL INVESTIGATOR: Chris Holzapfel, Indian Head Agricultural Research Foundation
FUNDING: SaskCanola
PURPOSE: In response to interest among canola growers and equipment manufacturers, a project was initiated in 2012 at Indian Head, Sask., to evaluate canola performance at row spacing up to 61cm. Three separate field trials were designed to evaluate row-spacing implications for side-banded nitrogen (N), seeding rate recommendations and crop competition with weeds.
PROGRESS: Despite high weed pressure, a single in-crop herbicide application kept weed competition acceptably low at all row spacing levels. Increasing row spacing resulted in slight but significant delays in maturity, but delays caused by row spacing were usually much smaller than those caused by nitrogen (N) fertilizer or seeding rate. Results to date suggest that N requirements of canola are likely similar regardless of row spacing, particularly for the range of 25-41 cm. Data from 2016 was not available at printing, but data from previous years showed minimal or no yield loss at wider spacing.

Right: In Chris Holzapfel's row width research, the canopy took longer to close in at 61cm (24-inch) row spacing, as shown. Canola at this wide row width also had more weed pressure, more lodging and some delay in maturity compared to narrower widths.
Credit: Chris Holzapfel

DEVELOPING CANOLA AGRONOMY WITH PRECISION PLANTERS

PRINCIPAL INVESTIGATOR: Ken Coles, Farming Smarter
FUNDING: ACPC, MCGA, Farming Smarter
PURPOSE: Precision planters provide superior depth control and seed distribution over conventional seeders, and thus have the potential to improve the proportion, uniformity and rapidity of canola emergence. This study hopes to explore optimum row spacing and seed-safe rates with in-row liquid phosphorus fertilizer.
PROGRESS: Six trials were planted in southern Alberta in 2016. All trials have been harvested but analysis of data was not complete at the time of printing.

TO GERMINATE OR NOT TO GERMINATE? TOWARDS UNDERSTANDING THE ROLE DORMANCY PLAYS IN CANOLA SEED VIGOUR, SEEDLING VIGOUR AND STAND ESTABLISHMENT

PRINCIPAL INVESTIGATOR: Sally Vail, AAFC Saskatoon
FUNDING: CARP, AIP
PURPOSE: This project is investigating the inter-relatedness of the potential for different forms of dormancy, seed biology characteristics and seedling vigour traits across a diversity panel of *Brassica napus* lines. It will also investigate the effect of maternal environment and source seed processing on enhancing or diminishing dormancy potential of canola seed. Results will guide plant breeding to ultimately reduce the secondary or inducible dormancy potential of canola.
PROGRESS: A wide range of secondary dormancy potential has been identified across the lines harvested in 2015. The role environment plays in primary and secondary dormancy potential is being explored with seed produced in two contra-season environments and from the 2016 field season. Additionally, characterization of lines for propensity to precociously germinate within the ripening pod is ongoing and values will be compared to

dormancy potential values. Seed vigour metrics for lines and seedlots will be explored over the next year and all values will be compared to both established (eg. oil, protein, fiber, glucosinolate and fatty acid profiles) and novel seed quality traits (eg. protein fractions). Researchers are also working with hybrid seed production partners to design a strategy to survey secondary dormancy potential within current commercial seedlots.

FERTILITY MANAGEMENT

CROP RESPONSE TO FOLIAR-APPLIED PHOSPHORUS FERTILIZERS

PRINCIPAL INVESTIGATOR: Jeff Schoenau, University of Saskatchewan
FUNDING: SaskCanola, ADF, SPG, SWDC
PURPOSE: To determine the effect of foliar-applied phosphorus (P) on crop (canola, wheat, pea) response and residual soil phosphorus fertility in comparison to soil-applied phosphorus.
PROGRESS: The study began in spring of 2016 with four field-research sites selected across the Brown, Dark Brown and Black soil zones of Saskatchewan. Different treatments of foliar-applied orthophosphate solution were applied mid-season to canola, wheat and peas. Some treatments were in combination with granular monoammonium phosphate (11-52-0) applied with the seed. Plant samples were obtained for analysis before and after foliar P application. Harvest samples were analyzed for yield and contents of total P, phytate, zinc and iron to determine crop recovery of P and the impact of the treatments on the nutritional quality of the grain. Soil samples were taken after harvest and analyzed for available P forms. Soil was also collected in fall of 2016 from sites for controlled environment studies to evaluate the effect of different foliar P forms and rates on the crop P nutrition and the fate of the P in soil and run-off water. Field trials will be repeated again in 2017.

Jeff Schoenau's assistants seed plots for his work on foliar-applied phosphorus.

ENHANCING CANOLA PRODUCTION WITH IMPROVED PHOSPHORUS FERTILIZER MANAGEMENT

PRINCIPAL INVESTIGATOR: Stewart Brandt, Northeast Agriculture Research Foundation
FUNDING: SaskCanola
PURPOSE: This research investigates whether current phosphorus (P) fertilizer recommendations are adequate for high-yielding cultivars and if all fertilizer P needs to be seed placed. It also examines if current recommendations regarding safe rates of P and sulphur (S) are suitable for typical knife or hoe openers in use today.
PROGRESS: In 2016, trials were conducted at three sites in Saskatchewan (Melfort, Scott and Indian Head). Results are being compiled as yield data is available and the annual report will be submitted in early 2017.

ENHANCED SASKATCHEWAN SOIL DATA FOR SUSTAINABLE LAND MANAGEMENT

PRINCIPAL INVESTIGATOR: Angela Bedard-Haughn, University of Saskatchewan
FUNDING: SaskCanola, SaskPulse, ADF
PURPOSE: This project aims to provide improved access to Saskatchewan soil information, both desktop and mobile. In addition, it will explore ways to enhance and utilize this soil information, including digital soil mapping at a resolution and scale useful for precision management and applications that allow producers to upload and integrate their own field-scale data to inform nutrient management decisions.
PROGRESS: As of October, an early prototype of the soil information storage and access framework is in place, including the web interface for accessing and querying information. As harvest wraps up, researchers are collecting information from test sites to begin work on refined soil maps using digital soil mapping techniques.

IDENTIFYING THE MECHANISMS RESPONSIBLE FOR GREATER THAN EXPECTED RESIDUE-INDUCED N_2O EMISSIONS FROM CANOLA AND FLAX

PRINCIPAL INVESTIGATOR: Richard Farrell, University of Saskatchewan
FUNDING: SaskCanola, ADF
PURPOSE: 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.
PROGRESS: Year 1 involved isotopically labeling the test crops (canola, flax, pea and wheat) with 15N and 13C by growing the crops under controlled conditions in a greenhouse. At maturity, the plants were harvested

and the seed, above-ground residue, and below-ground residue (roots) were separated, weighed, dried and analyzed. Biochemical and isotopic characterization of the different crop residues is currently underway.

CANOLA RESPONSE AND MINIMIZING NITROGEN LOSSES IN TWO-PASS SEEDING-FERTILIZATION SYSTEMS WITH VARYING PLACEMENT METHODS IN MANITOBA

PRINCIPAL INVESTIGATOR: Mario Tenuta, University of Manitoba
FUNDING: MCGA, KOCH Agronomic Services
PURPOSE: This project will evaluate the agronomic and environmental performance of surface broadcast, shallow banding and deep banding methods of applying nitrogen (N) fertilizer to canola. It will compare canola yield, nitrogen uptake and nitrous oxide (N_2O) emissions from urea and SuperU.
PROGRESS: Two replicated field trials were established in 2016 and taken to yield. Nitrous oxide emissions were monitored one to two times each week and soil extractable nitrogen sampled and determined several times during the growing season. Emission determinations and soil sampling will continue to freeze-up.

ENHANCING THE BENEFICIAL ROOT MICROBIOME IN CANOLA

PRINCIPAL INVESTIGATOR: Chantal Hamel, AAFC
FUNDING: SaskCanola, Alberta Canola, MCGA, NSERC
PURPOSE: This project aims to validate a list of the reliable microbial associates always present and abundant in the canola root microbiome, while determining crop rotations that favour the establishment of a beneficial root microbiome in canola-based rotations.

PROGRESS: Two field experiments were planted and sampled in 2016. At Indian Head, Sask., plots were sampled at the vegetative and full-bloom stages from three cropping systems. In Swift Current, Sask., samples were taken at full bloom from three levels of previous crop that will be followed by five different Brassica crops, including *B. napus*. DNA is being analyzed to describe crop root and rhizosphere microbiomes. The beneficial nature of the microorganisms is being determined based on identity and abundance of important functional genes, as well as on crop performance.

INTEGRATED PEST MANAGEMENT

CAN HARVEST WEED SEED MANAGEMENT BE USED TO CONTROL KOCHIA, CLEAVERS AND WILD BUCKWHEAT?

PRINCIPAL INVESTIGATOR: Steve Shirtliffe, University of Saskatchewan
FUNDING: SaskCanola
PURPOSE: The study has two main objectives: (1) To determine the timing of seed shed in kochia, cleavers and wild buckwheat to determine whether their seed dispersal can be managed effectively at harvest. (2) To see if pre-harvest herbicide can reduce viable seed production in these three weeds.
PROGRESS: The project is in its final year and results are promising. Kochia, wild buckwheat and cleavers retained on average 98, 90, and 91 per cent of their seeds at harvest, respectively. This indicates high potential for weed seed removal from the field with a timely harvest. Viability testing is currently underway to determine the efficacy of pre-harvest herbicide application in reducing weed seed survival.

MOMENT

I have experienced many "duh" moments where I realized something much later than I should have. One of those was at an international conference in 2006 when someone from Florida showed huge increases in phosphorus losses to runoff water when their wetland soils were flooded and ran out of oxygen. That presentation reminded me that 25 years earlier, while I was a graduate student at the U of M, I conducted an experiment where I was incubating soil samples with different combinations of nitrogen (N) and phosphorus (P) fertilizers. Whenever I added too much moisture to the soil samples, the soils would become anaerobic and the concentration of water soluble P in the samples went through the roof. At that time, I simply regarded those results as "mistakes" and reran those incubations, with less moisture added. What I did not think about until the 2006 conference was that slowing drainage on our agricultural land could make our water quality problems worse instead of better. Subsequent research in collaboration with Dr. Kumaragamage at the U of W confirmed that Manitoba's agricultural soils can release up to 15 times more P when they are flooded for too long. This needs to be considered for water management policies and regulations. I just wish I had thought of that much earlier!

—Don Flaten, professor in the Department of Soil Science, University of Manitoba

Right: Researchers monitor these mesh traps to determine the timing of seed shed for kochia and other weeds.
Credit: H.S. Duddu.

ASSESSING THE INFLUENCE OF BASE GERMINATION TEMPERATURE AND CHEMICAL DESICCANTS ON THE RECRUITMENT BIOLOGY OF CLEAVERS

PRINCIPAL INVESTIGATOR: Chris Willenborg, University of Saskatchewan
FUNDING: SaskCanola
PURPOSE: This project aims to determine the base germination temperature of several cleavers populations in Western Canada and determine the influence of chemical desiccants on cleavers seed properties.
PROGRESS: The first year of desiccant field trials were completed and data has yet to be analyzed. The base germination temperature experiment is currently underway and will be completed in December 2016.

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

PRINCIPAL INVESTIGATOR: Hector Carcamo, AAFC Lethbridge
FUNDING: Alberta Canola, SaskCanola
PURPOSE: The primary objective is to validate lygus threshold derived from cages in commercial canola fields. Secondary objectives are to assess insecticide sprays for other pests such as flea beetles or cabbage seedpod weevil on canola yield and relate landscape features to lygus distribution.
PROGRESS: Lygus were very scarce throughout the Prairies and Peace River region in 2016. The study was completed at two sites near Claresholm in southern Alberta. One farm was sprayed for flea beetles in southern Manitoba. The study has been extended for another three years to include more fields in the three Prairie Provinces.

CHARACTERIZING TURBULENT SPRAY DEPOSITION FROM SELF-PROPELLED SPRAYERS

PRINCIPAL INVESTIGATOR: Tom Wolf, AgriMetrix
FUNDING: Alberta Canola, SaskCanola
PURPOSE: This study will measure the spray deposit at 30 points along the boom to understand how travel speed, boom beight and nozzle choice affect the amount received by the crop and also how variable that deposit is. A more variable deposit means that some parts get too much and others too little, which can affect overall spray performance.
PROGRESS: The first study was done late in 2016 growing season and results were not available at the time of printing.

Far right, Researchers looking at spray deposition from self-propelled sprayers use coloured drinking straws to collect spray. The spray contains a fluorescent dye, hence the pink everywhere. In the lab, they wash the dye from the straws and measure the fluorescence to quantify the deposit amount.

IMPACT OF DROUGHT AND HEAT DURING FLOWERING ON CANOLA YIELD

PRINCIPAL INVESTIGATOR: Raju Soolanayakanahally, AAFC Saskatoon
FUNDING: SaskCanola, ADF, AAFC
PURPOSE: Changing precipitation and temperature patterns will cause significant yield losses if drought and heat waves become more common. The project evaluates spring canola lines for drought, heat and combined stresses in greenhouse and field conditions. The study employs physiological approaches to identify donor parents for stress-tolerance breeding.
PROGRESS: Work is in progress to screen diverse spring canola lines under controlled greenhouse conditions at AAFC to better understand stress response on flowering and yield.

Right: As part of AAFC's study into the impact of drought and heat on canola yield, Raed Elferjani measures carbon fixation capacity among canola lines.
Credit: Branimir Gjetvaj, AAFC.

Far right: A researcher checks the cages used to experimentally exclude pollinators and/or wind on commodity canola plots. This technique is used for the pollinator studies.
Credit: Shelley Hoover

TOXICOPATHOLOGICAL DETERMINATION OF SAFE DOSE RANGES OF NEONICOTINOIDS FOR HONEY BEE COLONIES

PRINCIPAL INVESTIGATOR: Elemir Simko, Western College of Veterinary Medicine (WCVM), University of Saskatchewan

FUNDING: SaskCanola, WGRF, Saskatchewan Beekeepers Development Commission, Canadian Honey Council, North American Pollinator Protection Campaign

PURPOSE: The 'gold standard' mammalian safety toxicopathological tests are very sensitive and veterinary pathologists use them to detect sublethal toxic effects of candidate drugs, pesticides and other chemicals in laboratory animals in order to determine the safe dose range. Comparable approaches have not been developed for honey bees. WVCM has the expertise and research capacity to adopt this mammalian 'gold standard' safety evaluation to honey bees and to determine the safe dose range for the three most commonly used neonicotinoids in agriculture.

PROGRESS: Adaptation of mammalian safety histopathology tests to honey bees has begun. Researchers are assembling databases of normal histology of larvae, pupae and adults of honey bee workers, drones and queens that will be used for subsequent testing.

POLLINATION MANAGEMENT TO MAXIMIZE CANOLA YIELD

PRINCIPAL INVESTIGATORS: Shelley Hoover, AF, Steve Pernal, AAFC Beaverlodge, Ralph Cartar University of Calgary

FUNDING: Alberta Beekeepers Commission, ASCA, ACIDF, CCC

PURPOSE: This project is to quantify the contribution of managed pollinators to canola yield, and to provide management guidelines to maximize both pollination and bee health.

PROGRESS: Year 3 of 3. Insect visitation of commodity canola flowers tends to decrease with depth into a field, whereas the volume of nectar available to pollinators tends to increase with distance from the field edge. Researchers are currently processing canola plants and pods to correlate yield metrics with bee abundance. Experimental data on pollen collection from summer 2016 will be used to compare the economics of pollen versus honey collection by beekeepers whose colonies are rented out to pollinate hybrid canola seed production fields. Observations in hybrid seed fields indicate numerous behavioural interactions within and among pollinator species. Female leafcutter bees transfer the most pollen to previously unvisited flowers. Leafcutter bees are also more likely to switch from a male to a female plant when foraging, thereby increasing the likelihood of transferring pollen.

GETTING MORE BANG FOR YOUR BUZZ: DOES POLLINATION COMPENSATE FOR CANOLA YIELD LOSS UNDER SUB-OPTIMAL MOISTURE, NITROGEN FERTILIZATION, AND/OR SEEDING RATE?

PRINCIPAL INVESTIGATORS: Ralph Cartar, University of Calgary; Shelley Hoover, AF Lethbridge; Steve Pernal, AAFC Beaverlodge; Neil Harker, AAFC Lacombe; Andony Melathopoulos, Oregon State University

FUNDING: Alberta Canola, Alberta Beekeepers Commission

PURPOSE: This study will test if pollination can compensate for canola yield loss under sub-optimal moisture, nitrogen fertilization and/or seeding rate.

PROGRESS: Year 1 of 3. Greenhouse trials will start this fall at AAFC Lethbridge. The team has agreements with multiple seed companies, and has acquired the 25 varieties of canola seed to get started. Further experiments will start in spring 2017 in Beaverlodge.

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: SaskCanola, Alberta Canola, MCGA, CCC

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 as well as the capacity of these beneficial insects to increase seed yield through pollination and pest reduction.

PROGRESS: Data collection on the diversity and abundance of pollinators near canola fields began in 2016, as did a pilot study to collect and identify natural enemies. The first meeting of the Prairie Beneficial Insect Working Group, an advisory group of academic and government researchers as well as representatives from the Canola Council of Canada, has been scheduled for November. Qualified personnel will identify insect specimens and analyze canola yield and insect diversity data.

Right: Sarah Johnson and Michael Gavin collect insects in a canola field near Okotoks, Alta., as part of Paul Galpern's biodiversity study.

Right: A Nevada bumble bee (Bombus nevadensis), photographed as part of Paul Galpern's insect biodiversity study, flies toward a clover plant.
Credit: Sarah A. Johnson

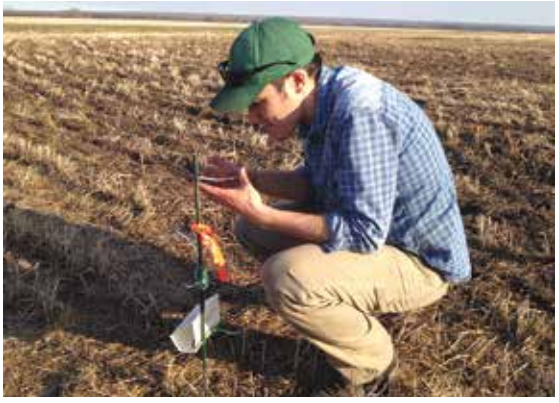
Far right, second column: AAFC swede midge researcher Boyd Mori checks an early season swede midge pheromone trap.

ENHANCED MODELLING OF SWEDE MIDGE POPULATION DYNAMICS IN NORTH AMERICA

PRINCIPAL INVESTIGATOR: Rebecca Hallett, University of Guelph
FUNDING: SaskCanola, Alberta Canola
PURPOSE: The aim is to develop a complete population dynamics model for swede midge. The model will be used to explore differences among North American populations of swede midge and will try to predict the lag time between first detection in an area and subsequent occurrence of economically damaging populations.
PROGRESS: A new graduate student started in September and is training on the modelling software. Evaluation of an older model that only predicted adult emergence of swede midge will identify weaknesses that need improvement. Collection of literature to support the addition of new life history information to the model is nearly complete. Feasibility of the model to assess the time from detection to economic damage is being assessed.

ECOLOGY OF SWEDE MIDGE – HOST PLANT INTERACTIONS

PRINCIPAL INVESTIGATORS: Boyd Mori, Owen Olfert, Julie Soroka, AAFC Saskatoon
FUNDING: ADF, WGRF, SaskCanola
PURPOSE: Year 1 of 4. The purpose is to investigate host plant susceptibility or resistance factors to swede midge, with the ultimate aim of identifying host plant resistance.
PROGRESS: Researchers are currently growing plants from a collection of plant species known to be swede midge hosts or non-hosts, creating a colony of swede midge for laboratory bioassays, and developing bioassay techniques to start experiments on midge-plant interactions.



DEVELOPMENT AND IMPLEMENTATION OF A WEATHER-BASED, NEAR REAL-TIME, CROP INSECT PEST MONITORING/PREDICTION MODEL AND PROGRAM FOR ALBERTA

PRINCIPAL INVESTIGATOR: Daniel Itenfisu, AF
FUNDING: Alberta Canola, AF
PURPOSE: The aim is to develop and implement a provincial weather-based, near real-time (NRT) insect pest prediction model as a web-based risk management tool for three significant insect pests: bertha armyworm, alfalfa weevil and wheat midge. The models will provide a timely prediction of the pests and assist in devising effective pest management practices.
PROGRESS: Year 2 of 3. The final field season concluded with data collection on phenology (seasonal cycles) and life history of three pests and their natural enemies along with crop phenology monitoring across 26 sites in Alberta. Pest phenological monitoring procedures

Far right: Verticillium has been found on canola in Manitoba. Mario Tenuta leads an investigation into disease dispersion and lines present.
Credit: Justine Cornelsen

included yellow sticky traps for wheat midge females and parasitoids, spring soil sampling to predict midge emergence and scouting for second-generation alfalfa weevil adults. Quality control and analysis on collected field data leading to improved phenology models for each species is currently underway.

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

PRINCIPAL INVESTIGATOR: Owen Olfert, AAFC Saskatoon
FUNDING: Alberta Canola, SaskCanola, MCGA, WGRF
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: Year 3 of 5. Data from annual surveys in 2016 provided a snapshot of current pest status and reflected the future risks to varying degrees. Provincial and industry collaborators, together with project team members, monitored over 4,000 sites for grasshoppers, 700 for wheat midge, 800 for cabbage seedpod weevil, 500 for bertha armyworm, 200 for pea leaf weevil and 95 for wheat stem sawfly. In addition, sentinel sites were monitored for flea beetles, cutworms, swede midge and cereal leaf beetle. Weekly updates were provided using the Prairie Pest Monitoring Network blog: prairiepestmonitoring.blogspot.ca

VERTICILLIUM LONGISPORUM IN MANITOBA: UNDERSTANDING THE PATHOGEN AND ESTABLISHING SURVEILLANCE CAPACITY.

PRINCIPAL INVESTIGATOR: Mario Tenuta, University of Manitoba
FUNDING: MCGA, Richardson International, MB Grain Hub, GF2 and WGRF.
PURPOSE: In 2014, *Verticillium longisporum*, a fungal wilt pathogen of crucifers, was identified on canola in a field in Manitoba. The pathogen is one of the most important diseases of rapeseed in Europe, but little is known about the pathogen and its behaviour in Manitoba or the Prairies. This project will study the ability of the pathogen to disperse, identify the lines of the pathogen present and establish high-throughput molecular DNA identification and quantification protocols. This prepares the province and industry for self-directed management of the pathogen.
PROGRESS: The farm found to have *V. longisporum* was sampled. Hundreds of other samples were also collected for quantification of *V. longisporum* at the Pest Surveillance Laboratory (PSI) in Winnipeg. Training of PSI personnel in the extraction protocol has begun.

DESIGN AND TESTING AN IN-FIELD REAL-TIME NANO-SENSOR DEVICE FOR PATHOGEN MONITORING IN CANOLA

PRINCIPAL INVESTIGATOR: Xiujie Li, Alberta Innovates – Technology Futures
FUNDING: ACIDF, Alberta Canola, AITF
PURPOSE: The long-term goal is to develop an in-field sensor for the detection of plant disease pathogen levels and transfer results to an electronic device in a real-time fashion. The purpose of this project is to design and make the device, and test it in the greenhouse and in the field.
PROGRESS: A *Sclerotinia sclerotiorum* ascospore trap has been selected and spore trapping under greenhouse conditions was successful. An electrode nano-chip to detect spores has also been designed and tested. Current work is putting these two together and testing the device in a greenhouse.

ANALYSIS AND MONITORING OF *LEPTOSPHAERIA MACULANS* RACE DYNAMICS IN WESTERN CANADA FOR EFFECTIVE USE OF CULTIVAR RESISTANCE IN MANAGEMENT OF BLACKLEG ON CANOLA

PRINCIPAL INVESTIGATOR: Gary Peng, AAFC Saskatoon
FUNDING: SaskCanola, Alberta Canola, MCGA, WGRF, ACIDF, ARDI and seed companies.
PURPOSE: To analyze and monitor the blackleg pathogen population using Westar trap plots scattered on the Prairies. This will provide industry with up-to-date pictures of *L. maculans* race structure, as well as the pathogen race dynamics to guide cultivar selection and rotation. Selected fields with different blackleg severity will be investigated to understand the role of *L. maculans* race changes in causing the cultivar to lose the resistance.
PROGRESS: A total of 334 *L. maculans* isolates from the 17 Westar trap plots across the Prairies were tested using a

differential set of Brassica lines for *Avr* profile. Results showed that *AvrLm1*, *AvrLm3*, *AvrLm9*, *AvrLep1* and *AvrLep2* were either very low or undetectable in the pathogen population while *AvrLm2*, *AvrLm4*, *AvrLm6* and *AvrLm7* were found in more than 50 per cent of isolates. However, *AvrLm4* in Alberta remained lower (20-40 per cent) than in other provinces, and *AvrLm2* and *AvrLm6* were noticeably lower than in 2015 in Manitoba. This information can help the selection of specific *R* genes for blackleg resistance breeding.

UNDERSTANDING THE MECHANISMS FOR RACE-SPECIFIC AND NON-SPECIFIC RESISTANCE FOR EFFECTIVE USE OF CULTIVAR RESISTANCE AGAINST BLACKLEG OF CANOLA IN WESTERN CANADA

PRINCIPAL INVESTIGATOR: Gary Peng, AAFC Saskatoon
FUNDING: GF2, CARP
PURPOSE: This study aims to characterize blackleg resistance used in western Canada, and assess potential influence of environmental factors, especially hot, dry conditions, on the expression of resistance to better understand the mechanisms of different types of resistance.
PROGRESS: Race non-specific resistance was assessed with eight selected commercial canola cultivars (CCCs) from four major seed companies supplying to the majority of canola acres in western Canada. These cultivars carry only the *R* genes *Rlm1* and/or *Rlm3*. Three of the CCCs with slightly different levels of resistance on cotyledon were assessed further using cotyledon and petiole inoculation, respectively, as well as the droplet digital PCR (ddPCR) and GFP-labelled fluorescent microscopy. Results showed that the spread of pathogen into the stem was more limited on CCCs than on Westar and the infection developed more slowly in the stem of CCCs. It appears that many Canadian CCCs carry non-specific blackleg resistance, while the common *R* genes *Rlm1* and *Rlm3* are no longer effective in most regions of western Canada.

CHARACTERIZATION OF THE NEW STRAINS OF THE CLUBROOT PATHOGEN IN ALBERTA

PRINCIPAL INVESTIGATORS: Sheau-Fang Hwang, AF, Stephen Strelkov, University of Alberta
FUNDING: ACIDF, WGRF, Alberta Canola, SaskCanola
PURPOSE: Objectives are to monitor 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.
PROGRESS: Pathogen strains capable of overcoming clubroot resistance have been identified in 42 fields. These fields are located mainly in central Alberta but with isolated cases found up to about 600 km apart. Eleven distinct strains have been identified, based on their virulence on a putative Canadian Clubroot Differential Set. Strains collected in 2016 will be characterized over the fall and winter under controlled conditions.

TOWARD A STRATEGY FOR REDUCING THE SPORE DENSITY AND DISSEMINATION OF CLUBROOT OF CANOLA IN ALBERTA

PRINCIPAL INVESTIGATOR: Sheau-Fang Hwang, AF
FUNDING: Alberta Canola, ACIDF, WGRF
PURPOSE: The aim is 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.
PROGRESS: Application rates of Vapam fumigant had a significant effect on canola stand establishment, plant height, pod number, seed yield and disease severity at both field sites. Disease severity and gall weight decreased as the Vapam rates increased. However, it should be noted that Vapam is a non-selective toxin. It is both volatile and highly soluble in water and as such constitutes a hazard to human health, as well as to non-target organisms in the area surrounding its application. Applicators must follow all regulations regarding its use and adhere to the label recommendations.

MOMENT

In Western Canada, most of our canola varieties don't carry the specific blackleg resistance (R) genes corresponding to any of the prevalent Avr genes in the current pathogen population, and the resistance to blackleg appears to rely primarily on race-non-specific (quantitative) resistance. Traditionally the latter is more difficult to identify because it relies on extensive field experimentation and can often be influenced by the environment. We tried to develop a lab-based assay to characterize and verify the non-specific resistance using a transformed pathogen isolate carrying a green-fluorescent-protein (GFP) gene and droplet digital PCR (ddPCR) to track the pathogen spread and quantify the infection development. Wow, the technologies are amazing! The green fluorescence followed the moment of pathogen hyphae vividly in canola tissues, showing that some varieties may prevent the pathogen in infected cotyledons from reaching the stem before the leaf drops off. The ddPCR, in combination with the GFP labelling, identified the varieties that reduced the infection development in stem tissues despite the establishment of pathogen there. Using theses technologies, we now can screen and characterize quantitative resistance to blackleg in our canola germplasm more efficiently under controlled environment conditions.

—Gary Peng, research scientist, Agriculture and Agri-Food Canada, Saskatoon

DEVELOPMENT OF CANOLA CULTIVAR BLACKLEG RESISTANCE GROUPS: FEASIBILITY EVALUATION

PRINCIPAL INVESTIGATOR: Ralph Lange, Alberta Innovates
FUNDING: Alberta Canola, WGRF, ACIDF
PURPOSE: The objective is to determine if Canadian canola cultivars can be organized into resistance groups that would allow producers to choose cultivars with different blackleg resistance genes from those previously seeded.
PROGRESS: Initial testing of a small set of commercial cultivars showed that cultivars appeared to divide into two groups on the basis of presence of the Rlm3 resistance gene. On the basis of this preliminary grouping, researchers identified fields in Alberta where the seeded cultivar was known and compared field and controlled-environment performance against blackleg. These data further supported a resistance group model with two cultivar groups. Next, they evaluated cultivars against field-collected residues from a wider range of collection locations. They also applied a new testing technique that corrects for different levels of inoculum in different residue samples and also allows seedlings and rosette-stage plants to be inoculated. When looking at wound-inoculated cotyledons, they found that all cultivars were equally, and highly susceptible to blackleg. This was true regardless of the source of the *L. maculans* population. When cotyledon-inoculated plants were allowed to reach maturity, or when plants were spray-inoculated, differences among cultivars and variability among locations were observed. Researchers will complete analysis of results before making any revisions to the putative resistance groups.

SUPPORTING CONTINUED DEVELOPMENT OF CLUBROOT-RESISTANT CANOLA AND EARLY DETECTION OF CLUBROOT OUTBREAKS.

PRINCIPAL INVESTIGATOR: Michael Harding, AF
FUNDING: Alberta Canola, WGRF, ACIDF
PURPOSE: The objectives are to evaluate canola lines and cultivars for their various levels of resistance to *P. brassicae* (pathotype 5) and evaluate the efficacy of soil amendments and treatments for clubroot management. Additionally, the project enhances clubroot surveillance in southern Alberta in attempts to rapidly identify any new introductions or outbreaks of clubroot south of Highway 1.

PROGRESS: Year 4 of 4. Since 2013, dozens of new lines/cultivars have been screened for resistance at this disease nursery and a number of them have shown strong resistance to pathotype 5. Soil amendments and chemical fumigants have demonstrated limited ability to provide significant or consistent control of clubroot in areas with high resting-spore populations. Clubroot surveillance has not discovered any new infestations south of Highway 1.

IMPROVING SCLEROTINIA DISEASE CONTROL IN EDIBLE BEANS AND CANOLA

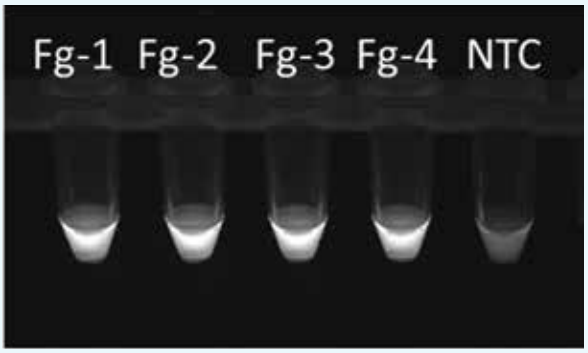
PRINCIPAL INVESTIGATOR: Michael Harding, AF
FUNDING: Alberta Canola, WGRF, APG
PURPOSE: The objectives were to look for synergistic relationships between foliar-applied micronutrients and fungicides when tank mixed, and to evaluate the efficacies of "resistance-priming" chemicals as seed treatments to improve sclerotinia management.
PROGRESS: Year 4 of 4. A few synergistic combinations appeared in some years, however none of the tank-mixed treatments were consistent in all years tested. One of the resistance-priming chemicals applied to seed has shown significant white mould reduction in two of three years in dry bean but none of these compounds have shown any significant effect on stem rot in canola. Dry conditions in 2015 resulted in very little sclerotinia disease pressure, making it difficult to evaluate these seed and foliar-applied treatments, but 2016 provided ideal conditions for sclerotinia development. Results from 2016 and a final report for the project will be submitted in 2017.

Right: Research to improve clubroot surveillance and genetic resistance may help to prevent this level of infection, but scouting remains important.
Credit: Amanda Wuchner

New projects for the PSI Lab

MANITOBA'S PEST SURVEILLANCE INITIATIVES (PSI) LAB HAS ADDED NEW PROJECTS. THEY INCLUDE:

- **Clubroot of canola pathotype characterization.** The lab is culturing isolates from the samples it collected over the past year. This is timely as seed companies are marketing 'resistant to pathotype YY' varieties but growers and extension workers do not know what is present in the Manitoba environment. The lab is exploring tools that would eventually move it from plant-based to DNA-based assays.
- **PSI is collecting blackleg** samples to build its isolate base and eventual assay development.
- **Field-proofing loop mediated isothermal amplification (LAMP) assays** for in-field assessment of several pathogens. LAMP could provide a quick "yes/no" for presence of the pathogen of interest. Only positive samples would go to the lab for quantification. Initial assays will focus on clubroot, blackleg and aster yellows. This is in cooperation with AAFC in Saskatoon
- **Verticillium in canola.** PSI is working with MCGA, Richardson International and the University of Manitoba on the development and validation of a DNA assay for *V. longisporum*. The lab will offer testing to growers once the method is validated and once the regulated status of the pathogen allows us to test beyond the research environment.



PSI is field testing the relatively simple LAMP technique for the amplification of DNA. Tubes that glow indicate a positive result for presence of the target pathogen in a sample. LAMP tests could provide a quick yes/no in the field, so only positive samples would be brought in for quantification with PCR.

Credit: Tim Dumonceaux, AAFC

- **Glyphosate resistant (GR) kochia DNA assay.** A pilot project from last fall indicated GR resistance in pockets around southern Manitoba. This year, the lab is expanding the pilot to collect and characterize more samples. PSI could also expand into other DNA-based assays for herbicide class and weed species.

Manitoba Canola Growers Association, which funds the PSI Lab, received support from GF2 to expand the lab's services.

HARVEST MANAGEMENT

DETERMINING BEST PRACTICES FOR SUMMER STORAGE OF CANOLA

PRINCIPAL INVESTIGATOR: Joy Agnew, PAMI
FUNDING: SaskCanola, MCGA
PURPOSE: The aim is to determine if aeration or turning of canola in the spring results in more stable storage conditions throughout the summer than leaving it alone. Data collected in 2016 was used to validate results collected in 2014.
PROGRESS: In 2016, three 4,000-bu bins were continuously monitored, beginning on June 2 and wrapping up on August 19. One bin was left alone, one bin was aerated in mid-June and one bin was turned on June 2. The average moisture content of the stored canola was nine per cent (compared to the 6.5 per cent canola monitored in 2014). Results indicated that no significant condensation or moisture migration occurred in any of the bins, but the baseline (control) bin had the most stable conditions throughout the summer and the coolest core (4°C) at the end of the monitoring period.

CANOLA DIRECT-CUT HARVEST SYSTEMS

PRINCIPAL INVESTIGATOR: Nathan Gregg, PAMI
FUNDING: SaskCanola, ADF, WGRF, PAMI
PURPOSE: The purpose is to compare yield, seed quality, header shatter loss and environmental shatter loss for draper, rigid and extendable cutterbar headers as well as a swath-based system. The three-year study has three test locations: Indian Head, Swift Current and Humboldt.
PROGRESS: Year 3 of 3. The first two years of data indicate a slight loss-reduction advantage with the extendable cutterbar header relative to other direct-cut headers tested, and marginal differences in yield, feeding, ground following and ease of operation. Other factors in loss, which include variety, field selection and crop condition, have shown a significant impact on header performance. Seed losses attributable to active knife dividers (rotary and vertical knives) were also compared to standard fixed dividers. These and other header-related comparisons continued through the fall of 2016, and full results will be released in early spring 2017.

PAMI's field crew prepares to put down loss pans as part of their straight-cut canola studies, which include desiccant and header projects.
Credit: Lorne Grieger

GENETICS

IDENTIFICATION AND GENETIC MAPPING OF *BRASSICA NAPUS* FOR RESISTANCE TO PATHOTYPE 5X OF *PLASMODIOPHORA BRASSICAE*

PRINCIPAL INVESTIGATOR: Fengqun Yu, AAFC Saskatoon
FUNDING: CARP, AAFC
PURPOSE: Year 2 of 4. The project aims to identify new sources of *B. napus* for resistance to pathotype 5x, map clubroot resistance (CR) genes and develop markers tightly linked to the genes for use in marker-assisted breeding. It will then work to facilitate the rapid incorporation of multiple CR genes into elite canola breeding lines.
PROGRESS: A total of 845 *B. napus* lines were tested for resistance to pathotype 5x. Thirty-one lines with a disease severity index of less than 20 per cent were obtained. A set of 189 lines were sequenced using next generation sequencing technology. Markers are being analyzed to understand the population structure and find sections of DNA associated with resistance to clubroot.

DEVELOPING NEAR-ISOGENIC *BRASSICA NAPUS* LINES FOR DIFFERENTIATING PATHOTYPES OF *PLASMODIOPHORA BRASSICAE*

PRINCIPAL INVESTIGATOR: Fengqun Yu, AAFC Saskatoon
FUNDING: WGRF, ADF, SaskCanola
PURPOSE: Year 3 of 4. This project aims to develop *B. napus* lines each with a single unique clubroot resistance gene from Brassica vegetable species. These lines could be used for differentiating pathotypes of *P. brassicae* and rapid incorporation into canola variety development programs.
PROGRESS: Researchers have obtained BC2, BC3 and BC4 introgressed *B. napus* lines containing eight single clubroot resistance genes.

MOLECULAR CYTOGENICS OF BLACKLEG RESISTANCE IN THE *BRASSICA* B-GENOME AND INTROGRESSION OF RESISTANCE INTO *B. NAPUS* THROUGH RECURRENT BACKCROSSING

PRINCIPAL INVESTIGATOR: Habibur Rahman, University of Alberta
FUNDING: ACIDF, Alberta Canola
PURPOSE: The aim is to identify, using molecular cytogenetic study, the B-genome chromosomes of *Brassica carinata* carrying cotyledon and adult plant resistance to blackleg PG4-type isolate. The purpose is to identify resistance for introgression into *B. napus*.
PROGRESS: Research has identified one B-genome chromosome of *B. carinata* carrying resistance to a PG2-type isolate. However, this resistance gene alone does not confer resistance to the more virulent isolates, despite *B. carinata* showing resistance to these isolates. This indicates that more than one gene in *B. carinata* may be involved in the control of resistance to these isolates. Identification of additional genes in *B. carinata* for introgression into *B. napus* is in progress.

COMPARATIVE GENOMICS OF APOMICTIC PLANTS: ADVANCING NOVEL TOOLS FOR NICHE BREEDING

PRINCIPAL INVESTIGATOR: Tim Sharbel, Global Institute for Food Security
FUNDING: SaskCanola, ADF, CGDP, GIFS
PURPOSE: The aim is to generate a high-quality genome of Boechera, a wild *Brassicaceae* that can reproduce apomictically. Apomictic plants produce seeds without pollen (male) fertilization, and thus all offspring are genetic clones of the mother. The ability to introduce apomixis into canola would enable single generation hybrids to be produced and fixed genetically, regardless of the genetic complexity behind the phenotypic traits of interest. This could provide the opportunity to produce more genetically-variable canola lines with ease, thereby enabling breeders to exploit niche breeding and rapidly breed varieties adapted to changing environmental conditions.
PROGRESS: Researchers have submitted high-quality DNA to NRGene for genome sequencing and assembly. They are micro-dissecting developing ovules from different apomictic genotypes for comparative genomics analyses.

Tim Sharbel is working on the genome of boechera (shown), a wild Brassicaceae that can produce seeds without pollen (male) fertilization. This apomixis trait could be valuable for canola seed production.

INTROGRESSION OF DISEASE RESISTANCE FROM *BRASSICA NIGRA* INTO CANOLA USING NEW-TYPE *BRASSICA NAPUS*

PRINCIPAL INVESTIGATOR: Fengqun Yu, AAFC Saskatoon
FUNDING: ADF, Alberta Canola
PURPOSE: Year 2 of 4. The project aims to identify clubroot resistance and blackleg resistance genes in *B. nigra* and transfer the genes into canola.
PROGRESS: Researchers have genetically mapped a clubroot resistance gene in *B. nigra* and obtained BC1 progenies from interspecific crosses between *B. napus* and the *B. nigra* line. Both clubroot and blackleg resistances in the BC1 populations have been confirmed.

ENHANCING THE DURABILITY OF CLUBROOT RESISTANCE WITH MULTIPLE RESISTANCE GENES

PRINCIPAL INVESTIGATORS: Tao Song and Gary Peng, AAFC Saskatoon
FUNDING: SaskCanola, ADF
PURPOSE: For optimal deployment of new clubroot-resistant (CR) genes, this study hopes to assess whether the better method is to pyramid them into a single hybrid or rotate among CR genes. Researchers also want to know whether longer crop rotations, which help reduce pathogen inoculum in the soil, can benefit resistance durability when multiple CR genes are used. The aim is also to identify potential downsides, if any, for using CR genes under low pathogen pressure background such as most fields in Saskatchewan and Manitoba.
PROGRESS: Initially, the work has been focused on the assessment of 19 single and multi-gene hybrids against different populations of the pathotype 5x identified in Alberta. There is differentiation of resistance depending on the population, but two of the multi-gene combinations seemed provide substantial resistance relative to the control 45H29.

DEVELOPMENT OF A GERMPLASM RESOURCE TO DISSECT COMPLEX TRAITS IN *BRASSICA NAPUS*

PRINCIPAL INVESTIGATOR: Isobel Parkin, AAFC Saskatoon/University of Saskatchewan
FUNDING: SaskCanola, ADF, Alberta Canola, CGDP and industry partners
PURPOSE: This study aims to broaden the genetic pool available for canola breeding, capturing diversity from all available collections of annual *B. napus*. The project will also provide the tools for rapidly introducing valuable variation into cultivar development.
PROGRESS: Highly diverse founder lines were selected and the final lines have been developed for a structured population, which will be used to characterize traits of interest and quickly move novel beneficial alleles into breeding lines. Extensive phenotyping of the founder lines has been completed in the field and genotyping is ongoing to develop marker resources to facilitate the transfer of identified valuable variation for target traits.

How to run a field-scale trial

Many growers want to run their own trials to test new products or techniques. Follow these Ultimate Canola Challenge protocols to set up trials that follow scientific principles and provide accurate results that you can implement.

STEP 1: SET AN OBJECTIVE

For example, you may want to determine whether the addition of a specific input provides an economic increase in yield or quality. That would be a one-variable trial comparing standard practices – the check – to standard practices plus this one additional input or technique.

Another objective could be to see whether a new product or technique is best applied at different times or in different formulations. In this case, this would require a three-part trial: the two tests plus a check strip of standard practices to provide a baseline for comparisons.

Including a check strip, which is basically your standard best management practices, in the trial ensures that differences in crop performance in the treatments are actually due to the treatment differences and not naturally-occurring variation that usually occurs in any field.

STEP 2: CAREFULLY CHOOSE A LOCATION

The selected field should be as uniform as possible in topography and soil. Soil sample the trial area, including for micronutrients if you're doing a micronutrient trial.

Prepare to replicate the strips at least four times across the trial area. (See the diagram.)

STEP 3: SEED THE TRIAL

If you are testing a product not related to seed or seeding practices, use the same variety for all treatments, and seed at the same depth and speed. Make sure each strip in the trial, including the checks, are wider than the swather or combine straight-cut header. This will reduce edge-effect when harvesting.

STEP 4: MANAGE THROUGHOUT THE SEASON

Follow best practices for weed, disease and insect control and apply the same treatments across all strips. Scouting the trial weekly will help make informed crop management decisions and allow you to observe any visual differences between the treatment and check. Spray perpendicular to the direction of seeding to leave the same tire tracks in each trial.

STEP 5: HARVEST

When swathing or straight-cutting, leave a four-foot (or more) buffer between the products where they meet in the field to be sure that a "true" test is being done to compensate for possible mixing of the products along the split line. This is why seeding strips wider than the swather is important.

After swathing each treatment, the rest of the field can be swathed. Make sure the swather passes that represent the trial have been marked.

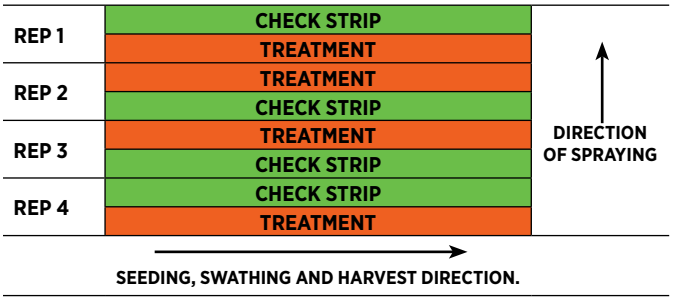
When combining, use a weigh wagon to get the most accurate yield data. Some local agronomists or retail outlets may have weigh wagons for rent. Calibrate the wagon prior to harvest. Start with an empty hopper and prime it using surrounding canola, then empty it. Harvest and weigh each strip separately.

Measure the exact length and width of the strips. If there were noticeable differences in maturity between strips, keep a grain sample in a zip-lock bag from each strip and measure moisture content later.

When calculating yield, remember...

1. To get total bushels per strip = Take weigh wagon weight in pounds and divide by 50.
2. To get total acres per strip = Multiply strip length in feet by total width in feet and divide by 43,560 (the square feet in an acre).

Yield (bu./ac.) = Total bushels (1) divided by total acres harvested (2).



STEP 6: KEEP DETAILED RECORDS

Keep all notes with regard to variety, seeding date, rate, fertilizer and conditions. Record weather events, such as hail, frost, excessive heat, excessive humidity and excessive rain.

For more specific protocols on how to set up a foliar-product trial or a nitrogen-rate trial, visit the UCC website at www.canolacouncil.org/crop-production/ultimate-canola-challenge/. The site also has a "Note Collection File" to help keep accurate records throughout the season.

Set up trials like this with four replicates each of the treatment and check strips.

Use a weigh wagon to capture accurate yield measurements for each strip.

MOMENT

While we grapple with the potential for swede midge damage in canola on the Prairies, I think back to the 1990s wheat midge outbreak. Back then, I asked our geographic information system (GIS) guru to prepare two maps of the annual wheat midge survey data. The first showed total midge population distribution and density in Saskatchewan. The second showed viable midge population distribution and density (i.e. without those midge larvae that were parasitized). I was amazed at the difference in the two maps. It showed the impact of the natural enemies on reducing the crop risk due to wheat midge. So we assessed this wheat midge/parasitoid trend over a 10-year period and were able to estimate that farmers in Saskatchewan had saved a total of about $250 million in insecticide costs. We published a paper on the topic. The findings paid tribute to the research that resulted in discovering the parasitoid and developing mitigation tools for their conservation, as well as to producers for their commitment to economic thresholds, spraying at the right time, etc.

—Owen Olfert, research scientist, Agriculture and Agri-Food Canada, Saskatoon

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