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CANOLA digest

Science 2015

Grower-funded research results

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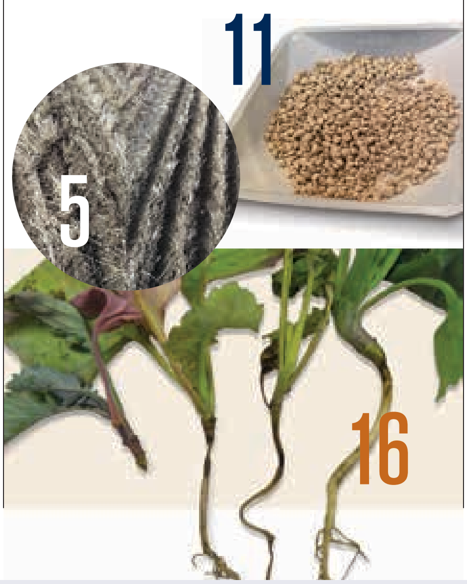

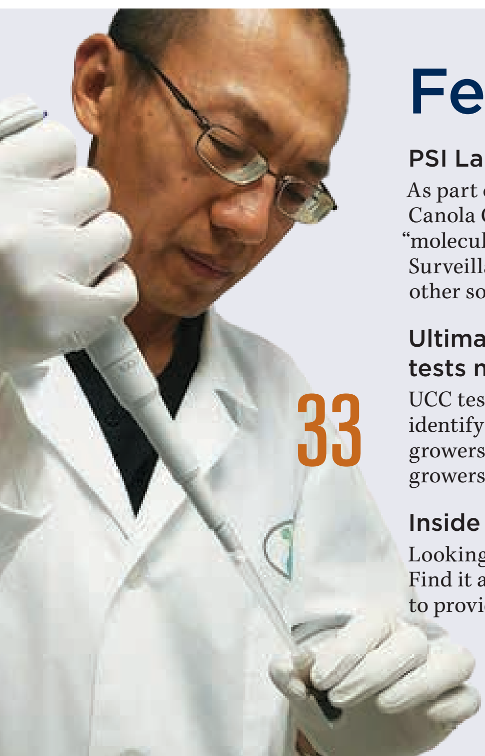

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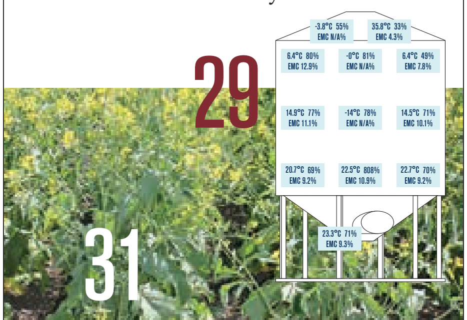

canolacouncil

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An essential investment

Canola growers need continued advanced research to address new threats to productivity, such as clubroot and swede midge, and test newer farming methods, such as straight combining, variable rate fertilizer application and drone-driven imaging. That is why provincial canola grower organizations invest in research.

This 2015 *Canola Digest* Science Edition is all about this investment, leading off with one-page highlights from 24 completed grower-funded studies. Findings from these studies will help growers target a profitable plant population, improve harvest results and make better decisions on insect, disease and weed management. This edition also features articles on the Ultimate Canola Challenge, Canola Research Hub, Manitoba's Pest Surveillance Initiative and ongoing Growing Forward 2 and grower-funded studies.

Since 1991, Saskatchewan Canola Development Commission (SaskCanola) has funded over 315 research projects, and its 2014-15 research budget was $1.8 million. Alberta Canola Producers Commission (ACPC) budgets about $1.8 million per year for research, which is about 30 percent of its budget. Manitoba Canola Growers Association (MCGA) allocated $384,000 of the past year's budget to research.

When growers invest directly in research through SaskCanola, ACPC and MCGA, they send a clear signal of their research priorities to other research funders — funders who want to fund projects that align with grower needs. These leveraged funds allow projects to cover more site years and produce more valuable results.

Wayne Truman
SaskCanola research chair
Director from Redvers, SK

Daryl Tuck
ACPC research chair
Director from Vegreville, AB

Chuck Fossay
MCGA research chair
Director from Starbuck, MB

The three provincial organizations also improve their return on research dollars through a collaborative partnership called the Canola Agronomic Research Program (CARP). Organization staff Errin Tollefson with SaskCanola, Ward Toma with ACPC and Bill Ross with MCGA lead the research portfolios and they work along with grower directors and the Canola Council of Canada's crop production research committee to review proposals put before CARP and choose which to fund based on grower research priorities. Growers who want to help guide research priorities and advise on decisions are welcome to attend regional meetings of our organizations or run for a director position.

With funding decisions made and research completed, the next step is to share research with growers who will put these discoveries into action. The Canola Council of Canada leads many of these efforts, delivering results through its agronomy team and through the Canola Research Hub, Canola Watch, the Canola Encyclopedia and the Canola Diagnostic Tool. This special issue of *Canola Digest* is another tool to share results.

Through all of these steps, the focus is always on how to improve grower profitability and sustainability while minding the needs of end-use customers.

Research is an essential ongoing investment because pest management and agronomic best practices continue to change and shift. And this ongoing investment of levy dollars continues to provide a strong return. We expect growers will find in this magazine many ideas that can improve their operations — some in small ways, some significantly. Through this discovery, growers will see why our own Prairie-grown third-party research is so valuable.

Sincerely,
Wayne Truman
Daryl Tuck
Chuck Fossay

1.1 Seeding between rows improves stand establishment

KEY PRACTICE: Seeding into bare soil between the previous year's stubble rows will improve canola germination and plant establishment without increasing seed costs.

PROJECT TITLE, LEAD RESEARCHER: "Seeding Between the Lines: evaluating the potential of inter-row seeding for canola in southern Alberta," 2011-14, Ken Coles, Farming Smarter

GROWER ORGANIZATION FUNDER: ACPC

Highly accurate GPS guidance and automated steering have given producers the ability to seed between the stubble rows from previous crops. This practice may allow for improved canola emergence due to more accurate seed placement, improved seed to soil contact, improved micro-climate, higher soil temperatures and seedling protection from more standing stubble.

In previous studies, Farming Smarter found that seeding on-row significantly reduced plant stand establishment in canola compared to seeding between the row and check plots. Also, canola yield was significantly higher with Pillar Lasers disc/hoe openers compared to Stealth paired row, and canola yield was not affected by row placement.

This study continued some of this work, comparing two openers: Pillar Lasers disc and Stealth paired row hoe; and three seed row options: between the stubble (inter-row), directly on the stubble (on-row) and a control with no attempt to align with stubble.

The field trial was set up on large-size plots (approximately 50m x 1.93m) in the Dark Brown Soil Zone near Lethbridge, AB. The study used glyphosate-tolerant hybrids seeded at 5 lb./ac. and 1/2″ into no-till cereal stubble. Soil moisture was excellent each year.

Three years were taken to yield — 2011, 2012 and 2014 (2013 was lost to hail and flooding). Data was collected on the plant emergence and final plant stands, weed presence and abundance, soil temperatures, canopy closure, stubble heights and yield.

Results from these three years validated Farming Smarter's previous findings that seeding on-row significantly reduced plant stand establishment in canola compared to seeding between the row and check plots.

The results showed that, on the average, seeding canola crop between stubble rows with Pillar Lasers disc hoe type seeding row openers produced the highest canola plant stand count and, therefore, would most likely benefit producers in establishing the healthiest and most profitable canola crop.

For this study, canola seeded with disc hoe openers produced significantly higher yields than the paired-row openers, especially when used for seeding between the stubble rows of the previous crop.

Conclusion

Based on the results, Farming Smarter concludes that producers with the ability to inter-row seed could adopt the practice to enhance plant stands and protect against yield loss. It would also allow for better germination without increasing seed costs. Future studies should include reduced seeding rates.

Does this investment increase profits? Advanced GPS signals such as real-time kinematic (RTK) and Omnistar give producers the precision accuracy to seed within 2.5 centimetres of their intended target. However the cost to upgrade from a basic WAAS signal is prohibitive without a proven return on investment. ●

Treatment means for the canola inter-row seeding

STUDY YEAR	TREATMENT COMBINATION	PLANT COUNT per m^2	CANOLA YIELD (lb./ac.)
2011	hoe-InterRow	134	1394
	hoe-OnRow	111	1253
	hoe-Control	126	1503
	disc-InterRow	132	1724
	disc-OnRow	123	1570
	disc-Control	130	1603
2012	hoe-InterRow	83	1725
	hoe-OnRow	52	1756
	hoe-Control	88	1655
	disc-InterRow	90	1962
	disc-OnRow	55	1781
	disc-Control	95	1844
2013	hoe-InterRow	54	N/A
	hoe-OnRow	57	N/A
	hoe-Control	55	N/A
	disc-InterRow	62	N/A
	disc-OnRow	56	N/A
	disc-Control	52	N/A
2014	hoe-InterRow	90	1798
	hoe-OnRow	79	1932
	hoe-Control	79	1776
	disc-InterRow	82	1872
	disc-OnRow	89	1864
	disc-Control	75	1800

Seeding between the rows (right) puts the seed into bare soil, which improves plant establishment compared to on row (left) or random placement.

1.2 Long-term no-till improves early N availability

KEY PRACTICE: With longer periods under no-till management, soil organic matter may attain a new equilibrium level, and nitrogen (N) mineralization may increase. This can result in lower N requirements.

PROJECT TITLE, LEAD RESEARCHER: "Quantifying the economic and soil quality benefits of long-term no-till using a canola-spring wheat rotation," 2012-14, Christiane Catellier and Chris Holzapfel, Indian Head Agricultural Research Foundation

GROWER ORGANIZATION FUNDER: ACPC, SaskCanola

This study found no difference in yield for canola or wheat on short-term no-till (ST) versus long-term no-till (LT), but LT was better at meeting crop nitrogen needs early in the season.

This finding was demonstrated in wheat in particular, in which flag leaf nitrogen (N) was higher overall in LT plots than in ST plots. This was true for all N rates applied, which suggests that LT soils have a greater ability than ST soils to provide early growing season N requirements. Thus, ST fields would require a higher rate of applied N to maintain an equivalent level of uptake in the crop early in the growing season.

The research site was southeast of Indian Head, SK on two adjacent fields — one LT and one ST. Both were Oxbow Loam, a Thin Black soil. Spring wheat was seeded in each plot in the spring of 2012 and 2014, and canola was seeded in 2013. All plots were seeded using a Conserva-Pak plot drill with 12 openers spaced 31 centimetres apart and all fertilizer was side-banded at 2.5 centimetres to the side and 7.5 centimetres below the seed row.

Overall no-till benefit. The key to higher canola yields is a soil with higher fertility or a greater ability to recycle nutrients. Long-term no-till can provide this. Agriculture and Agri-Food Canada (AAFC) research by Guy Lafond showed that canola yields were 16 percent higher for 22 to 31 years of no-till than 0 to 9 years of no-till. Wheat yields were 14 percent higher for long-term no-till.

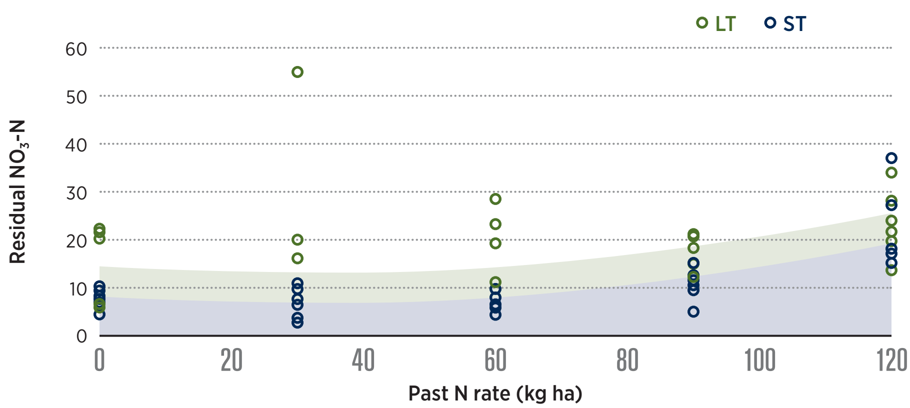
When no-till systems are initiated, surface soil organic matter (SOM) increases rapidly, increasing the N immobilization potential. During these first years, management is critical to minimize the potential for crop N deficiency. With longer periods under no-till management, the SOM may attain a new equilibrium level, and N mineralization may increase, resulting in lower N requirements. The length of time required under no-till to attain this level, or the "soil building" period, is not known, but it has important implications for efficient N fertility management in no-till systems.

Equilibrium reached. This three-year study did not see the same difference in yield for the two no-till durations as the Lafond study, suggesting that the equilibrium level may have been reached for these no-till fields. It's possible that after 10 years of no-till management, soil quality in ST fields is approaching that found in LT fields.

Residual nutrients and nutrient cycling are generally higher in LT than ST, as explained by the difference in flag leaf N response between the two fields. However it is likely that, later in the growing season, factors other than soil quality become more limiting to yield in both LT and ST fields equally.

Improving soil productivity faster. Given the yield benefits of no-till, the question remains whether growers can accelerate these benefits with higher N rates. In this study, the highest rate of applied N — 120 kg/ha (roughly 120 lb./ac.) — did not appear to be excessive for soil building purposes in either of the no-till histories. Further study is required to determine whether adding more N than is removed can improve soils more quickly without increasing environmental risks, and if soil-building using higher N rates is apparent in both long-term and short-term no-till soils. ●

Higher residual N in long-term no-till



Residual NO_3-N is higher with long-term no-till (green) than in short-term no-till (purple) after 10 years of varying applied N rates.

1.3 Yield drops with fewer than five plants per square foot

KEY PRACTICE: Analysis of 35 canola seeding rate studies shows that hybrid canola can achieve its yield potential when at least five plants per square foot survive to harvest.

PROJECT TITLE, LEAD RESEARCHER: "Determining the economic plant density in canola," 2009, Steve Shirtliffe, University of Saskatchewan
GROWER ORGANIZATION FUNDER: ACPC, SaskCanola

This meta-analysis of 35 previous canola seeding rate studies concluded that crops with fewer than 50 plants per square metre (about five per square foot) almost always have yield.

The objective of this study was to conduct a meta-analysis of canola seeding rate and plant population trials to determine the optimum seeding rate and plant population. A meta-analysis statistically combines the results of several studies to increase the inference of the results.

Summary data from 35 experiments was included in the dataset, which comprised 176 site-years of experiments. Categorical analysis comparing yields of approximately 3 kg/ha (roughly 3 lb./ac.) versus 5 kg/ha (roughly 5 lb./ac.) determined that canola seeded at 5 kg/ha had, on average, a four percent higher yield than canola seeded at 3 kg/ha. Site years with the greatest yield reduction were those in which the emergence of the 3 kg/ha treatment was lower than 45 plants per square metre (or about 4.5 per square foot).

A second analysis examined the effect of canola population density on yield. In general, hybrid canola reached its maximum yield at lower densities than open pollinated canola. Hybrid canola achieved 90 percent of its yield at 45 plants per square metre. Even plant populations of hybrid canola as low as 15 plants per square metre produced 70 percent of the maximum achievable yield.

But caution should be used when planting hybrid canola at very low densities because only five site-years in the study explored the effects of canola populations below 10 plants per square metre. Further research is needed.

When choosing a seeding rate, note that the yield loss from a lower seeding rate depends on field emergence. At high field emergence rates, and therefore higher canola populations, yield loss caused by reducing the seeding rate from 5 kg/ha down to 3 kg/ha is not great. For example, if the emergence of the canola at the lower rate is 80 plants per square metre, then this resulted in a predicted yield loss of only three percent. However when the emergence of canola is low, reducing seeding rates results in greater yield losses. Seed weight will also influence the plant population.

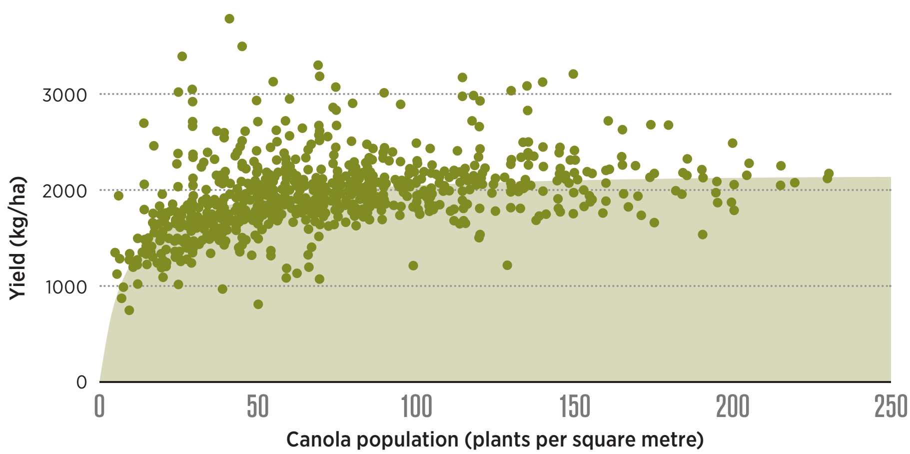
Conclusion

One could argue that when the seeding rate of canola was first determined the seed cost was incidental. This meant that producers could afford to seed at a much higher rate than was needed to maximize yield. Higher seed costs have put more emphasis on the seeding rate decision.

Hybrid canola appears to maintain a large proportion of its yield at low plant densities, although very few studies at the time of this meta-analysis had low canola densities. Economically it is more profitable to seed canola at lower rates when seed costs are high, and when the selling price and yield of canola is low. However reducing seeding rates increases the risk of lower plant populations, which can result in large yield losses. Emergence is often low in canola, so reducing seeding rates is a risky decision.

Canola farmers seeking to maximize returns should target populations greater than 50 plants per square metre (five per square foot). Plant populations lower than this will almost always have yield loss. ●

Hybrid canola yield drops with low plant populations (40 site-years)



1.4 Precise seed-to-seed spacing not necessary for canola

KEY PRACTICE: The key step in seed placement is to achieve the overall target population with some aspect of uniform distribution and depth. Precision tools to enhance seed spacing in the row provide little evident economic benefit.

PROJECT TITLE, LEAD RESEARCHER: "Seeding rates for precision seeded canola," 2012-14, Gazali Issah, Western Applied Research Corporation
GROWER ORGANIZATION FUNDER: SaskCanola

A general principle in nature is that uniform distribution within a plant community increases plant biomass and productivity compared with non-uniform distribution. This is because of the availability of resources such as light, soil water, and organic carbon. However, more uniform spacing of canola seeds in the seed row does not seem to improve seed survival or overall yield. The goal of seed placement is to achieve the overall target population with some aspect of uniform distribution. This study found that equipment used to provide more precise seed spacing down the row did not provide a benefit over a more basic metering system using the same openers.

The objectives of this experiment were: (1) to determine if the SeedMaster UltraPro canola roller produces more uniform canola seed placement than conventional rollers; and (2) to determine if more uniform plant density would allow growers to reduce canola seeding rates.

Treatments included seeding rates at 10, 20, 40, 80, 160 and 320 seeds per square metre applied with the traditional Valmar and SeedMaster's UltraPro roller. Field trials were conducted near Scott, Melfort, Redvers and Indian Head, SK in 2012, 2013 and 2014. The hybrid canola variety L150 was direct seeded at all locations in 2012 and 2013 on cereal stubble. In 2014 the variety L130 was seeded at all locations on cereal stubble. Seeding equipment varied between sites and row spacing ranged from 20 to 30 centimetres. Fertilizer was applied according to soil test recommendations, and herbicides and fungicides were applied as required. The plots were straight combined at Indian Head and Scott and swathed at Melfort.

Data collection included spring and fall seedling density and uniformity, days to maturity and seed yield.

Seeding rate was the only factor to significantly affect plant density, maturity and seed yield. There were generally no differences in plant density (in spring or fall), seed yield or maturity between the rollers at any level of seeding rate.

Average spring plant density was above the lower critical threshold of 50 plants per square metre with seeding rates ≥ 80 seeds per square metre.

At individual site years, there were generally no significant differences in spring or fall plant density between the two rollers at each level of seeding rate, except at the higher rates at some locations.

There appeared to be more uniform seedling distribution (on average) with the UltraPro roller than with the Valmar at seeding rates from 10 to 80 seeds per square metre, but this did not translate to improvements in seed yield. Differences in uniformity generally disappeared at fall plant population assessment, likely due to the self-thinning nature of canola.

Average distance between seedlings was similar for both rollers at each level of seeding rate. There was a general decrease in variability (standard deviation) within plants with increased seeding rates.

Because the rollers provided such similar results, this study did not provide a good comparison to achieve the second objective. For a full summary of this report, go to www.saskcanola.com and look for "research project reports" under the Research banner. ●

No clear yield advantage for more precise seed metering

ROLLER	SEEDING RATE (seeds m^2)	SPRING PLANT DENSITY (plants m^2)	DAYS TO MATURITY	SEED YIELD (kg ha)	FALL PLANT DENSITY (plants m^2)
Valmar	10	13^{e}	99.7^{a}	1873^{b}	11^{g}
Valmar	20	20^{de}	99.3^{a}	2292^{ab}	19^{fg}
Valmar	40	36^{de}	97.9^{abc}	2333^{a}	31^{efg}
Valmar	80	72^{cd}	96.6^{bcde}	2472^{a}	57^{cde}
Valmar	160	136^{b}	95.07^{de}	2464^{a}	91^{bc}
Valmar	320	212^{a}	94.4^{e}	2467^{a}	139^{a}
Ultra	10	12^{e}	99.4^{a}	1883^{b}	12^{g}
Ultra	20	17^{e}	98.8^{ab}	2154^{ab}	16^{fg}
Ultra	40	36^{de}	97.2^{abcd}	2421^{a}	32^{efg}
Ultra	80	60^{de}	97.2^{abcd}	2517^{a}	52^{def}
Ultra	160	118^{bc}	95.3^{cde}	2519^{a}	88^{bcd}
Ultra	320	193^{a}	94.5^{e}	2460^{a}	120^{ab}

Values that share a letter (a, b, c, d, e) are considered statistically equivalent.

1.5 Reseed when fewer than two plants per square foot

KEY PRACTICE: Reseeding is more likely to provide an economic benefit when the plant population is below 20 per square metre (two per square foot), when the timing is early June at the latest, and when growers reseed to the same or a similar hybrid.

PROJECT TITLE, LEAD RESEARCHER: "Response of canola to low plant populations and evaluation of reseeding options," 2010-12, Anne Kirk, Western Applied Research Corporation

GROWER ORGANIZATION FUNDER: SaskCanola

While hybrid canola has a high degree of phenotypic plasticity that allows it to compensate for low plant populations, growers need to know when the population is likely too low to compensate for the reduced plant stand. Reseeding is more likely to provide an economic benefit when: the population is below 20 plants per square metre (two per square foot); the timing is early June at the latest; and growers reseed the same or a similar hybrid.

Objectives of this project were to determine: (1) the plant population at which canola hybrids yield 90 percent of maximum; (2) the effect of plant population on maturity, seed size and green seed; (3) the minimum plant density at which reseeding would be recommended for hybrid canola; and (4) the risks with each reseeding option in terms of maturity, yield and quality.

Field experiments were conducted at Indian Head, Melfort, Saskatoon, Scott and Swift Current, SK in 2010, 2011 and 2012.

Hybrid canola was seeded at rates of 5, 10, 20, 40, 80, 150 and 300 seeds per square metre. Two varieties of *Brassica napus* (5440LL and short season 9350RR) and one variety of *Brassica rapa* were reseeded into existing stands of low density canola in early and mid-June. Results were based on the actual stand that emerged, not on the seeding rates.

Results and recommendations

Objective 1. In this study, hybrid canola was found to achieve 90 percent of maximum yield at 18 plants per square metre or around two per square foot. Precipitation was not limiting in any site year, except for Melfort in 2011. Adequate moisture improves yield compensation at low plant densities.

Objective 2. With site years combined, the study found that a reduction in plant density from 70 plants per square metre to 21 plants increased the flowering period by six days and maturity by three days. Extended maturity also resulted in higher harvest green seed counts at lower plant density.

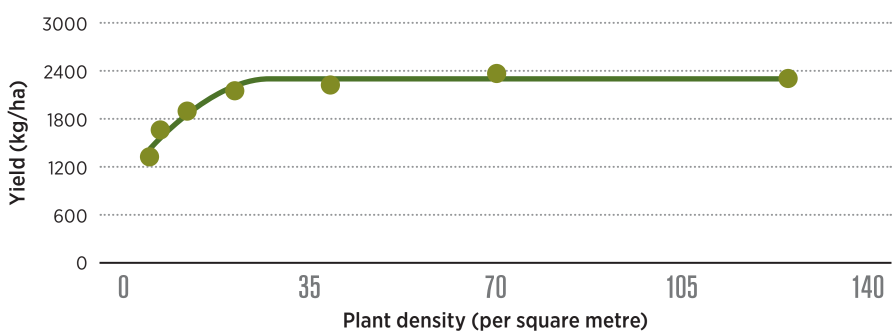
Objective 3. When faced with a plant stand of 20 plants per square metre or fewer, reseeding in early June to hybrid canola provides a yield and economic benefit compared to leaving the stand at low density. When faced with a low plant stand, reseeding to 5440LL in early June provided a yield benefit approximately half of the time. Reseeding to the shorter season 9350RR resulted in a significant yield increase in only three site years. Generally, reseeding in mid-June resulted in lower yield.

This study found no advantage to reseeding with *B. rapa*, even when reseeding was postponed to mid-June. If conditions do not allow for reseeding to occur in late May or early June, reseeding to canola is not recommended.

Objective 4. When reseeding is required, reseed as early as possible to reduce the risk of poor stand establishment and yield and quality reductions due to fall frost.

Do it right the first time. Even when the Saskatchewan crop insurance establishment benefit is included in the reseeding calculations, the early May treatment seeded at a traditional rate of 150 seeds per square metre resulted in a net return of $219 and $276 per hectare greater than 5440LL and 9350RR seeded in early June, respectively. For a full summary of this report, go to www.saskcanola.com and look for "research project reports" under the Research banner. ●

The plant population threshold



In this study, there was no significant change in yield when the plant density was above 28 plants per square metre (or around three per square foot). Ninety percent of maximum yield was achieved at 18 plants per square metre (two plants per square foot).

2.1 Annual soil tests improve nitrogen returns

KEY PRACTICE: Predicting how much nitrogen is reserved in the soil is difficult. Given its high cost in canola production, conducting an annual soil test on each field to determine appropriate rates is a good idea. The wild card is moisture supply throughout the growing season.

PROJECT TITLE, LEAD RESEARCHER: "Long-term effects of different soil test based fertilizer rates on crop production, contribution margin, and soil quality in the Peace region." 2009-12, Kabal Gill, Smoky Applied Research and Demonstration Association (SARDA)

GROWER ORGANIZATION FUNDER: ACPC, MCGA, SaskCanola

Nutrient carryover has a major effect on crop yield. In order to predict recommended fertilizer rates, an annual soil test is wise. Testing for nitrogen (N) levels helps, but this study did not show a benefit to testing for phosphorus (P), potassium (K) and sulphur (S) every year. Recommended rates for these were the same each year.

SARDA's objectives were to study the long-term effects of different soil-test based fertilizer rates on crop production, and whether soil testing can detect the effects of different fertilizer rates in previous years. Fertilizer rates were applied at zero, 60, 80, 100, 120 and 140 percent of the recommended rate through the four-year study. The same fertilizer rate was applied each year in a given plot to demonstrate the long-term effects. The study used a wheat-canola-barley-pea rotation, with all four crops grown every year. The study was done in the Peace River region with no tillage.

A composite soil test was taken each year for each plot at zero to six inch and six to 12 inch depths.

Spring and in-season moisture levels were much lower than normal in both 2009 and 2010. After the 2009 drought, there was no consistent effect on the recommended fertilizer rates for 2010. But after the 2010 drought, plots that had the higher N rates in 2009 and 2010 came back with a lower recommended N rate than plots that had lower N rates.

The first 60 percent of the recommended nutrient rate had the biggest improvement in yield in all years, and in the drought years there was little to no benefit to higher rates. This is as expected.

However, with adequate moisture in 2011 and 2012, canola yield continued to increase with higher rates. Maximum yields were observed at the 140 percent fertilizer rate for canola in 2011 and at the 120 percent rate in 2012.

Because canola seemed to use all the nitrogen available in 2011, regardless of rate, the recommended rates for 2012 were similar in all treatments. This was also true for P, K and S treatments.

In fact, residual nutrient levels after crop harvest showed no effect on the fertilizer rates with very similar amounts of P, K and S recommended in different treatments.

Conclusions

1. A soil test based fertilizer recommendation has to consider the odds of profit each year.

2. Soil tests were able to detect the effects of moisture supply levels and fertilizer rates applied on the residual nitrogen (N, P, K and S that could be available for the next crop).

3. Soil tests to show available N can be useful each year. When the previous crop has not used all available N (e.g. in a dry year) residual N in soil may result in lower N recommendations. Knowing this, growers may be able to trim N rate, make use of the soil N reserves, and increase profits in that year. Following a year with good moisture supply, residual N levels may be too low to achieve maximum yield using an average traditional rate, and growers may benefit from higher soil test based N application.

4. Soil tests for available P, K and S may not be required every year, given that their residual levels have less effect on recommendations, regardless of yield or moisture for the preceding crop. This is probably because they are applied at relatively small rates compared to much larger total soil reserves.

5. Greatest yield and economic benefit per unit of fertilizer came from the first 60 percent of the recommended fertilizer rates, but maximum yield was usually at higher rates.

6. The 100 percent rate seems to strike a balance. Soil tests, especially after very dry and wet years, appear to be a good strategy to optimize crop yields and profits. ●

Canola seed yield at different fertilizer rates

FERTILIZER RATE % of recommended	CANOLA (bu./ac.)			
	2009	2010	2011	2012
0	43.9	27.4	42.5	30.0
60	56.1	34.7	57.9	61.1
80	54.0	39.3	64.7	70.3
100	54.3	39.7	67.0	71.3
120	53.8	40.6	68.7	78.5
140	50.5	41.5	72.4	77.9
LSD	8.02	3.57	6.59	7.19
CV, %	8.46	5.3	5.7	6.1

Differences have to be greater than the LSD (least significant difference) to be statistically different. CV is coefficient of variation.

2.2 Manure-sourced P fertilizer increases crop safety

KEY PRACTICE: Struvite shows promise as a phosphorus-fertilizer source. This study shows that struvite recovered from hog manure can match yields compared to monoammonium phosphate and provides higher seed-placed safety.

PROJECT TITLE, LEAD RESEARCHER: "Can slow-release monoammonium phosphate and struvite improve phosphorus use efficiency and reduce seedling toxicity in canola?" Francis Zvomuya, University of Manitoba

GROWER ORGANIZATION FUNDER: ACPC, MCGA, SaskCanola

Struvite, a highly concentrated source of phosphorus removed from hog manure, can be used as a fertilizer to provide a slow-release source of phosphate that increases crop uptake compared to monoammonium phosphate (MAP). The slow release can allow for higher rates of seed-placed phosphate.

This study used greenhouse pot experiments to evaluate the effect of struvite on dry matter yield (which correlates to grain yield) and growth room experiments to assess canola seedling toxicity from seed-placed struvite. Experiments were repeated on a Dark Grey sand soil and a Black clay-loam soil. Struvite was compared to MAP and a polymer-coated slow-release MAP at two rates corresponding to 25 and 50 kg/ha of phosphate.

The pot experiments included two separate crop sequences in the same pots: canola-wheat-canola and wheat-canola-wheat. Pot studies found a significant response to all three phosphorus sources when compared to the check treatment with no phosphate, but only for the first crop in the rotation. Struvite produced dry matter canola yields similar to MAP in that first crop.

At the high rate (equivalent to 50 kg/ha of phosphate), struvite outyielded standard MAP in the second crop and both MAP sources in the third crop. Across soils and placement methods, doubling the rate of struvite and standard MAP improved dry matter yield, but rate of polymer-coated MAP did not have a significant effect on yield.

Seed-placed struvite and the polymer-coated MAP did not reduce seedling emergence when increased to the higher rate. The higher rate of standard MAP reduced seedling emergence in the Black clay loam soil by over 50 percent.

Results from this study indicate great potential for struvite from hog manure to be an effective phosphorus source for both canola and wheat. It could be a viable alternative to MAP, and it can be safely applied in the seed-row at higher rates than MAP.

Struvite also contains nitrogen, magnesium and smaller amounts of calcium and potash.

In addition to the agronomic benefits for canola producers, recovery of struvite from hog manure could be a sustainable way of recycling phosphate from livestock operations coming under increasing regulatory pressure to curb the application of high-phosphate manure. ●

Selected chemical properties of hog manure recovered struvite and commercial fertilizers used in the greenhouse bioassay

ANALYTE	STRUVITE	MAP	CMAP
	g kg (air-dry basis)		
Total N	57.7	110	110
Ammonium N	16	110	110
Total P (P_2O_5)	230	520	520
K_2O	4.4	—	—
Ca	5	—	—
Mg	64	—	—
pH	5.5	4.8	4.8
Moisture (%)	40	1.2	1.2

MAP is monoammonium phosphate (11-52-0) and CMAP is polymer-coated MAP.

3.1 Blackleg metabolites do not add risk to canola products for export

KEY PRACTICE: *L. maculans*, the fungal pathogen that causes blackleg in canola, can produce a mycotoxin called sirodesmin PL, but this study found none of it in Alberta canola samples.

PROJECT TITLE, LEAD RESEARCHER: "Evaluation of the toxicity of the secondary metabolites produced by *Leptosphaeria maculans*," 2012-14, Xiujie (Susie) Li, Alberta Innovates — Technology Futures

GROWER ORGANIZATION FUNDER: ACPC

Some strains of *Leptosphaeria maculans*, the fungal pathogen that causes blackleg in canola, produce the secondary metabolite sirodesmin PL. This metabolite is structurally related to gliotoxin, a mycotoxin (fungal toxin) that is a concern to the health of humans and farm animals. However, this study found no presence of sirodesmin PL in the end products of canola grown in Western Canada.

This two-year study under the Agriculture Funding Consortium, led by Xiujie (Susie) Li of Alberta Innovates, is the first to report on the toxicity of sirodesmin PL to animals and humans, and any levels to be found in canola. Although sirodesmin PL was found to have a toxicity comparable to that of gliotoxin, no sirodesmin PL was found in any of the canola seed, oil, and meal products in this study. This includes seed from tested fields, even where *L. maculans* contamination levels were very high.

The study also concluded that toxin production was not linked to disease virulence and is unlikely to increase over time, regardless of future blackleg resistance in canola. The low levels of both toxins produced and blackleg contamination in commercial canola seed would be contributing factors to these findings.

A total of 17 *L. maculans* isolates were collected from locations with differing virulence to investigate the relationship between virulence and toxicity. Canola seeds were collected from blackleg-infected fields on six farms in Alberta to evaluate sirodesmin PL contamination. Bin samples were also collected from four of these fields for reevaluation five months after harvest. Westar seeds were included as a blackleg-susceptible variety and clean canola seeds were used as a non-infected control.

Six oil samples were purchased from grocery stores or farmers' markets, and ADM (Lloydminster) provided one commercial sample each of canola meal and a 'super de-gummed oil'. All products tested showed zero content of sirodesmin PL throughout all aspects of testing — field survey, bin survey, lab seed samples and end-use oil and meal products.

Conclusion

These findings led to the conclusion that canola oil and meal products are currently free of sirodesmin PL and are safe for human consumption and to use as livestock feed.

- Sirodesmin PL is not produced by all the *L. maculans* strains. If a field is infected with *L. maculans*, it does not necessarily mean sirodesmin PL is present.
- Despite the presence of blackleg disease, zero sirodesmin PL was found in even the most infected field. ●

Blackleg disease severity and sirodesmin PL content in field survey and bin survey samples

VARIETY	LOCATION	BLACKLEG INFECTION RATE (%)	SIRODESMIN PL (ppb) IN FIELD SURVEY	SIRODESMIN PL (ppb) BIN SURVEY
1030	Vegreville	0.56	0	0
1033	Innisfree	1.0	0	0
1029	Minburn	0.69	0	0
1025	Vegreville	0.06	0	0
WESTAR	Vegreville	4.5	0	NA
1038	Wetaskiwin	2.0	0	NA
1044	Wetaskiwin	2.0	0	NA
DH12075	Greenhouse grown	0	0	NA

3.2 Fungicide strategies for blackleg

KEY PRACTICE: Consider early application of fungicide for blackleg management only when disease risk is high due to short crop rotations, erosion of cultivar resistance, or hail damage.

PROJECT TITLE, LEAD RESEARCHER: "Mitigating the risk of blackleg disease of canola using fungicide strategies," 2011-15, Gary Peng, Agriculture and Agri-Food Canada (AAFC); Dilantha Fernando, University of Manitoba; Ralph Lange, Alberta Innovates — Technology Futures
GROWER ORGANIZATION FUNDER: MCGA, SaskCanola

Blackleg is the most widespread fungal disease of canola in Western Canada and poses a serious threat to production. Selecting a rotation of R-rated varieties and maintaining a minimum break of two to three years between canola crops may protect against blackleg risk and allow effective long-term management of this disease.

Pathogen race shifts have been reported in recent years which may be linked to overuse of the same blackleg resistance genes in canola varieties. The trend towards tighter rotations due to market opportunities also increases the pathogen inoculum pressure. With increasing risk, prevalence and severity across the Prairies, growers have questions about which fungicides are most efficient, cost-effective and when they should be applied.

Gary Peng with AAFC led this four-year study to assess the benefits of fungicide treatments based on application timing and host resistance. A total of 17 site years were analyzed from five field sites in Vegreville, AB, Scott and Melfort, SK, and Brandon and Carman, MB.

In these tests, the blackleg-susceptible canola variety Westar was used to represent a worst-case scenario of resistance breakdown. Infection relied mostly on diseased canola residues in the plot areas. Several fungicides registered for blackleg control in canola were applied: Headline, Tilt, Quadris and Quilt Xcel. Application timings varied from: the 2 to 4 leaf stage, split application at the 2 to 4 leaf and prior to bolting, or an application of Headline alone just prior to bolting. These results were compared to unsprayed plots as a control.

Fungicide benefits susceptible varieties

VARIETY	TREATMENT	DIS INCIDENCE (%)	DIS SEVERITY (0-5)	GRAIN YIELD (bu./ac.)
WESTAR (S)	Non-treated control	54.1	1.5	26.4
	Headline (2-4 leaf)	42.8*	0.9*	30.4*
	Quadris (2-4 leaf)	41.8*	0.8*	30.2*
	Tilt (2-4 leaf)	57.0	1.5	27.1
	Quilt (2-4 leaf)	47.2	1.1*	30.5*
	Headline (rosette)	49.4	1.3	28.1
	Tilt + Headline**	46.8*	1.2*	29.4*
	Headline + Tilt**	41.6*	0.9*	30.5*
43E01 (MR)	Non-treated control	53.2	1.3	37.3
	Headline (2-4 leaf)	40.3*	0.8*	37.5
45H29 (R)	Non-treated control	44.1	0.9	49.3
	Headline (2-4 leaf)	35.9*	0.6*	50.2

* Means are significanly different from the non-treated control of the same cultivar (P ≤ 0.05, Dunnett's Test).
**Split applications at the 2-4 leaf and prior to bolting stages, respectively.

Effect of fungicide treatment on blackleg and grain yield of canola with varying levels of disease resistance over 17 site-years between 2011 and 2014.

Over all site years, all but two of these treatments (Tilt applied at the 2 to 4 leaf stage or Headline alone prior to bolting) reduced blackleg and increased seed yield in the susceptible variety.

This was also the trend when analyzing the eight site years where infection occurred at moderate to high levels (average disease severity of greater than 1.0). However, in the nine site years with low levels of the disease severity, these differences were not evident.

Disease incidence and severity on the moderately resistant and resistant canola varieties in this study were of similar patterns as those of the susceptible variety, with or without fungicide treatment. However, seed yield from the MR and R tests was higher and did not significantly benefit from any fungicide application, producing more seed than Westar with or without a fungicide treatment.

Recommendations

- Genetic resistance and longer crop rotations continue to be the main course of action for blackleg management in Western Canada.

continued on next page

FUNGICIDE STRATEGIES FOR BLACKLEG

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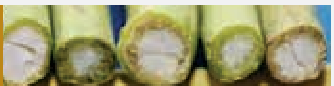
- Scout crops for accurate identification of the proportion of plants affected by the disease (shortly after swathing) to estimate economic impact based on disease incidence and severity (see below) for blackleg management planning.
- Strobilurin fungicide application at the 2 to 4 leaf stage may be considered only when the variety is susceptible (short crop rotations or after hail damage) and disease risk is high. Multiple applications are generally not required for maximum efficacy.
- Don't use blackleg fungicide if varieties are resistant in your field. •

Blackleg field rating scale

Score blackleg for each clipped tap root using the following scale

0

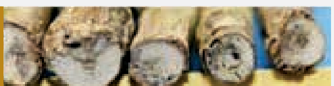


No diseased tissue visible in the cross section.

1

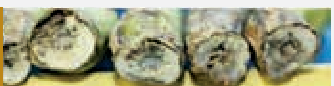
Diseased tissue occupies 25% or less of cross section.

2



Diseased tissue occupies 26-50% of cross section.

3

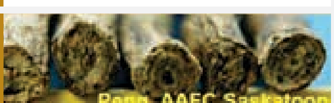


Diseased tissue occupies 51-75% of cross section.

4

Diseased tissue occupies 75% or more of cross section.

5



Diseased tissue occupies 100% of cross section with significant constriction of affected tissues; tissues dry and brittle; plant dead.

INTEGRATED PEST MANAGEMENT

3.3

Diversity key to blackleg resistance stewardship

KEY PRACTICE: Diversity of cultivar resistance, crop rotation and fungicide usage can prevent both infection and breakdown of blackleg resistance.

PROJECT TITLE, LEAD RESEARCHER: "Blackleg Resistance Stewardship: Improving our management of host resistance," 2010-14, Dilantha Fernando, University of Manitoba

GROWER ORGANIZATION FUNDER: ACPC, MCGA, SaskCanola

Leptosphaeria maculans, the fungal pathogen that causes blackleg in canola, is a limiting factor of canola production in Western Canada. Although resistant cultivars are widely used to control this disease, the breakdown of canola's genetic resistance, the emergence of new blackleg races, market restrictions, and economic losses are increasing and important concerns to growers.

The objectives of this study, led by Dilantha Fernando, University of Manitoba Department of Plant Science, were to:

- understand pathogen races on-farm and by region;
- identify blackleg-resistant genes in commercial cultivars and strategies to reduce resistance breakdown; and
- initiate a new blackleg management stewardship program that would optimize grower success with moderately-resistant and resistant cultivars through rotations designed to maintain genetic resistance.

Between 2010 and 2012, a total of 930 *L. maculans* isolates were collected from field stubble across the Prairies and examined for the presence of 10 different avirulence genes. When these genes are absent, there is the possibility of infection on the corresponding blackleg resistance genes in the host. Summary of these results showed that, on average, three of the avirulence genes were absent in more than 90 percent of the pathogen population (*AvrLm3*, *AvrLm9* and *AvrLepR2*), but two others (*AvrLm6* and *AvrLm7*) were present in more than 85 percent of the population. Blackleg races are composed of combinations of these avirulence genes. In 2010-11, 55 races were detected with each isolate

carrying an average of 4.18 out of the 10 genes examined.

Evaluation of 206 Canadian canola lines found the *Rlm3* gene to be present in the majority, but all other known *Rlm* genes were rarely detected. *Rlm3* corresponds with the *AvrLm3* avirulent gene, which was among the rarest to be found in all tested pathogen isolates. The low frequency of the *AvrLm3* gene coupled with the overuse of *Rlm3* single resistance gene to blackleg in planted Canadian canola varieties is the probable cause of current resistance breakdown in many growing regions.

Among the canola varieties examined, 85 percent showed seedling resistance and eight known *Rlm* genes were found to be present. *Rlm3*, the most common, was found in 57 percent of the samples. Single-gene resistance was found in 36 percent of these canola samples with the *Rlm3* gene again being the clear majority at 92 percent of that subset. All other *Rlm* traits combined were found in only 14 percent of the samples, and a surprising 43 percent showed no *Rlm* genes at all.

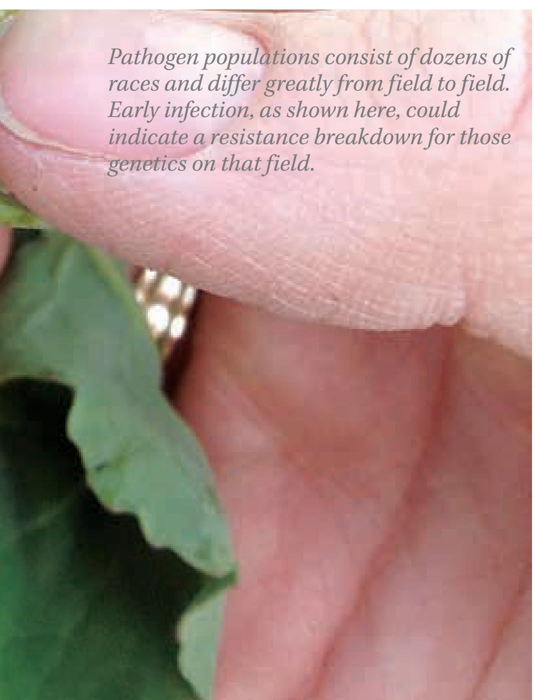
Among the tested *L. maculans* isolates, only 8.15 percent carried the *AvrLm3* allele, which would prove to be the lowest risk of blackleg infection to canola cultivars carrying this most common *Rlm3* gene. More than half of the isolates carried either four or five of the 10 avirulent alleles and a further 11 percent carried three of them.

Indications from these findings are that *L. maculans* diversity is not evenly distributed in Western Canada. Pathogen populations consist of dozens of races and differ greatly from field to field.

Conclusion

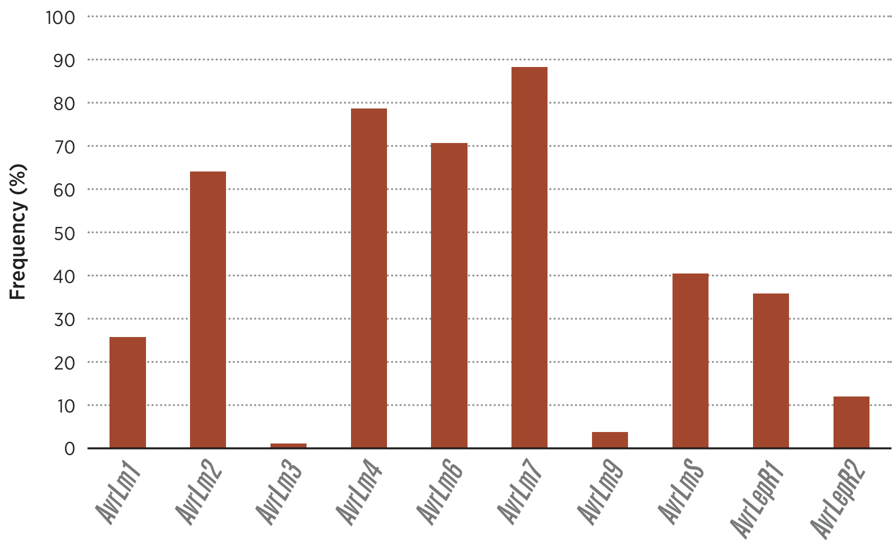
Blackleg management recommendations based on this study are:

- Selecting canola varieties with genetic resistance is the best strategy to control blackleg.
- Frequent monitoring of the *Avr* gene frequency in fungal populations and presence of *Rlm* genes in canola varieties is critical to disease control.
- Diversification of blackleg resistance in commercial cultivars will allow strategies for disease control such as rotation of diverse *Rlm* genes.
- The results of this and earlier studies have shown that selection pressure against some *Rlm* genes may alter the frequency of avirulent genes in *L. maculans*. This could be exploited for future deployment of *Rlm* traits. ●



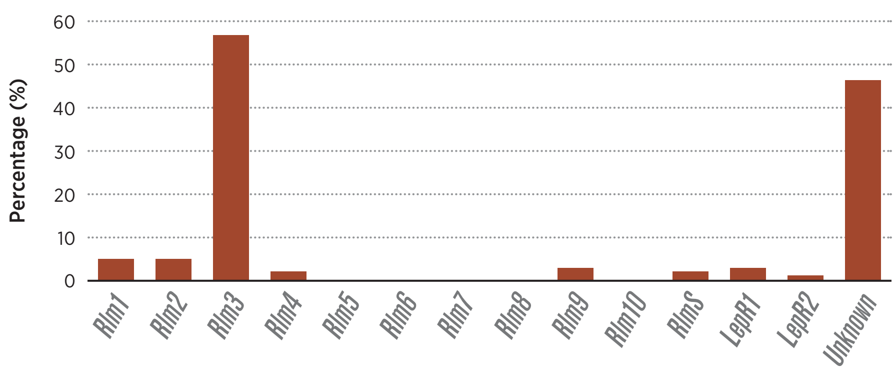
Pathogen populations consist of dozens of races and differ greatly from field to field. Early infection, as shown here, could indicate a resistance breakdown for those genetics on that field.

Frequency of avirulence genes in fungal population *AvrLmS* was assessed in 193 *L. maculans* isolates



As shown in the figure above, the blackleg fungal population has a high level of diversity in Prairie fields. However, the figure below shows that genetic resistance relies primarily on just one gene, Rlm3. The low frequency of the AvrLm3 allele in the fungal population coupled with the overuse of Rlm3 single resistance to blackleg in planted Canadian canola varieties is the probable cause of current breakdown in many growing regions.

Percentage of *Rlm* genes in 102 canola varieties/lines



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INTEGRATED PEST MANAGEMENT

3.4 Diverse crop rotations reduce soil-borne disease pressure

KEY PRACTICE: Following a diverse rotation reduces soil pathogen populations and disease pressure. However, crop rotation should only be one part of your integrated approach to disease management.

PROJECT TITLE, LEAD RESEARCHER: "Effect of crop rotation on canola seedling blight and soil pathogen population dynamics," 2006-07, Sheau-Fang Hwang, Alberta Agriculture and Forestry

GROWER ORGANIZATION FUNDER: ACPC, SaskCanola

Long-term crop rotations have been used as a standard practice to reduce disease pressure in field crops. However, current market opportunities and cultivar advancements have resulted in a trend toward tighter rotations. This study determined that this shift in production practices increases soil pathogen populations, and may result in poor seedling establishment and losses to seedling blight and damping off of canola.

Led by Sheau-Fang Hwang of Alberta Agriculture and Forestry's Crop Diversification Centre North, field experiments were established in Scott and Melfort, SK to determine the impact of long-term crop rotations on soil pathogen populations and on the growth parameters of canola.

Seven diverse crop rotations were studied, as follows: continuous canola; continuous field pea; canola-wheat; pea-wheat; pea-canola-wheat; canola-wheat-pea-wheat; and canola-wheat-flax-wheat. The canola rotations also had the additional factor of hybrid versus conventional cultivar.

A total of 21 soil samples were collected from these rotations and soil fungal populations were examined. The greatest number of isolated CFU (colony-forming units — a measure of pathogen abundance) represented *Fusarium* species, followed by *Pythium* and then *Rhizoctonia*, the primary pathogens in the disease complex affecting canola seedlings.

On average, soil pathogen populations and the number of CFUs were approximately five percent lower in a diverse four-year cycle compared to shorter rotations or continuous cropping. Interestingly, the number of CFUs for all fungus types was also higher in soil planted to hybrid versus conventional canola varieties.

Fusarium levels showed a maximum reduction of 52 percent in the four-year rotations when compared to continuous field pea, and an average reduction of 21 percent over all treatments. *Rhizoctonia* was reduced by as much as 23 percent when compared to shorter rotations at Scott, SK in 2006. Average counts for *Pythium* varied much more widely between the test sites and treatments, and resulted in similar final numbers from both four-year and tighter rotations.

In the case of the continuous crops, isolated *Fusarium* numbers were consistently higher where pea was grown, compared to continuous canola. Greater numbers of *Pythium* were isolated from the continuous canola soils compared to those planted to peas.

In addition, greenhouse studies indicated greater seedling emergence and growth parameters resulting from diverse four-year rotations. Emergence increases were as high as 41 percent and root vigour as high as 61 percent when comparing a four-year rotation to continuous cropped pea. Increases in shoot weight were as high as 51 percent over those resulting from tighter rotations.

This study also found higher emergence and growth patterns in pasteurized soil and when seeds were treated with fungicide, demonstrating that these are additional measures toward reducing the effect of soil pathogens and could be considered as part of an integrated strategy for disease management.

Recommendations

- Diversity in crop rotation can reduce disease pressure caused by soil-borne pathogens.
- Economic disease management relies on an integrated approach including varietal resistance, other cultural practices and fungicides. ●

3.5 How to protect clubroot resistance

KEY PRACTICE: Use an integrated approach to clubroot management that includes a resistant cultivar, proper rotations and sanitation of seed and equipment.

PROJECT TITLE, LEAD RESEARCHER: "Effects of clubroot resistant canola lines on soils infested by Plasmodiophora brassicae," 2010-14, Sheau-Fang Hwang, Alberta Agriculture and Rural Development (AARD) and Stephen Strelkov, University of Alberta

GROWER ORGANIZATION FUNDER: ACPC, MCGA, SaskCanola

Clubroot is a soil-borne disease caused by *Plasmodiophora brassicae*. It's an emerging threat to canola production. Results of this study show that effective clubroot management relies on cultivar resistance in combination with management practices that reduce viable resting spore populations.

Originally identified near Edmonton in 2003, clubroot has since spread to nearly 2,000 fields across Alberta. It has been detected in Saskatchewan and has been confirmed through soil testing in several municipalities in Manitoba. Yield losses in severely diseased fields have ranged from 30 to 100 percent. Clubroot resting spores can remain in the soil for many years, and mitigation is required to minimize the impact to grower and industry profitability.

Researchers at the University of Alberta and AARD conducted a four-year study to: provide tools to slow the spread of clubroot on the Prairies; develop effective soil fumigation methods to hinder establishment of the disease; and provide information to help growers optimize rotation strategies and improve stewardship of clubroot resistance.

Through a combination of field trials, mini-plot trials using naturally infested field soil and greenhouse trials, this study specifically examined the effects of clubroot-resistant canola lines on soils infested by *Plasmodiophora brassicae*.

Experiments were conducted on crop rotations planted in clubroot-infested soils as follows:

- Field tests: continuous canola; canola-pea-wheat-canola; canola-oats-pea-canola; canola-oats-wheat-canola; canola-barley-pea-canola; canola-fallow-fallow-canola
- Three-year mini-plots: continuous susceptible canola (S); pea-wheat-S; barley (B) -pea-S; oats-wheat-S; fallow (F) -F-S
- Four-year mini-plots: resistant canola (R) -R-R-S; R-R-B-S; R-B-B-S; B-B-B-S

As expected, soil pathogen populations were higher after the susceptible cultivar (45H26) when compared to the resistant cultivar (45H29). At the end of the four-year susceptible-resistant cropping sequence, disease severity was 10 times higher in the continuous S than in the R-R-R-S rotation. Resting spore numbers were higher after each cycle of the continuous S rotation and decreased throughout the F-F-S and R-R-R-S sequences.

Continuous planting of canola resulted in greater clubroot severity than all other treatments in the field trials, and seed yield was higher in the canola-oats-peas-canola rotation than all others.

Overall, introduction of a susceptible cultivar resulted in greater *P. brassicae* spore populations in the soil, higher disease levels and increased infection.

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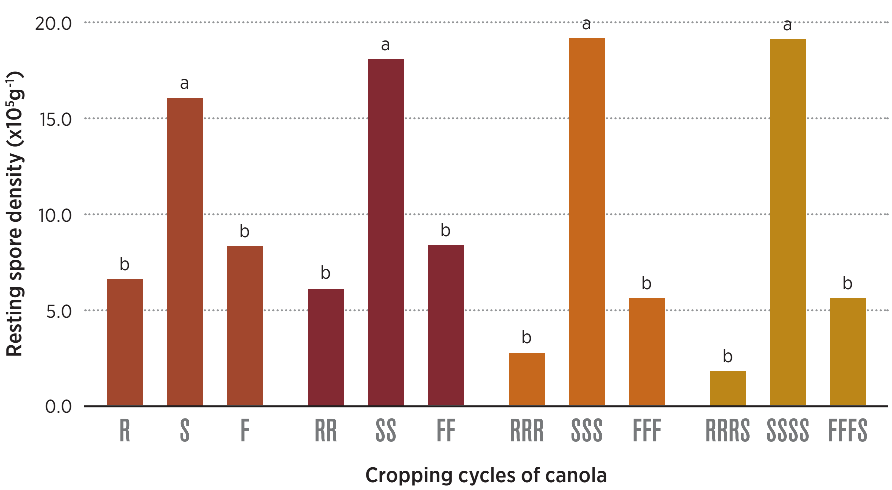
Susceptible varieties greatly increase clubroot resting spores



Changes in resting spore concentration over cropping cycles with resistant (R, '45H29', Pioneer Hi-Bred) or susceptible (S, '45H26, Pioneer Hi-Bred) canola cultivars, or a fallow (F) treatment. The fallow conditions were maintained over the same period in which three cycles of resistant or susceptible canola was cropped. In year four, the same susceptible (S) variety was grown on all three treatments to compare clubroot risk.

HOW TO PROTECT CLUBROOT RESISTANCE

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Greenhouse trials also showed that increased *P. brassicae* soil populations significantly reduce plant growth and yield.

Further study of clubroot continues under AAFC's Growing Forward 2 program. "Management of clubroot in a dynamic environment," and "Clubroot surveillance and epidemiology: staying ahead of an important canola issue," also led by Hwang and Strelkov, aim to: provide critical information about the nature and extent of the clubroot outbreak in Canada; further investigate the impact of cropping resistant canola; evaluate the effectiveness of soil fumigants; and improve clubroot sanitation protocols.

Hwang also leads the grower-funded study titled "Toward a strategy for reducing the spore density and dissemination of clubroot of canola in Alberta," currently in the second of four years. One objective of this study is to develop methods to reduce newly established infestations. In greenhouse and field experiments, use of Vapam fumigant on clubroot-infested land has reduced clubroot severity and improved crop establishment, plant height and seed production.

Conclusion

Agronomy recommendations based on this study:

- Manage infected fields through crop rotation combined with the use of resistant varieties.
- Practice good sanitation to restrict the movement of possibly contaminated material — resting spores are most likely to spread via contaminated soil and infected canola plant parts.
- Consider including the application of nutrient supplements (such as calcium and boron), soil fumigants and fungicides. ●

INTEGRATED PEST MANAGEMENT

3.6

Mapping a route to clubroot resistance

KEY PRACTICE: *P. brassicae* can rapidly adapt to the selection pressure provided by currently available clubroot-resistant canola varieties. For durable clubroot resistance, it will be important to stack resistance genes and rotate them in clubroot-infested fields.

PROJECT TITLE, LEAD RESEARCHER: "Studies on the genetic and molecular basis for clubroot resistance in canola," 2010-15, Stephen Strelkov, University of Alberta

GROWER ORGANIZATION FUNDER: ACPC

The clubroot pathogen *Plasmodiophora brassicae* has a complex pathotype structure and its soil inoculum levels build up quickly in the presence of susceptible hosts. This means it can quickly adapt to selection pressure. This project provides significant insights to facilitate the improvement and development of sustainable clubroot management strategies.

Project objectives were to:

- identify major resistance genes and develop knowledge of their effectiveness against the predominant pathotypes of *P. brassicae* in Western Canada;
- gain knowledge of the relationship between different sources of clubroot resistance to enable rotation of resistance genes in infested fields;
- improve understanding of the basis for resistance and influence of different resistance sources on *P. brassicae* populations in the soil; and
- develop an understanding of a subset of host and pathogen genes that could serve as targets for resistance breeding and fungicide development.

In the clubroot resistance tests, a total of 347 successful double-haploid (DH) canola lines were produced from three different parent populations. The first-generation DH lines were tested with single-spore *P. brassicae* isolates representing all pathotypes of *P. brassicae* reported in Canada. Results indicate that a single gene most likely controls *P. brassicae* resistance in these canola populations.

Pathogen cycling experiments involved five successive cycles of inoculation, resting spore extraction and reinoculation on seven host *Brassica* genotypes. These genotypes exhibited a range of clubroot resistance from susceptible (S), moderately resistant (MR) to resistant (R). The objectives here were to evaluate changes in pathogen virulence and durability of host resistance at each cycle.

Disease levels in two genotypes — a clubroot-resistant commercial hybrid (CV-R) and a moderately-resistant line — increased significantly after the first inoculation but then remained relatively constant throughout subsequent cycles. In the case of CV-R, this may have reflected the presence of both major and minor clubroot resistance genes, demonstrating the erosion of major-gene resistance at first inoculation followed by partial resistance thereafter.

This quick erosion of clubroot resistance is an accurate prediction of what would happen under field conditions and shows that resistance does not seem to be durable on the presently available CR canola varieties. Indeed, in the 2013 and 2014 growing seasons, several fields in Alberta developed higher clubroot levels than expected, despite being sown to clubroot-resistant (CR) varieties.

Testing on both primary and secondary zoospores indicates that their ability to cause infection may be essentially the same, and that secondary zoospores caused earlier secondary infections than those caused by resting spores. Based on this, the research team hypothesizes that *P. brassicae* uses primary infection to overcome the plant's resistance to secondary infection.

P. brassicae zoospore tests conducted on canola and ryegrass plants also provided the first report of host infection by secondary zoospores produced by a non-host. Although rates of secondary plasmodia and infection were highest in canola inoculated with zoospores collected from canola, tiny clubs also developed on 16 percent of the canola plants inoculated with those from the ryegrass. The absence of club formation on the ryegrass in these tests also indicates the build-up of secondary resistance during primary infection in that non-host crop.

Through RNA sequencing of the parent populations and both resistant and susceptible DH lines, a subset of genes has been identified as potentially having key roles in clubroot resistance. Twelve molecular markers were identified that will be useful in breeding programs including gene pyramiding for durable clubroot resistance.

A new resistance gene was also identified in one of the *B. napus* populations providing resistance to *P. brassicae* either in combination with the previously-identified resistance gene (*CRa*) or alone, and proving to have a stronger effect than *CRa* in the population tested.

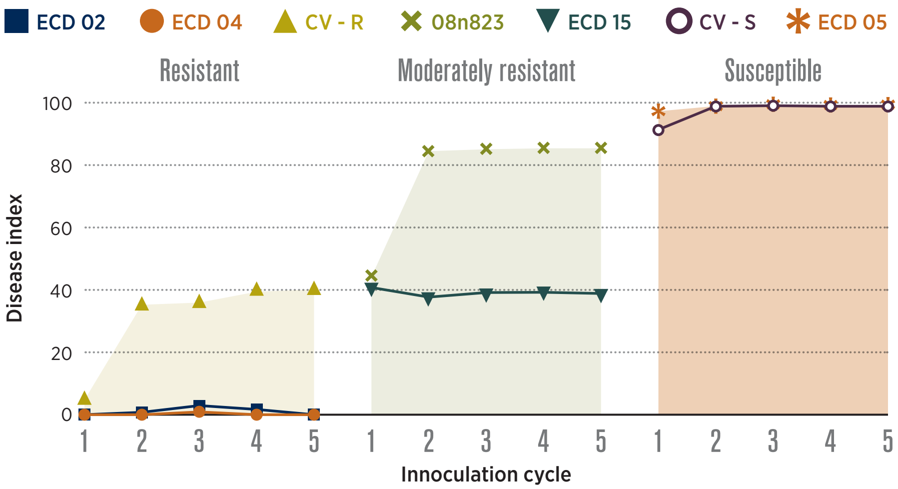
Findings of this study are being used to formulate recommendations for farmers and have laid a foundation for further research activities.

Conclusions

Recommendations based on this research:

- Manage infected fields through crop rotation out of canola combined with the use of resistant varieties. Even small percentages of susceptible plants within a CR crop can reduce the effectiveness of rotations.
- Practice good sanitation to restrict the movement of possibly contaminated material — resting spores are most likely to spread via contaminated soil and infected canola plant parts.
- Due to *P. brassicae*'s complex race structure, it has the ability to rapidly adapt to the selection pressure provided by currently available CR canola varieties. Therefore, to provide durable clubroot resistance, it will be important to: (1) stack or pyramid resistance genes in canola varieties; and (2) rotate resistance genes in clubroot-infested fields. ●

Testing durability of clubroot resistance



*The study put seven **Brassica** genotypes (denoted by the symbols at the top) through five successive cycles of inoculation, resting spore extraction and reinoculation. Two resistant experimental lines (shown in the graph on the left) held their resistance, with very low levels of disease over the five cycles. Disease levels in the clubroot-resistant commercial hybrid (CV-R) and moderately-resistant line increased significantly after the first inoculation but then remained relatively constant throughout subsequent cycles. This quick erosion of clubroot resistance is an accurate prediction of what would happen under field conditions.*

3.7 Night spraying outperforms dawn for weed management

KEY PRACTICE: Midday herbicide applications are most effective for canola; midnight application for grassy weeds.

PROJECT TITLE, LEAD RESEARCHER: "Night spraying — Pesticide efficacy with night time application (2012-14)," Ken Coles, Farming Smarter
GROWER ORGANIZATION FUNDER: ACPC

Any reduction in herbicide efficacy quickly impacts the return on input investment. With the short Prairie growing season, canola has to be seeded and sprayed in a short window, and timing is critical to optimum performance. This study shows that nighttime herbicide application could be useful as an alternate timing when daytime conditions are poor, helping growers avoid the economic and environmental consequences of waiting for ideal daytime conditions.

This project was developed to answer three questions:

1. Is applying herbicides at night a practical option for producers?
2. What is the efficacy and tolerance of applying herbicides at night?
3. What are the possible issues or complications with night spraying?

Pre-seed burndown (PSBD) trials were conducted in Lethbridge, AB and in-crop trials at research plots in three Alberta locations — Lethbridge, Bonnyville and Falher — during the 2012, 2013 and 2014 growing seasons.

PSBD trials were sprayed with four different herbicides at label-recommended and three-quarter-label rates and at three different timings: day (noon to 2 p.m.), night (midnight to 1 a.m.) and dawn (4 to 5 a.m.). In-crop trials were sprayed at three-quarter-label rates with nine different herbicides using similar equipment and timings as in the PSBD trials. Tame mustard and tame oats were used in this study to simulate broadleaf and grassy weeds.

Across all treatments and site years, on average, herbicides were most effective when applied in the daytime, and night spraying gave better results than dawn application. Dawn application was the least effective timing overall. A substantial advantage was observed in both day and night applications over the dawn application.

In 2013, heavy rainfall shortly after spraying rendered the herbicides almost totally ineffective in weed kill for the trials that year. However, averaged over all three years, PSBD application in the daytime was still more effective than dawn 75 percent of the time when measured in terms of efficacy rating, and about 67 percent of the time based on weed biomass ratio. When only the 2012 and 2014 results are averaged, those values increase to 94 percent and 75 percent, respectively.

Both day and night PSBD applications were concluded to be more effective than dawn application in about 82 percent of the instances in 2012, and 88 percent of the instances in 2014. This suggests night spraying of herbicides is a strong alternative when midday conditions are too hot, windy or dry for optimum treatment.

In-crop trials evaluated herbicides for efficacy and crop tolerance in Liberty Link canola (LL), Roundup Ready canola, wheat and peas. Results were consistent with those of the PSBD trials, with day and night applications performing better than dawn applications in about 75 percent of all instances.

Tests were also conducted around efficacy of herbicide application timing given the nighttime vertical position of leaves in some weed species. Broadleaf plants that exhibit diurnal leaf movement keep their leaves horizontal relative to the stem with maximum surface area exposed during daylight. However, this leaf-movement phenomenon is not as prevalent in grassy weeds.

When the efficacy rating and weed biomass ratio means were averaged over all herbicide and crop treatments, the daytime applications performed better than night and dawn timings in all site years for controlling mustard, a broadleaf weed. However, for oats, a grassy weed, daytime treatment only outperformed night and dawn treatments in 50 percent of the instances in terms of efficiency, and 75 percent of the instances based on weed biomass.

All factors considered, the results suggest nighttime application could be employed as an alternative to optimize herbicide use when daytime application opportunities are limited. It may also save farmers money and time through improved efficacy. Night spraying has become a more practical alternative through the evolution and widespread adoption of technology such as GPS guidance and auto-steering systems.

Conclusion

Recommendations based on this study:

- Pre-seed and in-crop herbicides provide the most consistent results when applied in the daytime, but avoid early morning applications, because they are the least consistent in efficacy.
- Consider the type of herbicide, mode of action and weather conditions such as temperature, relative humidity, wind and delta T.
- If in doubt, spray wheat in the morning, canola in the afternoon and peas in the evening, says Coles. ●

3.8

Glyphosate-resistant kochia survey

KEY PRACTICE: Taking action to manage glyphosate-resistant kochia before it is visible in the field is critical to success. Use a rotation of broadleaf control products with good activity on kochia.

PROJECT TITLE, LEAD RESEARCHER: "Glyphosate-resistant kochia (Kochia scoparia L. Schrad.) in Saskatchewan and Manitoba," 2013-14, Hugh Beckie, Agriculture and Agri-Food Canada (AAFC)
GROWER ORGANIZATION FUNDER: ACPC, SaskCanola

As the most-widely used herbicide in Western Canada and around the world, glyphosate popularity has led to global selection for glyphosate-resistant (GR) weeds. Kochia was the first GR weed in Western Canada, confirmed present in southern Alberta in 2011. The efficacy of herbicides is much stronger on weeds when they are small, and taking measures against GR kochia before it is visible in the field is critical to successful management.

Hugh Beckie, who accurately predicted that kochia was becoming glyphosate resistant, continues to study options for its control. Building on kochia surveys conducted in Alberta in 2011 and 2012, 615 sites across southern Manitoba and southern and central Saskatchewan were surveyed in the fall of 2013.

The collection and screening of mature plants confirmed 17 GR kochia populations in Saskatchewan and two in different parts of the Red River Valley in Manitoba. The majority of these originated in chemfallow fields, but some were derived from fields of GR canola, *B. napus* L, GR corn and soybean as well as non-cropped areas.

Mature kochia plant

In an earlier study, Beckie found that 90 percent of Prairie kochia populations were resistant to acetolactate synthase (ALS) inhibitor Group-2 herbicides. In 2011, he discovered kochia in southern Alberta with multiple resistances to glyphosate and ALS-inhibitors. A 2012 survey in that region identified GR kochia in four percent of fields surveyed. In addition, 10 of the kochia samples submitted from growers in west-central and southwest Saskatchewan were also confirmed as GR. The most recent studies conducted in south-central Saskatchewan and southern Manitoba support these findings.

These post-harvest surveys were conducted to determine GR kochia's geographical distribution and abundance. Sites were randomly predetermined and viable seeds were collected from: 342 sites in the mixed grasslands and moist mixed grasslands (Brown/Dark Brown Soil Zones) of Saskatchewan; and 283 sites in the Aspen Parkland and Lake Manitoba Plain eco-regions of southern Manitoba.

Among the confirmed samples from Saskatchewan, six were from municipal-ities where GR kochia populations had not previously been found. Added to the previously confirmed populations, GR kochia has now been identified in a total of 14 municipalities across the province.

The two confirmed GR samples from Manitoba derived from a GR corn crop in the south-central portion of the Red River Valley and a GR soybean crop in the southeast. This lower occurrence was as expected due to the much lower

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3.9 Spraying for weevils reduces lygus bugs and increases yield

KEY PRACTICE: Managing cabbage seedpod weevils (when they reach thresholds) with a single insecticide application at early flower stage can reduce pod-stage abundance of lygus bugs and may increase yield by an average of 1.5 bu./ac.

PROJECT TITLE, LEAD RESEARCHER: "Management of lygus bugs and seedpod weevil in canola at the farm level," 2010-14, Hector Carcamo, Agriculture and Agri-Food Canada (AAFC) Lethbridge

GROWER ORGANIZATION FUNDER: ACPC

Cabbage seedpod weevil (CSPW) and lygus bug are both chronic pests of canola in Western Canada. It is important to periodically scout for these insects with a sweep net starting at late bud stage, and also to consult economic threshold charts to determine the need for insecticidal control. The results of this study show there are additional benefits to spraying for weevils at the early-flower stage (at or above the economic threshold).

The goal of this four-year project in Alberta was to determine through farm studies the best practices for managing a combination of CSPW and lygus bug as a pest complex. This includes the definition of combined thresholds for the early flower stage when product application is most effective at reducing weevil damage. One particular area of focus was the impact of this treatment on the abundance of lygus bugs at early pod stage, which is when they tend to be the most damaging.

Overall, controlling CSPW with insecticide application at the early flower stage reduced the pod-stage abundance of lygus bugs.

Data was collected from a total of 75 sites between 2010 and 2014, with 41 fields situated in the Lethbridge/Fort Macleod area and 34 in the Vulcan/Medicine Hat area. These locations contain overlapping populations of both CSPW and lygus bug. With the exception of three southern fields that were planted to Polish (*B. rapa*) canola, all sites grew Argentine (*B. napus*).

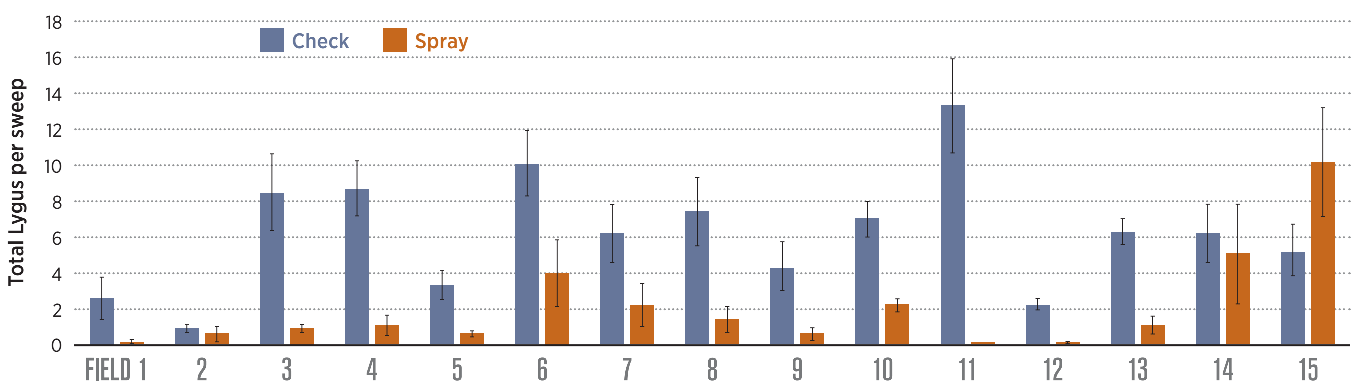
Seeding date, which varied widely ranging from late April to early June, had a clear influence on both insects, but in opposite ways. Fields planted early attracted the most weevils and fewest lygus bugs while those planted late showed the opposite. Planting within the normal seeding period (first two weeks of May) resulted in moderate numbers of both pests.

Yield data was collected through a combination of quadrant samples from all fields and from farmers' combine monitors in 20 fields. This study found that spraying insecticide at early flower increased yield by an average of 1.5 bu./ac. over that of the untreated check. However, there was not a linear relationship between yield and the abundance of the two pests studied.

Researchers also looked at the effect of weather conditions on the abundance of CSPW and lygus bug. Precipitation levels reported from both regional weather stations and on-farm rain gauges were tested for correlations to insect counts during the pod stage. This data suggested that the localized rain gauges were a much better tool to predict insect population.

High rainfall on a field over a short time period during the early pod stage when lygus bugs are small has the potential to significantly reduce their numbers. After being knocked to the

Total lygus at pod stage, 2013



Results from 15 sites in 2013 show that lygus numbers at the pod stage were often lower in fields that required spraying for cabbage seedpod weevil.

ground, lygus bugs at this stage are susceptible to natural enemies or may not be able to make their way back onto the canola plants.

The results of this study combined with ongoing cage tests will be used to provide more accurate and combined thresholds for best management of both CSPW and lygus bugs.

Conclusion

Insect management recommendations based on this study are:

- Start scouting regularly for both CSPW and lygus bug at late bud (yellow buds on bolted crop).
- Plant canola early and consult economic thresholds to determine the need for application of insecticide.
- To conserve and protect natural enemies, do NOT spray fields where weevils are below threshold as an attempt to reduce pod-stage lygus bug numbers. The resulting benefits of predation and other factors including rainfall may contribute to control of this pest.
- Sweep for lygus bugs after a heavy rainfall before making a spraying decision.
- It is very important to make decisions based on thorough field monitoring rather than practices applied on neighbouring fields or reported local and regional weather conditions.
- Tank mixing insecticide with fungicide spray in full flower is not recommended for weevils or lygus bugs and can be harmful to pollinators and natural enemies. ●

GLYPHOSATE-RESISTANT KOCHIA SURVEY

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frequency of chemfallow in Manitoba and the strong link between this practice and glyphosate resistance.

All GR kochia populations from Saskatchewan and Manitoba proved susceptible to dicamba, an organochloride compound with reported resistance in the U.S. The effectiveness of alternative herbicides was also confirmed in greenhouse studies.

Conclusions

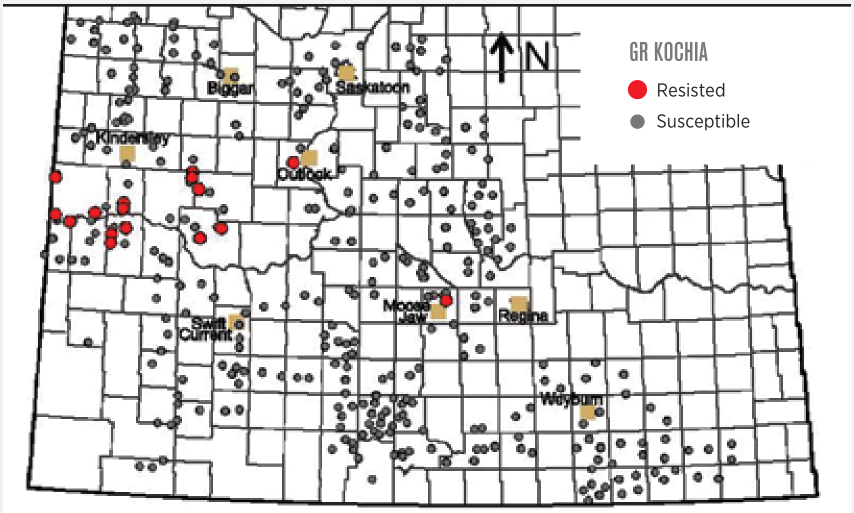
Agronomy recommendations based on this study are:

- The cost-benefit of chemfallow needs to be closely evaluated due to its strong association with GR kochia.
- Better cover crops where chemfallow is practiced would lessen selection pressure.
- Reliance on the same tank-mix partner will inevitably select for multiple-resistant weed populations.

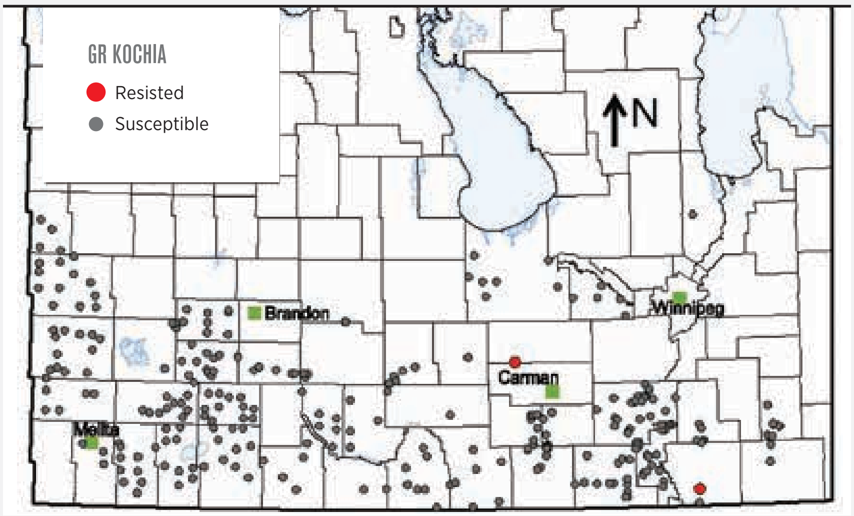
Beckie also warns of the future risk for glyphosate resistance in other abundant weed species including wild oats, green foxtail, cleavers and wild buckwheat.

Periodic surveys of GR kochia will continue across the Prairies as the demonstrated ease of spread demands close monitoring and a collective response to management. ●

Glyphosate-resistant kochia in Saskatchewan, 2013



Glyphosate-resistant kochia in Manitoba, 2013



3.10 Seed early to reduce swede midge damage

KEY PRACTICE: Where swede midge is a concern, seed as early as possible. Where swede midge can cause significant losses, consider *B. juncea* or *S. alba* varieties over *B. napus*.

PROJECT TITLE, LEAD RESEARCHER: "Assessing the impact of swede midge on canola production in the Prairies and Ontario," 2005-08, Rebecca Hallett, University of Guelph

GROWER ORGANIZATION FUNDER: ACPC, SaskCanola

Swede midge were found in three fields in Saskatchewan for the first time in 2007 and eco-climatic modeling indicates that most of Canada is suitable for establishment. Although researchers expect the insect will become a regular pest of canola in the Prairie provinces, they do not expect the populations to reach the high levels found in Ontario.

Rebecca Hallett, researcher with the University of Guelph's School of Environmental Science, led a three-year project beginning in 2005 to provide canola producers with information about the distribution and impact of swede midge and appropriate management practices.

Researchers mapped areas where conditions favoured population establishment and development and chose areas with the highest risk of initial swede midge invasion. These results identified nine locations to be surveyed across Alberta, Saskatchewan and Manitoba using pheromone traps in canola fields and cole crops.

In a 2007 survey conducted by the Canadian Food Inspection Agency, a total of 11 swede midges were found on different dates on traps in three Saskatchewan fields. However, no larvae were found in the soil cores collected from those three fields, nor from three nearby fields.

In the third year of this study, the relationship between swede midge damage, insecticide treatments and canola varieties was explored at sites in Elora and Arkell, ON. These tests included 20 canola varieties, seeded in mid-late May, with alternating applications of Assail and Matador applied at weekly intervals from June 1 to August 17.

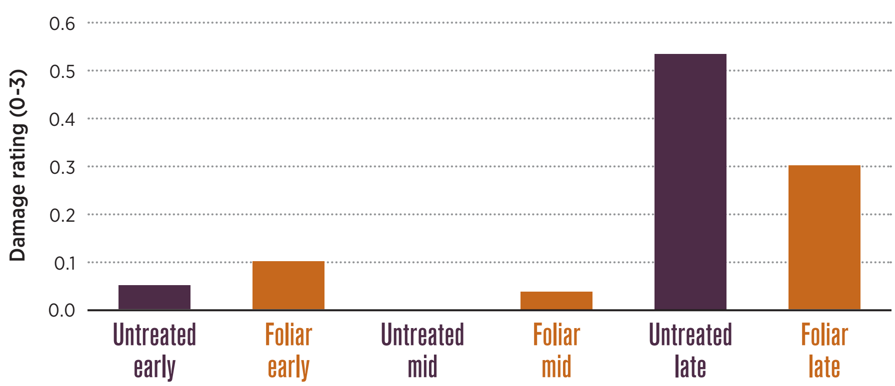
Across these variety tests, damage was higher among *B. napus* canola varieties than among *B. juncea* and *S. alba* varieties. AC Pennant, AC Sunbeam, Arid and Ochre had the lowest ratings for swede midge damage to the primary raceme and InVigor 5030, InVigor 5020, AP7978RR and OAC Senator had the highest. Among *B. napus* varieties, OAC Senator, Hyola 401, Arkell, Hyola 357RR and 45H21 had significantly lower primary raceme damage ratings than AP7978RR, InVigor 5030 and InVigor 5020.

In terms of insecticide timings, plants treated at the first bud stage at Elora had less damage. However, there were no significant differences between treatment dates at the Arkell site.

Hallett is also heading up a study titled "Development of Pest Management Decision-making Protocols for the Swede Midge in Canola," currently in its third year. Findings to date have resulted in revisions to the swede midge management recommendations for 2015 and adoption by canola growers and advisors of pheromone-based swede midge monitoring. Further details can be found on the Ontario Canola Growers' website at www.ontariocanolagrowers.ca.

These tools improve the ability to time insecticide applications appropriately to protect canola in the early and late vegetative stages (2.1 to 2.5) when it

Swede midge damage at vegetative stage



2006 spring canola trial, Elora, ON — at the vegetative state, swede midge damage was highest on late planted canola. Source: Rebecca H. Hallett, University of Guelph.

is most vulnerable. Insecticide application at the secondary bud stage is no longer recommended.

Conclusion

Agronomy recommendations based on this study:

- Planting early can ensure your crop is past the susceptible stage by the time the pest emerges.
- Intensive monitoring and consultation is required to identify populations and accurately time spraying within the insect's one- to five-day lifespan.
- Use pheromone traps to determine swede midge presence. Samples can be sent to AAFC Saskatoon for identification.
- Damage from swede midge is less prevalent in *B.juncea* and *S. alba* varieties than in *B. napus*.
- Swede midge causes occasional isolated economic crop losses, but no economic threshold has been established. ●

PHOTO: Larry Grenkow, AAFC Saskatoon

INTEGRATED PEST MANAGEMENT

3.11 Biocontrol of canola cutworms

KEY PRACTICE: The key to minimizing damage from cutworms is early detection through frequent field scouting. Proper identification of cutworm species can be important in the protection of beneficial insects and implementation of other biocontrols.

PROJECT TITLE, LEAD RESEARCHER: "Biocontrol of canola cutworms: Identification and attraction of parasitoids," 2012-15, Barbara Sharanowski, University of Manitoba

GROWER ORGANIZATION FUNDER: ACPC

Insecticide application is the most common control option for cutworms in canola but it is very difficult to manage. Effective timing of these treatments varies between cutworm species based on life cycle and their subterranean and nocturnal habits. This study looked at parasitoids as the most effective biocontrol option for cutworms affecting canola.

The objectives of this three-year study were: to develop an understanding of the species involved; learn which species of cutworm each parasitoid would attack; and determine whether these parasitoids effectively reduce cutworm damage.

Cutworm samples were collected from Manitoba farm fields from May to July in 2012, 2013 and 2014. Research collaborators in Alberta provided additional reared parasitoids and their host cutworms. Results showed a reduction in parasitized cutworms in Manitoba for 2013 and 2014 compared to 2012. Numbers in Alberta were lower in 2012 and 2014 compared to 2013.

A total of 16 different species of hymenopteran parasitoids were found attacking Prairie cutworms, several of which were new host identifications.

A user-friendly online identification key to all 16 species, complete with high-resolution images, will be published by the end of 2015.

Dual-choice tests were conducted to determine the effectiveness of various cover crops to attract beneficial parasitoids based on the flower colour and flower odour preferences of both fed and starved parasitic wasps. In these tests, yellow flowers proved much more attractive than white or green and starved wasps clearly favoured floral odours from canola and mustard over camelina and buckwheat.

The tested cover crops also added the nutritional resources necessary to maximize the parasitoid's ability to lay eggs. However, all the benefits provided by these cover crops may still not be enough to reduce cutworm populations below economic levels due to relatively low rates of parasitism. Despite aiding

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3.12 Shift in flea beetle species composition

KEY PRACTICE: Crucifer and striped flea beetles react differently to their environment and to seed treatments. It is important to monitor emerging canola seedlings to know what you're up against.

PROJECT TITLE, LEAD RESEARCHER: "Potential flea beetles species composition shift in Prairie canola," 2007-12, Juliana Soroka, Agriculture and Agri-Food Canada (AAFC) Saskatoon

GROWER ORGANIZATION FUNDER: ACPC, MCGA, SaskCanola

Flea beetles are chronically the most economically damaging insect pests of canola. Although the crucifer flea beetle remains the predominant species, this study shows the striped flea beetle to be expanding its range across Western Canada. As these two species respond very differently to their environment, spring scouting is critical to planning proper control strategies.

Crucifer flea beetle (*P. cruciferae*) is most frequently found in the southern Prairies while striped flea beetle (*P. striolata*) is traditionally found in the Parkland Region of the northern Prairies and the Peace River Region of Alberta. A third species, the hop flea beetle, occurs across the Prairies in low numbers along with several other flea beetle species of minor importance to canola.

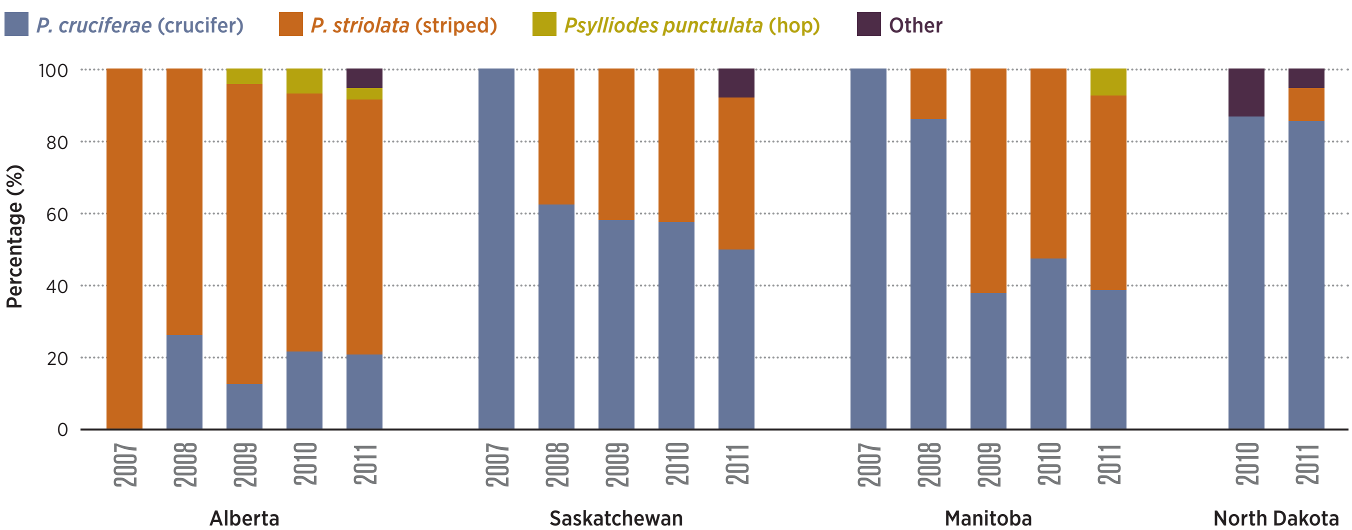
This five-year Prairie-wide study was conducted to determine the number and distribution of the most common flea beetle species that canola growers will find in their fields. The project also investigated whether striped flea beetle numbers indicate a major shift in flea beetle species.

Earlier studies quantified the risk to canola from crucifer and striped species. As insecticidal seed treatments are the primary method of flea beetle management, results from Tansey et al. and Elliott concluded that control failures are more likely when populations of striped flea beetles outnumber crucifer flea beetles, because the striped species is less susceptible to these treatments.

Principal investigator Julie Soroka conducted a preliminary survey in 2007 at 25 locations in the Canadian canola-growing region. This survey expanded to include 34, 44, 98 and 99 sites from 2008 to 2011, respectively, across the Prairies and in the U.S. state of North Dakota. Yellow sticky traps were placed in or near canola fields starting at the time of seedling emergence and for an average of three to four weeks in May and June.

In total, 11,180 traps were retrieved from 300 sites. When compared to surveys conducted in the 1970s, the numbers of striped flea beetles in

Proportion of flea beetle species collected from yellow sticky traps placed near or in canola fields in the spring across the Prairies, 2007-2011



The two most common flea beetle species are striped (top) and crucifer (bottom).

northern areas had increased dramatically. The striped species is now the most frequently encountered flea beetle in the Peace River Region and central Alberta, central Saskatchewan and much of Manitoba. Striped flea beetle is also now found in increasing numbers across southern canola fields where it was once a very rare sight.

Conclusion

Despite this shift in species frequency and the expanding range of *P. striolata's* occurrence across the prairies, *P. cruciferae* remains the predominant species in those canola fields where flea beetle numbers are particularly high.

Recommendations:

- Scout fields in the spring. Assess damage to cotyledons and the first true leaves of seedlings daily. Continue to scout until the seedlings are past susceptibility, especially when temperatures exceed 14°C.
- The action threshold for applying foliar insecticide is typically at 25 percent defoliation to reduce yield loss, but only spray if flea beetles are still present and actively feeding. For crops with lower plant populations, the action threshold will be lower. ●

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in the control of cutworm numbers, parasitized cutworms also tend to feed more frequently and for longer periods, which can increase damage.

These lower rates of parasitism may be partly due to a lack of crop diversity, reduced rotations and the elimination of hedgerows and natural edges to maximize cropping space. This creates an overall agricultural landscape that may not provide parasitoids with adequate nutritional resources.

According to the data from this study, entomopathogenic fungi (EPF) caused greater cutworm mortality rates than any of the collected parasitoids and may be a more suitable biocontrol agent. Few studies have reviewed the potential of this environmentally friendly option.

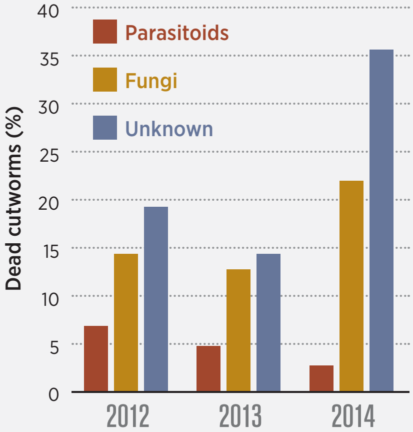
The best time for EPF application is at the early seedling stage, as cutworm damage also occurs early. Since this is the same timing as herbicide application, studies must be conducted on their interactions. Sharanowski will lead further testing on EPF as a biocontrol of cutworms in 2015-16.

Conclusions

The key to minimizing cutworm damage is early detection. Scout the fields and inspect seedlings every three to four days during the first few weeks of crop development, looking for bare areas, holes or notches in foliage, and plants that are wilting, toppling over or completely cut off.

Knowing the species of cutworm can be important because some species complete the larval stages earlier in the year than others, and some species are more likely to feed on and clip stems than others.

Cause of death for cutworms collected in Manitoba



Percentage of dead cutworms due to different mortality factors by year. All other cutworms collected for the study lived to form adult moths.

A nominal economic threshold for insecticide application may be reached at 25 to 30 percent stand reduction.

Determine if the population is patchy or evenly distributed throughout the field. High populations are often localized, leading to expanding bare patches in fields as they consume all the canola plants in an area and move outward in search of more food. Spot spraying the affected patches and a pass or two in the surrounding crop can often be effective in limiting outbreaks.

After the second or third year of infestation, beneficial organism populations such as parasitic insects, viral diseases and bacterial infections usually build up enough to begin bringing cutworm numbers down. ●

4.1 Straight combining: environment and timeliness matter more than variety

KEY PRACTICE: This study found that most hybrids could be straight combined successfully with minimal harvest losses when harvested in a timely manner under reasonably average environmental conditions. When making a seed decision, balance pod shatter resistance with other selection factors including yield potential, herbicide system, days to maturity and other agronomic factors.

PROJECT TITLE, LEAD RESEARCHER: "Quantifying genetic difference in seed losses due to pod drop and pod shattering in canola," 2011-15, Chris Holzapfel, Indian Head Agricultural Research Foundation (IHARF)

GROWER ORGANIZATION FUNDER: SaskCanola

Some varieties are better suited to straight combining than others, but success largely depends on environmental factors and timeliness of harvest.

This four-year, multi-site study aimed to evaluate the resistance of various varieties to environmental pod shatter and pod drop losses. More specifically, it intended to: quantify the frequency and amount of seed losses in straight combined canola across a range of environmental conditions; determine relative resistance to pod shatter and pod drop of varieties recommended for straight combining; and evaluate the environmental seed losses from pod drop versus pod shatter.

Yield losses due to pod shatter and pod drop were examined at optimal and delayed harvest dates for 15 canola hybrids at four Saskatchewan locations (Indian Head, Scott, Swift Current and Melfort) over four growing seasons (2011 through 2014). This number of site years provided a respectable range in environmental conditions over which to compare yield losses.

Since canola varieties rapidly turnover, the study was updated in 2013 to include varieties that were not available when the project started in 2011.

Results

This 13 site-year study determined that while varieties showed differences in resistance to pod drop and pod shatter within individual site-years, environmental conditions often had a greater impact on the quantity of yield losses. Furthermore, while the effects of varieties on yield losses varied between site years, strong genotype by environmental (GxE) interactions occurred for all variables.

A factor that may have impacted these findings was the varying days to maturity for each variety. The days to maturity ranged from 90 to 106 across all varieties used. (There was a tighter range of days to maturity across the 2013-14 varieties than those used in the 2011-12 seasons.)

Seed yield also varied by varieties in seven of the 13 site years, although rankings varied by site, likely due to the strong GxE impact and potentially due to varying weed populations as a result of different herbicide systems.

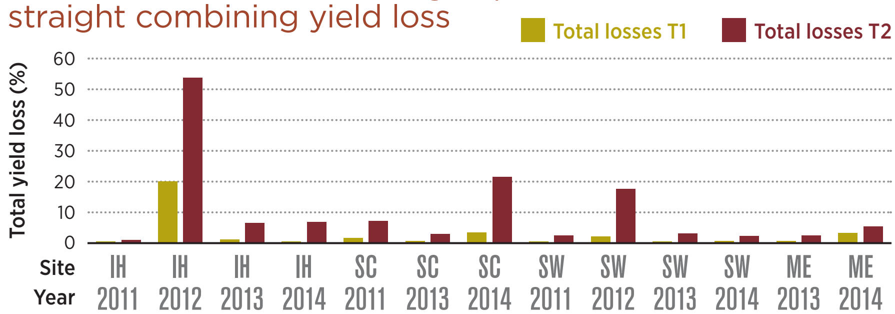
As expected, timing of harvest also affected total yield reductions. Varieties harvested when ready had very low losses (less than five percent) compared to the sites harvested three to four weeks later that reported an average yield reduction of 15 percent across all site years and varieties (although variety performance varied by site). Holzapfel determined that 25 to 50 percent of these yield losses were generally the result of pod dropping (as opposed to pod shattering). Varieties with pod shatter tolerance exhibited the lowest percent losses at five of the six sites.

Conclusions

Differences in resistance to pod drop and pod shatter were observed between varieties, but may be predominantly due to the stability of the varieties across varying environmental conditions, which generally had a larger impact on yield reductions than varieties. However, as long as harvest wasn't delayed too much, this study found that losses from straight combining any varieties shouldn't be significant under normal environmental conditions.

Although new shatter tolerant varieties have excellent potential for straight combining, pre-season variety selection should still include consideration for yield potential, days to maturity and herbicide system rotation. Another key factor is harvest timing. Growers should still strive to complete harvest as soon after the crop is fit to combine as possible in order to minimize loses while straight-combining canola. ●

Environment and late timing impact straight combining yield loss



T1 is the optimal harvest date. T2 is 3-4 weeks later.
IH is Indian Head, SC is Scott, SW is Swift Current and ME is Melfort.

4.2 Monitor stored canola heading into summer

KEY PRACTICE: As winter transitions into summer, monitor the temperature profile in canola bins for any rapid increases that may indicate spoilage. Aerating and turning seed to warm up canola stored throughout the cold western Canadian winter is not necessary.

PROJECT TITLE, LEAD RESEARCHER: "Determining Best Practices for Summer Storage of Canola in Western Canada," 2014, Joy Agnew, Prairie Agricultural Machinery Institute (PAMI)
GROWER ORGANIZATION FUNDER: ACPC, MCGA, SaskCanola

High yielding canola fields, recent challenges with railway transportation, and canola varieties producing increasingly high oil content all emphasize the need for good storage practices. This study filled a knowledge gap on what to do with canola stored through the winter and into the summer. Aerate? Turn it? Leave it? The study found that monitoring is critical for noticing sudden temperature increases, but turning or aeration is often not necessary.

The one-year study used regular, commercial-sized grain bins to measure temperature, relative humidity and airflow rates. Three different management practices — aeration, turning, leaving it alone — were implemented on three 4,000-bushel bins full of canola. Two of the bins were monitored throughout June and July, while one collected data all the way until the end of November.

Canola used in this study had very low moisture — six percent. Prior to the study period, canola had been stored over the winter and frozen.

Based on the success of this project, Agnew is seeking a continuation to test conditions in bins with larger diameter, canola with higher moisture content and potentially different winter temperatures.

Results

Agnew found that despite a large temperature differential (28°C) within the bin, temperature and moisture of the grain remained fairly stable throughout the summer.

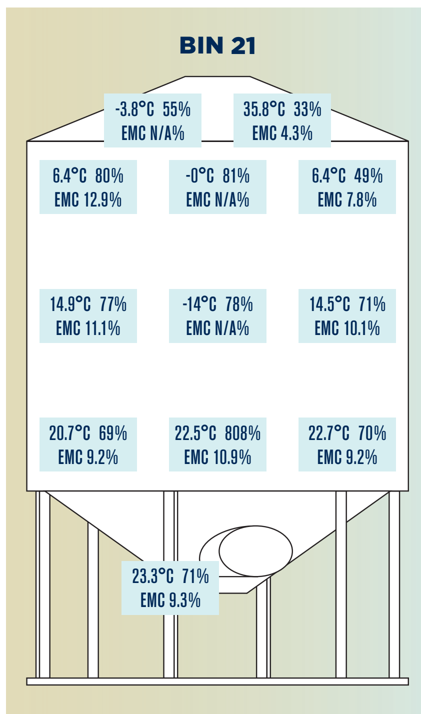
There was very little moisture migration and therefore no spoilage or condensation with the dry canola. The temperatures at the edge of the bin (25°C) were much different than the core (-3°C) throughout most of July, with no difference between temperatures on the sunny or shady side of the bin. Bin headspace temperatures varied drastically from day to night, but the relative humidity was low (less than 40 percent) so there was very little condensation on the top layer. Due to the insulating effect of canola, the temperature of the grain in the top two feet of the bin didn't fluctuate throughout the day.

In terms of management options, turning the seed initially resulted in more uniform temperature distribution. However, due to the fact that the grain funnels down the centre of the bin when a portion of it is removed, there were several zones of cold grain adjacent to warm grain. These zones were considered unstable and could have resulted in condensation. In addition, while aerating with warm summer air evened out the temperature distribution, the transition between warming and cool seed created unstable conditions (which could have caused some spoilage). Despite the formation of these unstable zones, neither aerating nor turning resulted in any spoilage, fortunately.

Conclusions

The results of this study of very dry canola that had been cooled to -30°C over the winter suggest that neither turning nor aerating canola minimizes summer storage risk. The best option found was to just monitor the temperature profile (watching for any rapid increases in temperature, regardless of the actual temperature value) and have a plan to move it if this or another issue arises.

See more details at www.canolawatch.org/2014/06/13/blog-canola-bin-watch/ ●



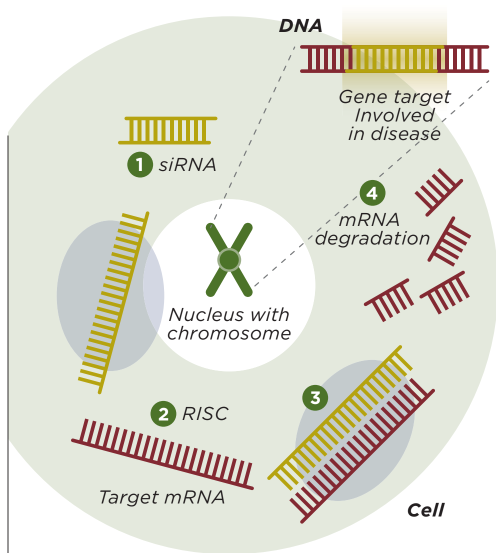
This screen capture shows the temperature and relative humidity in the aerated bin just after starting the fan when the bottom layer had already warmed up, but the warming front hadn't reached the middle and top layers. Aeration evened out the temperature distribution, but the transition between warming and cool seed created unstable conditions that could have caused some spoilage.

5.1 Understanding the cellular mechanisms of clubroot disease and developing a new form of clubroot resistance

KEY PRACTICE: Rather than using genetically resistant varieties or the application of soil amendments and fungicides, this study is working to develop a new, alternative approach to clubroot resistance by silencing pathogen gene expression within the plant itself.

PROJECT TITLE, LEAD RESEARCHER: "Genomics of Clubroot disease development in canola and development of in-plant RNAi to impart novel resistance," 2010-15, Peta Bonham-Smith and Yangdou Wei, University of Saskatchewan

GROWER ORGANIZATION FUNDER: ACPC, SaskCanola



The RNA interference process

1. Small interfering RNA (siRNA) is targeted to a specific gene.
2. Within cells, siRNA unwinds and is incorporated into RISC, a protein-RNA complex.
3. siRNA is directed to a targeted messenger RNA (mRNA) that is involved in a disease pathway, for example.
4. The mRNA undergoes degradation, thereby interrupting the protein synthesis of the targeted gene.

Clubroot, caused by *Plasmodiophora brassicae*, is one of the most economically important diseases affecting canola. Through the detailed study of the cellular and molecular mechanisms underlying *P. brassicae* development within the plant, the joint research program of Peta Bonham-Smith and Yangdou Wei has found a low level of plant resistance gene expression in the plant root response to *P. brassicae* infection. From a library of RNA extracted from canola root gall tissue, the project identified previously undocumented *P. brassicae* sequences. These sequences provide a range of potential molecular targets to achieve clubroot resistance through select gene silencing (RNAi) within the pathogen once it has infected the plant root.

This project focuses on pathotype 3 of clubroot, the predominant pathotype in Western Canada. In order to continue providing resistance to clubroot in canola, research is needed to identify how the pathogen infects plants and how the infection spreads internally.

One of the project's objectives was to extract RNA from canola (*B. napus*) root gall tissue and construct a complimentary DNA (cDNA) library from canola infected with *P. brassicae*. From the library, 20,000 clones were picked. Of these, 10,000 full-length cDNAs were sequenced. Of these, 7,000 sequences have been analyzed and annotated against the National Centre for Biotechnology Information (NCBI) database, with 2,730 cDNAs from the *P. brassicae* pathogen and 2,590 cDNAs from infected canola. Examination of the plant's response network to *P. brassicae* infection showed a low level of gene expression involved in defence stress responses and cell wall reinforcement. The sequencing revealed detailed molecular pathways of both the pathogen and the host response to clubroot formation.

RNA interference (RNAi) is a natural process cells use to suppress the activity of specific genes. RNAi has been exploited in plants for resistance against pathogens, insects, nematodes and viruses. In an attempt to develop canola plants with *P. brassicae* resistance, one of the main objectives of this project is to generate transgenic *B. napus* plants with the ability to silence specific *P. brassicae* sequences, and therefore disrupt the pathogen life cycle. Researchers are using the much smaller canola relative plant, arabidopsis, to test the effectiveness of RNAi in providing resistance to the pathogen.

Using a dual culture system, researchers performed clubroot disease testing in petri dishes and examined the cellular interactions between *P. brassicae* and arabidopsis. Observations revealed that both epidermal and cortical cells of root elongation zones (growth zones) are primary sites for *P. brassicae* infection. Further analysis indicated altered auxin homeostasis in this region, which may contribute to disrupting normal growth and differentiation of these tissues, resulting in gall formation.

EST sequencing (expressed sequence tag or short sub-sequences of a cDNA sequence) has allowed researchers to identify approximately 180 putative secretory proteins from among the 2,522 sequenced *P. brassicae* transcripts, the vast majority of which have not been previously documented (earlier this year the genome sequence of *P. brassicae* was published). These sequences provide a range of potential molecular targets to facilitate the RNAi approach to clubroot resistance. ●

GENETICS

5.2 An improved hybrid system for breeding canola *Brassica juncea*

KEY PRACTICE: The Ogura cytoplasmic male sterility (CMS) hybrid system, commonly used in *B. napus*, will position *B. juncea* breeders to produce more stress tolerant, blackleg resistant and pod shatter resistant high-yielding canola *B. juncea* hybrid varieties.

PROJECT TITLE, LEAD RESEARCHER: "Improving the Ogura CMS hybrid system and establishing heterotic gene pools for hybrid breeding in canola Brassica juncea," 2010-14, Bifang Cheng, Agriculture and Agri-Food Canada (AAFC) Saskatoon Research Centre

GROWER ORGANIZATION FUNDER: SaskCanola

For *Brassica juncea* to be successful in Western Canada, a fully functional hybrid breeding system is needed to develop high-yielding hybrids. This study successfully developed an improved *B. juncea* restorer line, resulting in a fully functional Ogura CMS hybrid system. A more stress tolerant, blackleg resistant and pod shatter resistant variety of *B. juncea* can now be developed to enhance yield potential, especially in hotter, dryer regions of the Prairies.

Researchers at the French National Institute for Agricultural Research (INRA) in France transferred the *B. napus* Ogura CMS hybrid system into *B. juncea*. The hybrid system is composed of three components: the A Line (male sterile), B Line (a maintainer) and an R Line (restorer). Researchers at the AAFC Saskatoon Research Centre obtained the *B. juncea* Ogura CMS A line and R line from INRA in 2003. However, the Ogura CMS hybrid system was not functional in *B. juncea* since the R line had poor growth vigour and low fertility.

In May 2010, Bifang Cheng's team began work on improving the Ogura CMS restorer line in *B. juncea*. The objective was to develop a fully functional Ogura CMS hybrid system for breeding high-yielding hybrids in canola-quality *B. juncea*.

Using molecular marker-assisted selection (a selection process where a trait of interest is selected based on a marker linked to it) in combination with the increased recombination frequencies involving the restorer gene in resynthesized *B. juncea* germplasm, the AAFC team developed an improved *B. juncea* Ogura CMS restorer line (VR441) with improved male and female fertility, and better agronomic performance.

VR441 exhibited strong growth vigour and good seed setting with an average 14.3 seeds per pod. Development of the improved *B. juncea* R line VR441 made the Ogura CMS hybrid system fully functional in *B. juncea*.

The agronomic performance of the first test hybrid O2152 between the oriental mustard variety "Cutlass" Ogura CMS A line and the improved R line VR445 was evaluated in a four-replicated yield trial at four locations in 2014 (Saskatoon, Scott, Swift Current and Lethbridge). On average, O2152 yielded statistically significantly higher (17.4 percent) than the check variety Cutlass.

The improved *B. juncea* Ogura CMS R lines were developed after the improved Ogura restorer line VR441 was crossed as female with *B. juncea* line C671.

Conclusions

Brassica juncea has several inherent advantages over *B. napus*. It exhibits better drought and heat tolerance, making it well suited to production in hotter and drier Prairie regions. It is also more resistant to blackleg and pod shattering than *B. napus*.

Canola-quality *B. juncea* has been developed as an oilseed crop. With a fully functional Ogura CMS hybrid system available in *B. juncea*, hybrid breeding can be successfully used to enhance yield potential in this species.

The broad genetic base of canola-quality *B. juncea* breeding lines is essential for hybrid breeding since hybrids produced from genetically diverse parental lines are more likely to have high heterotic potential. Projects to develop genetically diverse elite canola quality *B. juncea* lines have begun.

The improved *B. juncea* Ogura CMS restorer line developed from this research will be offered under a non-exclusive license to all industry companies or institutions interested in accessing the improved restorer line. ●

*Unimproved **B. juncea** Ogura CMS restorer line O1491 has poor growth vigour (top) compared to improved **B. juncea** Ogura CMS restorer line C2436-15-1 (bottom).*

5.3 Feasibility of growing winter types of *Brassica rapa* in Alberta

KEY PRACTICE: Growers in southern Alberta may want to consider winter *B. rapa* as a suitable alternative to hybrid spring canola (*B. napus*), which could be a good fit with other winter crops grown there, especially winter wheat.

PROJECT TITLE, LEAD RESEARCHER: "Evaluation of winter *Brassica rapa* for cultivation in Alberta," 2007-11, Habibur Rahman, University of Alberta, Murray Hartman and Ross McKenzie, Alberta Agriculture and Rural Development, and Kevin Falk, Agriculture and Agri-Food Canada

GROWER ORGANIZATION FUNDER: ACPC

This study shows that the milder region of southern Alberta could be suitable for production of winter *B. rapa*, and that winter *B. rapa* could be a good fit with other winter crops grown in the area, especially winter wheat.

Habibur Rahman, University of Alberta, in collaboration with Murray Hartman and Ross McKenzie, Alberta Agriculture and Rural Development, and Kevin Falk, Agriculture and Agri-Food Canada (AAFC), led a four-year study to learn the feasibility of growing winter *B. rapa* in Alberta.

In 2007, Rahman's team collected *B. rapa* lines from Europe and China and evaluated them for two years (2007-08 and 2008-09) in field trials in Beaverlodge, Edmonton, Lacombe and Lethbridge. Then for another two years (2009-10 and 2010-11) only in Lethbridge. Rahman also generated F1 hybrids by crossing European and Chinese types and evaluating them in Lethbridge in 2010-11.

The crop was seeded in August and winter survival was evaluated the following spring. Winter *B. rapa* survived the Canadian winter for three of the four years tested in Lethbridge, where winter is generally milder compared to the other locations.

Crops seeded and grown under retained stubble showed significantly better survival compared to those grown in bare soil under tillage conditions. Among the two winter *B. rapa* gene pools, the European type showed greater winter hardiness compared to the Chinese type.

Rahman's team also experimented with growing the winter *B. rapa* plants in pots under outdoor conditions in the northern city of Edmonton. All plants were winter-killed by January, when the air temperature reached -15°C or below. In this experiment, the European and Chinese winter *B. rapa* and their F1 hybrids were used, and seeded in August.

Conclusions

Results obtained from this study show promise for the cultivation of winter *B. rapa* in the southern region of Alberta. Further research will be needed for genetic improvement of winter survival. Agronomic research will need to identify the factors affecting winter survival and yield, such as seeding date, seeding rate, stubble height, location temperature and climate, and soil temperature.

The benefits of introducing winter *B. rapa* as an alternative crop in southern Alberta include earlier maturity and greater shatter resistance compared to spring *B. napus*, however a major increase in winter hardiness is required for successful production, as well as disease resistance. The results of this study show there is potential for *B. rapa* to be introduced in southern Alberta, but more work is required to ensure success. ●

*Murray Hartman examines **B. rapa** plots for winter survival.*

As part of its research investment, Manitoba Canola Growers Association funds a specialized "molecular detection" laboratory called the Pest Surveillance Initiative (PSI) to track clubroot and other soil-borne diseases.

By Lee Anne Murphy

PSI Lab tracks clubroot in soil

PHOTO: Pest Surveillance Initiative

PSI lab director Xiaowei Guo and his team follow a precise protocol to isolate and detect clubroot DNA.

Detecting soil-borne diseases like clubroot before plant symptoms are visible gives growers time to change management practices before yield loss occurs.

In 2013, two fields in Manitoba were confirmed to have positive clubroot plant symptoms. Previous clubroot DNA concentrations in Manitoba soil samples had been less than 10,000 spores per gram of soil. That's the threshold required to consistently cause noticeable plant symptoms, says University of Alberta clubroot researcher Stephen Strelkov. So what changed in Manitoba to cause the increase in spores resulting in symptoms in these two fields?

To answer this question, the Manitoba Canola Growers Association (MCGA) and others established a specialized "molecular detection" laboratory called the Pest Surveillance Initiative (PSI). PSI works in partnership with growers, government and researchers to advance discoveries off the lab bench; optimize methodology for molecular level analysis; and provide access to molecular assays not currently offered (due to high costs per sample or a small number of users).

PSI's first project is to benchmark the current levels of clubroot across Manitoba. Several technical challenges had to be overcome before the more than 400 soil samples collected from growers' fields could be analyzed. In order to accurately and consistently detect the low levels of clubroot DNA typically found in Manitoba soils, lab staff had to modify the existing methodology. PSI addressed three areas as part of the

continued on next page

LAB CHECKS SOIL SAMPLES FOR CLUBROOT

continued from page 33

sampling project: field sample collection, DNA extraction, and quantification of clubroot DNA.

"Clubroot spores are believed to be transferred during soil movement between fields, so we maintain strict biosecurity practices between fields and between samples," says Xiaowei Guo, PSI lab director.

The PSI team follows the 'W' sampling pattern from field entry and access points as described by the Canola Council of Canada (CCC) and Manitoba Agriculture, Food and Rural Development (MAFRD). Soil from the field is transported to the PSI lab in south Winnipeg and prepared for DNA extraction. Soil is complex and has many DNA-containing organisms in it, so each sample is screened, sieved and finely ground to improve the reliability of clubroot detection.

While time consuming, this meticulous approach provides a high level of confidence that any clubroot DNA present in the sample can be detected. Knowing clubroot is present provides only part of the answer to a canola grower. PSI can also quantify the amount of clubroot DNA in soil. This is important for agronomists, because it is believed that, if clubroot is managed when low levels are present, plant symptoms and yield loss can be avoided. When higher spores per gram of soil are present, more diligent management is required to prevent clubroot from spreading between fields.

Soil samples are screened, sieved and finely ground to improve the reliability of clubroot detection. Strict clean up protocols are practiced between samples to reduce the risks of cross contamination.

HOW TO SUBMIT A SAMPLE

Detecting low levels of clubroot requires careful soil sampling to ensure a representative sample. Biosecurity measures (including cleaning and disinfecting footwear and tools between fields) reduce the risk of cross contamination. Sampling follows a 'W' pattern from the field access, as clubroot concentration has been found to be the highest at field approaches in infected fields. Clear away crop residue from the soil surface, and scoop approximately one cup of the top zero to 10 cm of soil at each 'point' along the W to obtain a total of five cups (approximately one litre) of soil. Mix the sub-samples and air-dry before submitting to PSI via mail or courier. More information on soil sampling procedure can be found at www.mbpestlab.ca/field-testing.

Who can submit a sample?

PSI accepts samples for clubroot testing from growers and landowners across Canada who are interested in knowing if clubroot is present in their soil. The sample submission portal is at www.mbpestlab.ca/field-testing.

Clubroot testing costs $125 plus GST per sample. Prepaid shipping labels are provided for tests submitted from Manitoba growers. Manitoba growers are eligible for rebates on a portion of the testing cost after completion of the biosecurity self-assessment questionnaire found at www.mbpestlab.ca/biosecurity and approval of a biosecurity plan by Manitoba Agriculture, Food and Rural Development. The Manitoba Canola Growers Association offers an additional rebate on testing fees for members. ●

PHOTO: Pest Surveillance Initiative

Clubroot DNA is reliably quantified using a quantitative polymerase chain reaction (qPCR) assay developed at the University of Alberta*. A "cocktail" of reagents is used in a stepwise manner to ensure only clubroot DNA is detected. Several modifications to the original assay were made to improve the ability to detect clubroot spores at the very low levels of DNA typically found in Manitoba soils.

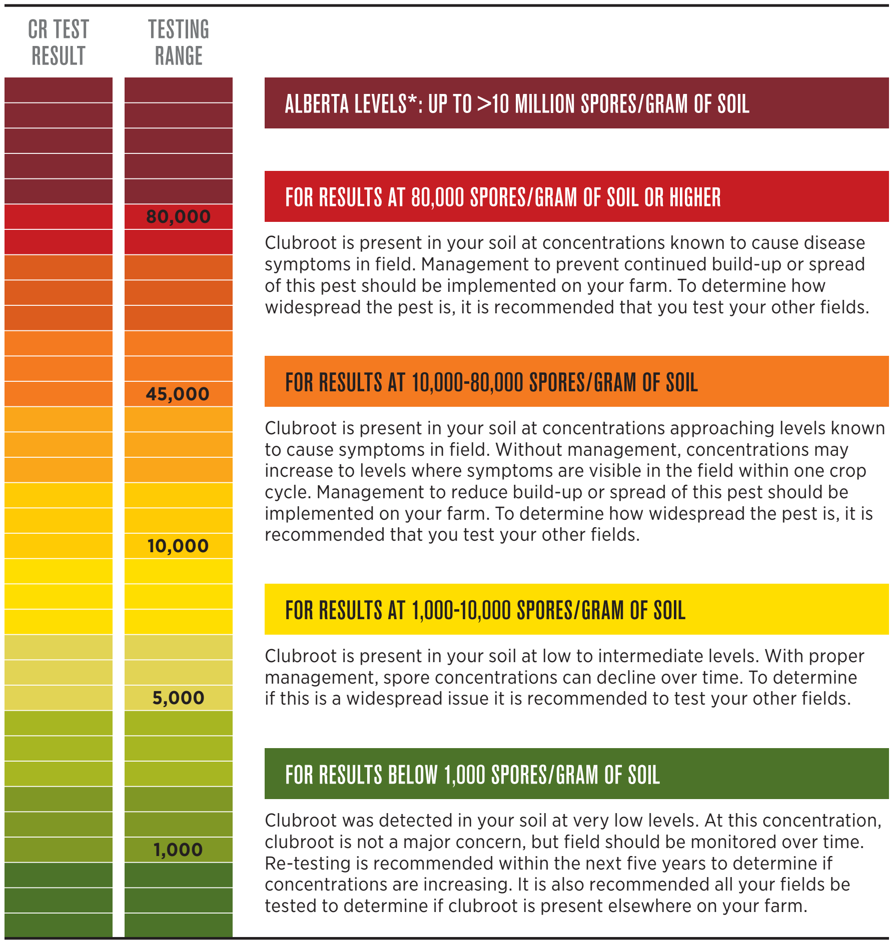
"Each clubroot DNA analysis we conduct is replicated, and standards of known spore concentration are included with every analysis to ensure analytical proficiency," Guo says. "These technical modifications have resulted in the ability of the PSI lab to detect as few as 500 spores per gram of soil."

PSI provides growers with test results along a grid that includes management tips prepared by MAFRD to minimize the spread of clubroot between fields. Results from the bench-mark sampling are updated on the PSI and MAFRD websites at the Rural Municipality level. Cumulative results from sampling indicate non detectable to high levels of clubroot present in Manitoba. As sample numbers increase, aggregate results at the Township-Range level will be displayed on the PSI website at www.mbpestlab.ca.

Facilities like the PSI represent the "next generation" of surveillance for crop pests. Their DNA-based tools provide a powerful early warning system that alerts growers to the problem before crop pests begin to cause visible symptoms. Working with DNA from soil and plant samples opens up other crop-pest combinations for the PSI, such as detection and analysis of herbicide tolerant weed species and tracking pathogen race prevalence. Field level information using advanced technology, coupled with training tools and extension programs, provide growers with the information they need to make informed management decisions. PSI is funded in part by Growing Forward 2. ●

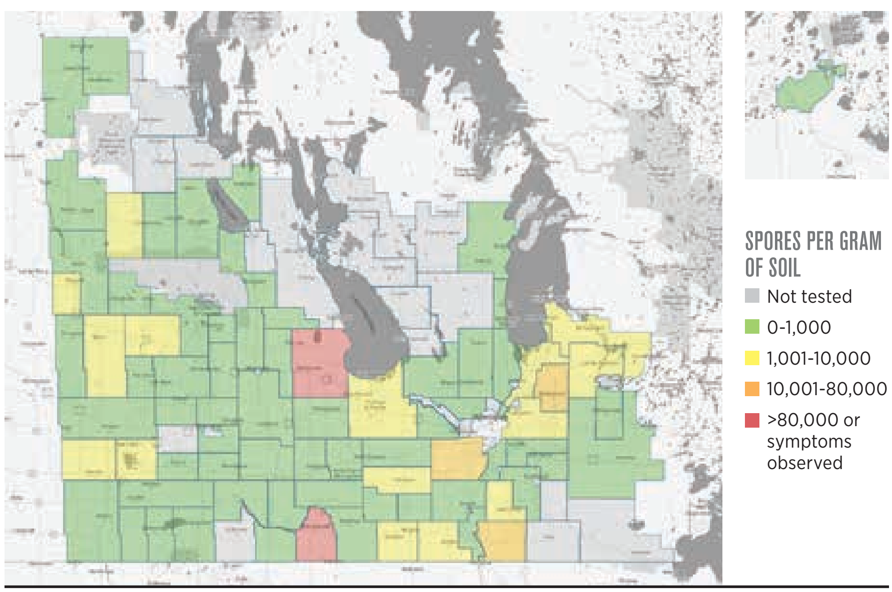
Lee Anne Murphy is CEO of the Pest Surveillance Initiative (PSI) laboratory in Winnipeg. Find out more about the lab at www.mbpestlab.ca.

*Cao,T., Tewari, J., and Strelkov, S.E. "Molecular Detection of *Plasmodiophora brassicae*, Causal Agent of Clubroot of Crucifers, in Plant and Soil," Plant Dis. 91:80-87. 2007.



An interpretive grid puts clubroot results into context for growers.

Manitoba clubroot distribution
(cumulative testing, 2009-14)



This map shows where clubroot has been detected in Manitoba.

MAP: Manitoba Agriculture, Food and Rural Development

Ultimate Canola Challenge (UCC) tests various techniques and products to identify the best management strategies for canola growers. In 2015, UCC added an objective to help growers run their own on-farm trials.

By Nicole Philp

Ultimate Canola Challenge tests new products

In an effort to reach the Canola Council of Canada's (CCC's) average yield goal of 52 bu./ac. by 2025, the Ultimate Canola Challenge (UCC) aims to test available products to see if they add benefit and profitability for canola farmers in Western Canada.

For the past three years, the UCC has used small plot research to test a range of products and practices available to producers, including different macro- and micronutrient rates, seeding rates and the use of additive canola products. Results from 2013 and 2014 are available on the Canola Research Hub at www.canolaresearch.ca.

The scope of the UCC was expanded in 2015. The intent is still to identify the best management strategies by testing various techniques and products beyond the CCC recommended best management practice. But in 2015 the UCC also looked for ways to help growers with on-farm research.

Every acre is a research acre

With changes in equipment and technology, more research is shifting to on-farm testing. The UCC has evolved to help growers conduct trials on their farms to see which practices work for them.

The goal of the field-scale UCC is to generate agronomic data on different products and practices at a scale applicable to canola growers, while also helping them discover the most effective way to carry out on-farm trials. These are useful skills now that fertilizer products no longer have to show a yield or agronomic benefit in order to be registered.

The first product tested for on-farm UCC demonstrations was boron. Canola needs boron, but research on its use in canola is limited. The experiments that have been done haven't shown a consistent yield response. In order to understand when and where there is a consistent yield response with boron, CCC agronomists worked with Western Canadian farmers to implement on-farm trials.

Jay Anderson ran a UCC trial on his farm at Cluny, AB. "I believe we as producers should assist in researching and providing information to each other," he says. "This may help us meet our goal of increased yield and more profit."

What it takes to do a trial

Things you need to do an on-farm trial well:

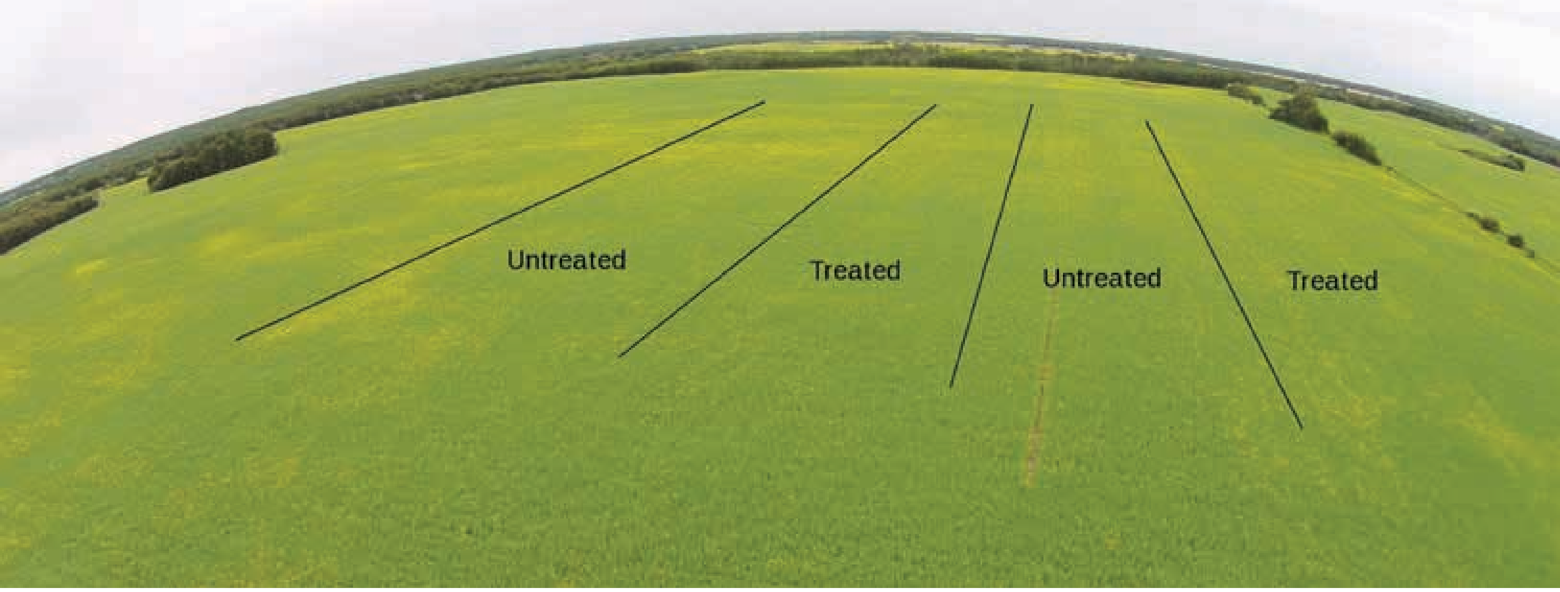
- A question that needs to be answered
- Planning
- Ability to set up replicated trials with a check strip
- Commitment to see the trial through

The most important part of the on-farm trial is a check strip. A check strip ensures that differences in crop performance are due to the treatment differences and not due to naturally occurring spatial variation. The further the check strip is from the other treatments, the less confident you can be that differences in product performance are real.

All variables must be the same across the check strip and the treatment plot, except the treatment being tested. Things like variety, seeding rate and depth, seeding speed and pest control need to be consistent across the entire trial. The check strip should reflect best management practices for canola, and should not be on field edges or areas that are not typical of the field. Ensure the check strip is wider than the width of your swather.

Jay Anderson ran a UCC trial on his farm near Cluny, AB. He says it took extra time but the results were worth the effort.

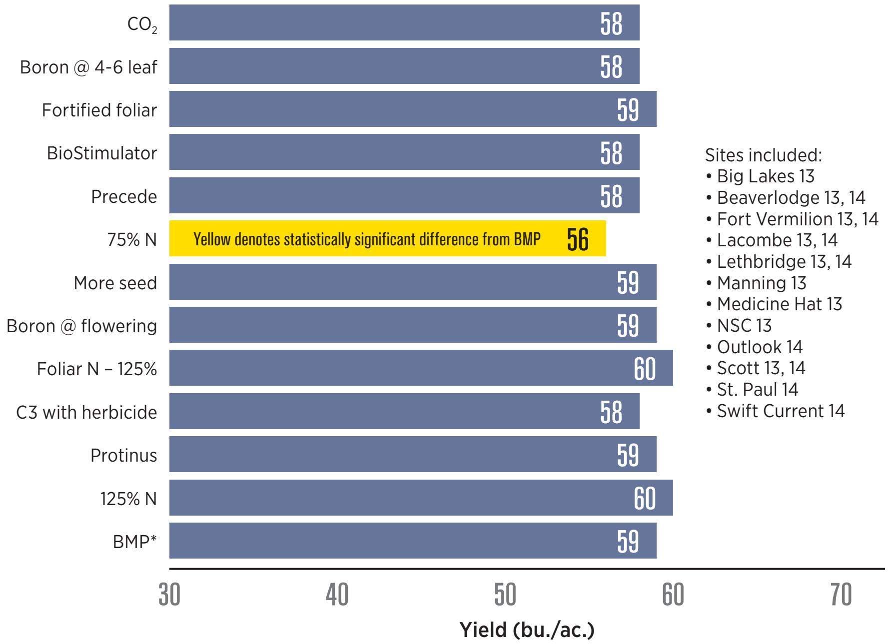
Once you have your check strip, it is time to add your treatment. If using a product that can be tank mixed, such as boron, add it after all other products have been applied. For example, if applying a fungicide to the field, apply the fungicide first to the whole test area, then go back and add the test treatment in strips across the field.



This photo taken with a drone highlights the strip boundaries at one UCC site in Medstead, SK.

Ultimate Canola Challenge yield results

All sites – 2013 and 2014 (17 locations)



All treatments, though small numerical differences exist, produced essentially the same yield. The only exception is the yield for nitrogen at 75 percent of the recommended rate.

*Best management practices (BMPs), as outlined in the UCC protocols, include: Seed into cereal stubble, preferably two or more years since last canola crop. Use a different herbicide-tolerance system than the previous canola grown on field. Seed early to mid-May, if possible, after pre-seed herbicide. Aim for 100 live seeds per square metre. Soil sample and apply N, P, K and S according to soil test and consensus adjustments from CCC agronomists and Murray Hartman. Apply herbicides at the two- to three-leaf stage. Apply fungicide for sclerotinia at the appropriate stage, unless drought conditions. Spray for insect pests that exceed economic thresholds. Swathing is the preferred harvest method.

The second most important part is replication. Don't use just one strip. Replicating the check and test strips three or four times in the test area will help determine whether the difference between plots is due to chance or treatment performance. Chance variation is caused by differences in weather, soil and other factors. These factors change significantly from field to field and year to year. Replicating your check strip and treatment plot will give you much greater confidence in your results and final conclusions about the new practice.

PHOTO: Amanda Wuchner

Also, replicating your trial over multiple years will give you an understanding of treatment performance year over year.

Mark the strips with GPS or flags. Make them wider than your swather or combine header so that, at harvest, full passes can be made through each strip. Careful harvest of the test strips is essential for a good comparison. Combine each strip separately and, ideally, weigh the results for each strip with a weigh wagon.

"Extra time definitely was needed to do the trial, but I'm not sure it was measurable or that it matters," Anderson says. "Having these results for this field, this year, under these conditions was worth the effort."

It all comes down to profitability

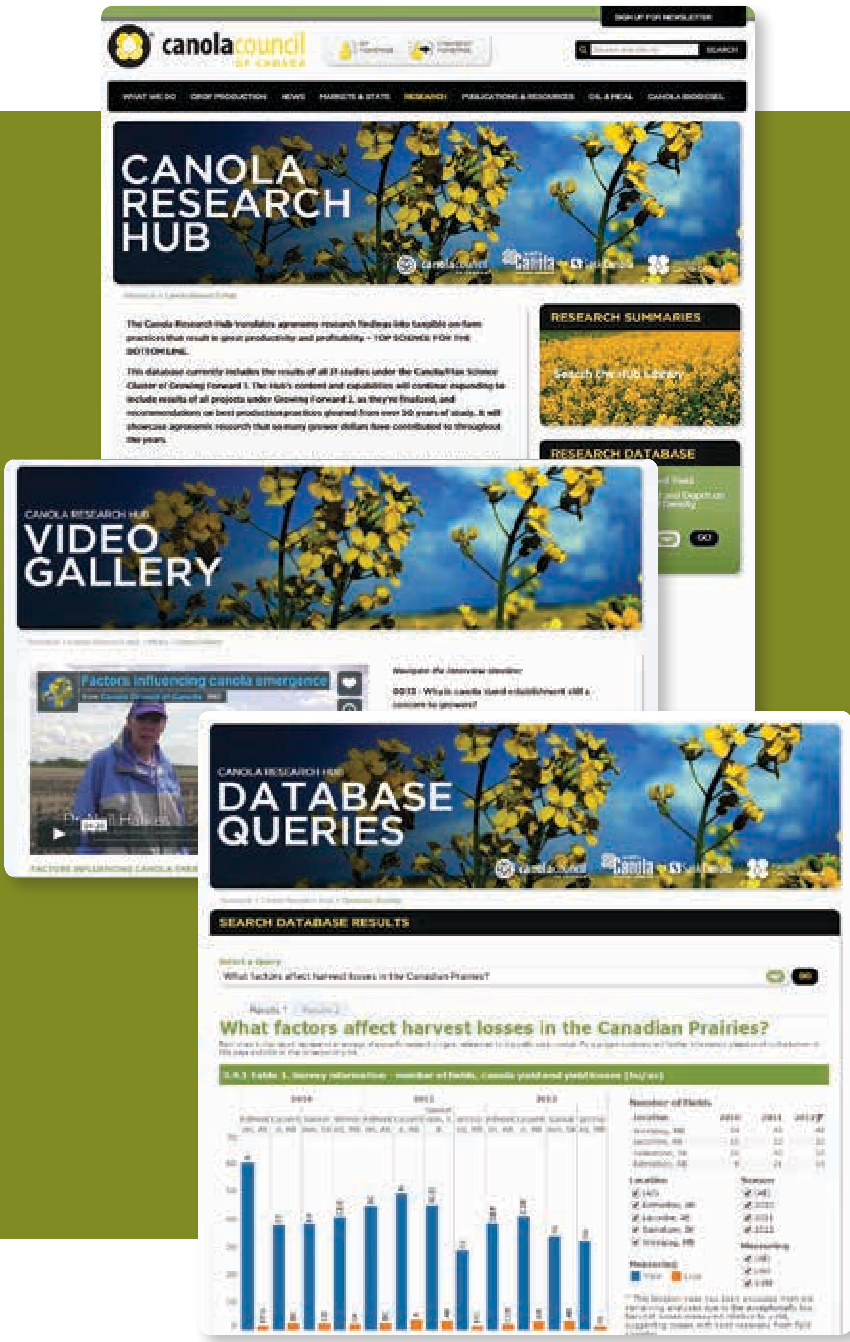
Once you have conducted your trial, run the economics to see if your treatment paid off. Economic significance occurs when the value of the average treatment effect is greater than the cost of the treatment. To evaluate a return on investment, one needs to know the average treatment response, cost, and expected crop price. Profitability margins can be calculated using these parameters. Keep in mind that profitability isn't just about yield. Non-yield factors can improve profitability (such as quality improvements or differences in lodging that improve harvestability).

For more information about the Ultimate Canola Challenge and to view 2015 trial results, visit www.canolacouncil.org/crop-production/ultimate-canola-challenge/. ●

Looking for canola research and best practices? Find it at canolaresearch.ca – providing "top science for your bottom line."

By Barbara Chabih

Inside the Canola Research Hub



Launched in January of this year, the Canola Research Hub is designed to translate agronomic research findings into on-farm practices that increase both productivity and profitability. This is a tangible return on the canola industry's investment in this research through the Canola Council of Canada (CCC), government-backed partnerships and grower check-off dollars paid through their provincial organizations.

The Canola Research Hub is a vital, first-of-its-kind science-to-farm technology transfer tool, supported by the Agriculture and Agri-Food Canada (AAFC) canola research cluster investment under Growing Forward 2 (GF2). It was developed to meet and evolve with the specific needs of several user audiences:

- Canola growers in Western Canada
- Crop production influencers (agronomists, specialists, etc.)
- Agricultural and rural media
- All other aspects of the canola value chain (scientists, seed developers, processors, exporters, scientists, etc.)

The Hub content is drawn from the 31 completed projects under Growing Forward 1 (GF1); from over 15 years of findings under the Canola Agronomic Research Program (CARP); and additional research funded by each of the provincial grower groups. This knowledge base will continue to expand as results become available, such as those from the 16 projects currently in progress under GF2.

With support from Alberta Canola Producers Commission (ACPC), Saskatchewan Canola Development Commission (SaskCanola) and Manitoba

For more about navigating the Hub, view a guided-tour tutorial, available from the landing page. Or, anywhere you see '?' click to access the FAQs.

Canola Growers Association (MCGA), the Hub can be found within the CCC's main web site and accessed directly at www.canolaresearch.ca. From the landing page, users can: navigate through a library of summaries, view and filter research data, watch video interviews and clips, access published resources, download multimedia materials, and keep up to date on science-based industry news and events.

Library of Research Summaries. Each study is categorized under one of four agronomic research pillars: Plant Establishment, Fertility Management, Integrated Pest Management or Harvest Management. Links are provided where available to full final reports, published papers, and downloadable summary PDFs.

Advanced search functions allow users to find studies based on parameters such as timeframe, principal investigator, organization, or testing location.

Research Database and Tools. The research database contains a wealth of information that can be analyzed and packaged into dashboards illustrating the science behind particular recommendations. Filtering capabilities allow the user to focus on results that are most relevant to their own conditions and concerns. These dashboards are fully referenced back to each study from which supporting data was pulled.

With these existing capabilities and the opportunities for expansion of both data and tools, the Hub will be a valuable resource towards achieving the industry goal of 52 bu./ac. by 2025.

Events and Links. This section provides access to relevant online resources, listings of current and upcoming events with links to further information and registration, as well as information and materials from past events.

Media Kit. The interactive digital media kit provides background information along with the photo and video resources that agricultural and rural media would need to effectively share the key science-based messages.

Research in the News. Advancements in canola research and the issues they are addressing frequently make the headlines. The Hub provides a comprehensive list of links to these news items within the Media section.

Image and Video Galleries. A series of video interviews provide direct answers from several researchers on location in their offices, greenhouses and test sites. Web-quality and high-resolution images are also available to download as supplements to users' own presentations and articles.

Guided Tour. For more information on navigating the Canola Research Hub, view the short tutorial available on the landing page at www.canolaresearch.ca.

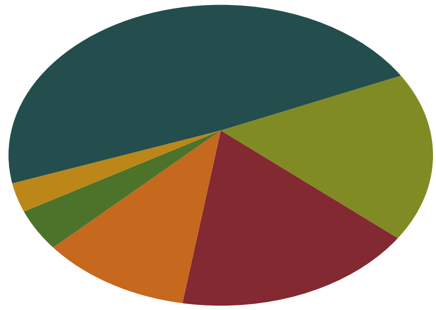
"The Canola Research Hub provides the platform for collaboration between growers, consultants, agronomists and the scientific community," says Kelly Turkington, researcher with Agriculture and Agri-Food Canada in Lacombe, AB. "This facilitates the pairing of scientific knowledge with the expertise of working with the crop to address the industry's latest hot topics and concerns." ●

Barbara Chabih is program coordinator with the Canola Council of Canada's communications department.

Canola Research Hub

Traffic by section – 2015 year-to-date

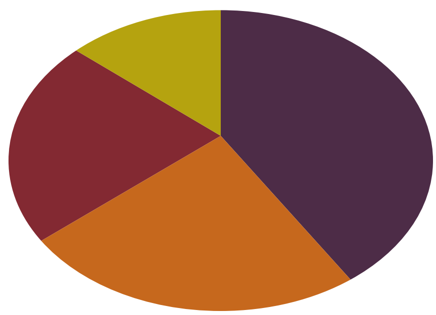
Research summaries
Database queries
Media page
Research in the news
Guided video tour
Events and links



Database queries

2015 year-to-date

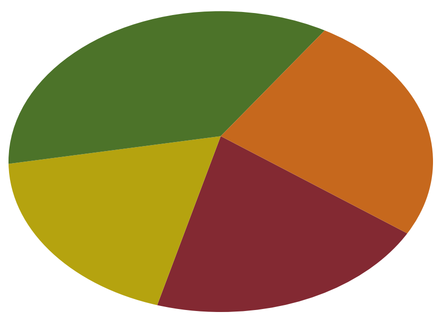
Canola emergence
Harvest losses
Yield impact of fertilizer
Flea beetle management



Research summaries

Views by category – 2015 year-to-date

Plant establishment
Integrated pest management
Harvest management
Fertility management



The federal government's $15 million investment in canola research through Growing Forward 2 combined with the canola industry's $5 million contribution (which includes input from the canola grower organizations) is funding 23 research projects for five years. Here are short descriptions and progress reports for 15 agronomy projects on that list.

Growing Forward 2
A federal-provincial-territorial initiative

Growing Forward 2 projects

PLANT ESTABLISHMENT

Seed size and seeding rate effects on canola yield and quality

LEAD RESEARCHER: Neil Harker, Agriculture and Agri-Food Canada (AAFC), Lacombe, AB
PURPOSE: With continual canola improvement and cultivar changes, a re-examination is necessary to find the optimal seed size and seeding rate for canola production in terms of impact on crop emergence, growth, yield and quality.
PROGRESS: Higher seeding rates increased early crop biomass, thousand-seed weights and seed oil content, and reduced both the number of days until the beginning of flowering and days to crop maturity. Increasing seed size also increased early canola biomass and thousand-seed weights. Days to flowering and days to the end of flowering decreased with increasing seed size. Seed size effects on canola emergence, yield or seed quality were not significant.

Investigating tolerance of canola genotypes to heat and drought stresses, and estimating root traits by electrical capacitance

LEAD RESEARCHER: Bao-Luo Ma, AAFC Ottawa, ON
PURPOSE: To develop knowledge and technology for selection of canola genotypes with better tolerance to heat and drought stresses.
PROGRESS: A non-destructive method for measuring canola root size was developed and used in subsequent experiments. In the field experiment early May planting produced better yields than the earliest planting in April and both the late May and early June plantings (which produced the two lowest yields). Increasing seeding rate from 2.5 to 5.0 kg/ha (roughly 2.5 to 5.0 lb./ac.) also increased seed yield for early-seeded canola, though further increases didn't augment yield.

Growth chamber results revealed that early flowering stage may be a critical period for canola genotypes sensitive to heat and drought stresses and for causing flower abortion. Selection for high root capacitance may also be used as a simple indicator for mitigating heat and drought stresses.

Canola rotation studies

LEAD RESEARCHER: Claude Caldwell, Dalhousie University, NS
PURPOSE: This project is built on an established rotation experiment and aims to gain a better understanding of how canola will fit into existing cropping systems.
PROGRESS: A four-year, three-location (Canning, NS, Ottawa, ON and McGill, QC) study with canola, wheat, soybean and corn in various rotations determined that continuous crop rotations showed a tendency to yield less than non-continuous rotations.

Other than the continuous canola rotation, canola did not show any significant effect on the yields of following crops. Similarly, preceding crops did not show any significant effect on canola yields. However, wheat crops tended to yield greater when following canola than other crops.

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

LEAD RESEARCHER: Alan Moulin, AAFC Brandon, MB
PURPOSE: To examine variable rate nitrogen fertility programs in terms of: the impact on canola yield in areas with consistently high production; the economic return and efficiency of fertilizer use; the relationship between the variability of canola yield and soil test nitrogen and phosphorus; variability related to soil test recommendations; and the correlation between digital elevation, landform and remote sensing data and canola yield.
PROGRESS: In 2014 and 2015 field scale trials with varying fertilizer treatments (0, 50, 100 and 150% of soil test recommendations for N) were tested in low, average and high producing field zones. Canola yield in 2014 generally increased with increasing nitrogen fertilizer rates and varied between low, average and high zones. Yield data were collected in 2015 and are awaiting analysis.

Bao-Luo Ma with AAFC Ottawa leads a study to develop knowledge and technology for selection of canola genotypes with better tolerance to heat and drought stresses. The photo on the left shows a heat stress test. The team also developed a non-destructive method for measuring canola root size.

INTEGRATED PEST MANAGEMENT

Characterization and development of new resistant sources for sustainable management of clubroot in canola

LEAD RESEARCHER: Gary Peng, AAFC Saskatoon, SK
PURPOSE: To investigate the resistance mechanisms of different clubroot resistance (CR) genes. These potential novel CR genes could provide industry with opportunities to incorporate more effective genes into canola cultivars to increase the durability of clubroot resistance.
PROGRESS: This collaborative (AAFC Saskatoon, University of Alberta and University of Manitoba) project has made progress with marking and mapping genes that control clubroot resistance in related species. The researchers have developed molecular markers for CR genes in *B. napus*, which allowed different CR genes to be transferred from *B. rapa* into canola. They have also developed double haploid lines and evaluated them for agronomic and quality traits.

The host-pathogen interaction of *Plasmodiophora brassicae* and canola

LEAD RESEARCHERS: Sheau-Fang Hwang, Alberta Agriculture and Forestry, and Stephen Strelkov, University of Alberta
PURPOSE: To investigate the host-pathogen interactions in the clubroot patho-system in order to guide the industry, management options and resistance-breeding decisions.
PROGRESS: The researchers have determined in greater detail the roles of primary and secondary zoospores in clubroot pathogenesis. They have also developed protocols to genetically transform *P. brassicae*. A draft genome of the pathogen is now being assembled to help the researchers better understand how *P. brassicae* causes clubroot disease.

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In addition, differential host cultivars were identified and will be further evaluated so the researchers can develop a Canadian clubroot differential set to more effectively characterize new strains of *P. brassicae*.

Management of clubroot in a dynamic environment

LEAD RESEARCHERS: Sheau-Fang Hwang, Alberta Agriculture and Forestry, and Stephen Strelkov, University of Alberta
PURPOSE: To develop economical and effective techniques to eradicate localized clubroot infestations using soil fumigants; to assess the impact of crop rotations that include clubroot resistant canola varieties on clubroot pathogen population dynamics in the soil; and to optimize practices for disinfesting agricultural and industrial equipment that has been contaminated with clubroot-infected plant material and/or soil-containing spores.
PROGRESS: Results indicate that non-host crops in rotations with at least a two-year break between canola crops reduce clubroot severity. Soil fumigation results strongly suggest that the fumigants tested may have potential as a tool to contain localized infestations of *P. brassicae*, particularly when the pathogen is not yet well established.

Clubroot surveillance and epidemiology

LEAD RESEARCHER: Stephen Strelkov, University of Alberta
PURPOSE: To stay ahead of clubroot disease in Western Canada through continued clubroot surveillance; to track the prevalence and predict the spread of clubroot; to monitor pathogen populations for pathotype shifts; and to evaluate clubroot resistance in fields.
PROGRESS: There were 103 new cases of clubroot found in the 648 commercial canola crops surveyed across Alberta in 2014. All severe clubroot cases were found on susceptible hybrids or hybrids of unknown resistance. In the canola crops confirmed to be resistant hybrids, symptoms of clubroot were generally absent or very mild. Nonetheless, some resistant cultivars with higher than expected levels of clubroot were found, and the corresponding *P. brassicae* populations will be isolated and tested for any shifts in virulence patterns. An additional 279 new records of pathogen infestation were reported by collaborating municipal personnel, for a total of 382 clubroot-infested fields in 2014.

Aster yellows and swede midge: New threats to prairie canola production

LEAD RESEARCHER: Owen Olfert, AAFC Saskatoon, SK
PURPOSE: To investigate the distribution, economic impact, thresholds, host plant resistance, and management of aster yellows vectored by leafhoppers and swede midge in western Canadian canola production.
PROGRESS: Swede midge survey results found that populations are increasing and have spread westward across Saskatchewan. Fortunately, economic impact was mitigated by how late in the season swede midge appeared. Regarding management options, preliminary results showed that *Camelina sativa* was less damaged by swede midge than other crucifers, and it may provide a source of resistance to the pest. Collection of two undescribed parasitoids of swede midge added to potential management options.

Aster yellow survey results showed incidence was very low in leafhopper populations and in canola fields in 2015, although leafhoppers were present and reproducing in neighbouring cereal fields. In 2015 *Macrosteles quadrilineatus*, the aster leafhopper, was the only leafhopper species to test positive for the disease, at a level of 1% of all leafhoppers tested.

Development of pest management decision-making protocols for the swede midge in canola

LEAD RESEARCHER: Rebecca H. Hallett, University of Guelph, ON
PURPOSE: To develop pheromone-based action thresholds for swede midge in canola and to optimize insecticide application timing (in terms of plant growth stage) for maximum yield protection. This is especially necessary because swede midge have multiple, overlapping generations each year and canola plants are susceptible to damage at multiple growth stages.
PROGRESS: Strip trials found that multiple insecticide applications were required to reduce swede midge damage, and early or mid-timing applications were more effective than later ones. Early applications should be made when a cumulative ≥20 midges are captured (based on four pheromone traps per field with swede midge counts beginning at the cotyledon stage) prior to the four-leaf stage.

In addition, in preliminary pheromone-based action threshold trials, no differences were reported between the pheromone and plant stage based insecticide timing treatments, despite the use of an additional spray in the latter.

Improved integrated crop management with beneficial insects

LEAD RESEARCHER: Julie Soroka, AAFC Saskatoon, SK
PURPOSE: To investigate the phenology of diamondback moth larvae and its parasitoids (including its principal parasitoid *Diadegma insulare*) in four eco-regions of Saskatchewan at three different times in the canola growing season.
PROGRESS: Considerable information about the effects of temperature on the development of both diamondback moth and *D. insulare* was collected. New recorded minimum temperature thresholds for the survival of both diamondback moth and *D. insulare* were reported. Also, the expression of a heat shock protein in both diamondback moth and *D. insulare* was revealed and may provide a viable means of tracking arthropod responses to changing climates.

Overall, three scientific publications based on this project are in press or have been published and two other manuscripts are in progress.

Canola sustainability: Risk mitigation

LEAD RESEARCHER: Neil Harker, AAFC Lacombe, AB
PURPOSE: To determine if the risks of growing canola in tighter rotations can be mitigated by: planting different cultivars in subsequent years; adding inputs that are higher than normal

(fertilizer, seed); or unusual practices (such as enhanced seed treatment, chaff removal, or mixing cultivars at seeding). **PROGRESS:** While there have been trends for successful mitigation in some treatments, none of these strategies have worked as well as simply rotating canola with another crop such as wheat or field pea. When canola cultivars can be classified according to their specific blackleg avirulence genes, cultivar rotations will be better designed and seed mixing strategies will be more effective.

The environmental footprint of canola and canola-based products

LEAD RESEARCHER: Vern Baron, AAFC Lacombe, AB
PURPOSE: To study farm-gate canola carbon footprints and determine the greenhouse gas intensity for canola production using best management practices in a high yield and high input region.
PROGRESS: The major contributors to farm-gate canola footprint were the production and use of fertilizers and the use of field equipment for on-farm practices and tillage. The environmental profile of canola production per tonne has improved since 1990 and the carbon footprint was reduced between 1990 and 2010. Reductions in environmental effects were the result of increased yields and plant biomass, the adoption of herbicide tolerant and hybrid canola, and improved crop production management practices. These practices included the shift to conservation tillage and direct seeding, as well as improved weed management strategies.

The field study showed that early-planted canola provided a higher net income but had higher nitrous oxide emissions, while all treatments sequestered more carbon than they released through respiration.

Operational models to forecast canola growth stage, sclerotinia risk and yield in Western Canada

LEAD RESEARCHER: Rishi Burlakoti, Weather Innovations
PURPOSE: To develop models for forecasting canola growth stage, sclerotinia stem rot risk and canola yield on a near real-time basis.
PROGRESS: Preliminary results from the 2014 small plot and field-scale trials show that current varieties require more heat units than older varieties, especially from flowering to maturity. The highest sclerotinia stem rot incidence was observed in the small plot trials and the short season variety was the most affected. The yield prediction model that was tested underestimated overall yield, indicating that more work must be done in yield modeling. A preliminary phenology model is still in progress and will be updated and fine-tuned as more phenological data becomes available.

Research by Digvir Jayas determined that canola seeds with moisture content of eight percent or less can be stored for 10 months in grain storage bags.

HARVEST MANAGEMENT

Feasibility of bag storage systems for canola storage under Prairie conditions

LEAD RESEARCHER: Digvir S. Jayas, University of Manitoba
PURPOSE OF STUDY: To investigate the feasibility of bag storage systems for canola on the Canadian Prairies by quantifying canola quality values throughout the storage duration.
PROGRESS: Results determined that canola seeds with moisture content of eight percent or less could be stored for 10 months in silo bags. Seeds with 10 percent moisture could be stored for seven months without seed quality deterioration and seeds with 12 percent moisture could maintain their grade if unloaded before the ground thawed. Also, the application of lime (calcium carbonate) on the ground of the silo bag site can reduce rodent activity. •

Canola growers across the Prairies fund dozens of research projects with their levy payments to SCDC, ACPC and MCGA. Many of those projects are funded jointly through CARP —an arrangement that has been ongoing for almost 30 years. Other projects are funded through arrangements with other organizations listed in these summaries.

Here are short descriptions and updates for all ongoing projects directly funded by provincial canola grower organizations.

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

LEAD RESEARCHER: Chris Holzapfel, IHARF

FUNDING: SaskCanola

PURPOSE: The objective of this ongoing project is to evaluate the feasibility of growing canola at row spacing levels exceeding 30 cm (12″) and explore the potential implications of wider row spacing on side-banded N recommendations, optimal seeding rates and competition with weeds.

PROGRESS: Despite high weed pressure in both years, a single in-crop herbicide application kept weed competition acceptably low at all row spacing levels. The potential for increased risk of seedling injury with side-banded N at very wide row spacing exists, but N effects on emergence were similar and variable for 25 to 41 cm spacing. Despite the reduction in plant populations, particularly in 2013, canola responded well to side-banded N with sequentially increasing seed yields at all N rates, with maximum yield increases of 40 percent in 2013 and 370 percent in 2014. Averaged across other factors, row spacing effects on seed yield have been minimal or insignificant.

Glossary of abbreviations

AAF
Alberta Agriculture and Forestry (was AARD)

AAFC
Agriculture and Agri-Food Canada

ABC
Alberta Barley Commission

ACIDF
Alberta Crop Industry Development Fund

ACPC
Alberta Canola Producers Commission

ADF
Agriculture Development Fund (Saskatchewan)

AFC
Agriculture and Food Council

AIBIO
Alberta Innovates Bio Solutions

AIP
Agricultural Innovation Program (AAFC matching initiative for GF2)

AITF
Alberta Innovates Technology Futures

APG
Alberta Pulse Growers

ARDI
Agri-Food Research and Development Initiative (Manitoba)

ASCA
Alfalfa Seed Commission Alberta

ASP-GF2
Agriculture Stewardship Program — Growing Forward 2 (Saskatchewan)

AWC
Alberta Wheat Commission

CARP
Canola Agronomic Research Program

CCC
Canola Council of Canada

CGDP
Canola Germplasm Development Project (SCDC)

GF2
Growing Forward 2

IHARF
Indian Head Agricultural Research Foundation

MCGA
Manitoba Canola Growers Association

PAMI
Prairie Agricultural Machinery Institute

PGA
Potato Growers of Alberta

SARDA
Smoky Applied Research and Demonstration Association

SaskCanola
Saskatchewan Canola Development Commission

WGRF
Western Grains Research Foundation

FERTILITY MANAGEMENT

Understanding soil variability for effective zone management in precision agriculture: An evaluation of sensor-based mapping

LEAD RESEARCHER: Ken Coles, Farming Smarter
FUNDING: ACPC, Farming Smarter
PURPOSE: This study seeks to evaluate soil sensors as tools for understanding the spatial variability of soils, and their relationship to crop productivity. Soil sensors studied (Veris and EM38) generate geo-referenced maps of electrical conductivity, pH, organic matter and accurate digital elevation models when coupled with enhanced guidance systems.
PROGRESS: Preliminary results indicate that, despite the complexity of soil variability, electrical conductivity appears to be a reliable and static indicator of underlying spatial patterns in agricultural soils. Further analysis will assess the value of these layers of mapped data to manage production using variable rate technology.

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(Above and centre)
Farming Smarter researchers calibrate the EM38 soil sensor, which is pulled across the field to measure electrical conductivity.

(Bottom)
A hydrometer determines the sand, silt and clay (texture) of soil. With this information, Farming Smarter researchers can determine how well the electrical conductivity (EC) readings from the soil sensors can predict varying texture across a field. More sand means less soil water and gives a lower EC value. More clay gives higher readings.

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Transformations and fate of seed-placed sulphur fertilizers in Saskatchewan soils

LEAD RESEARCHER: Jeff Schoenau, University of Saskatchewan
FUNDING: SaskCanola, ADF
PURPOSE: To determine the fate of different forms of sulphur fertilizer applied in the seed-row of canola, peas and wheat.
PROGRESS: Little or no crop yield response (in wheat, canola or pea) to added sulphur (S) fertilizer may be anticipated in the Brown Soil Zone when adequate supplies of sulphate S are present in the sub-soil (as at the site used in this study). Soils with high organic matter and with good mineralization capacity for S, such as Black chernozems, also show reduced response. The most responsive soil to S fertilization was the Gray Luvisol, owing to lack of subsoil sulphate reserves and low S mineralization potential. Even with a history of good S fertility management, canola is likely to respond significantly to S fertilization on soils like these. As part of this study, the SXRMB beamline at the Canadian Light Source was used to track the oxidation of S fertilizers like elemental S into more oxidized forms, and eventually into plant-available sulphate. Results indicate oxidation of the elemental S fertilizer form (Sulvaris Vitasul) proceeded over the eight weeks following application in this study.

Improving growth and yield of canola with the novel fungal endophyte *Piriformospora indica*.

LEAD RESEARCHER: Janusz Zwiazek
FUNDING: Agriculture Funding Consortium, ACPC
PURPOSE: This project examines the effects of the novel growth-promoting fungus *P. indica* on the growth and yield of canola plants subjected to different phosphorus and nitrogen fertilization levels and environmental stresses. The main objective is to determine whether inoculating canola with this fungal endophyte can increase stress resistance, growth and yield, and reduce fertilization levels.
PROGRESS: The researchers examined the effects of *P. indica* on growth and yield of canola plants supplied with full (100 percent) and reduced (50, 25 and five percent) concentrations of nitrogen and phosphorus, and the drought stress responses. Seed production was strongly increased by fungal inoculation in canola plants regardless of phosphorus fertilization levels. However, the fungus had little effect on the growth and yield of canola plants subjected to drought stress and nitrogen deficiency.

Long-term residual effects of alternative nitrogen management practices in canola production systems

LEAD RESEARCHER: Ramona Mohr, AAFC Brandon
FUNDING: SaskCanola
PURPOSE: The objective is to determine the effect of different nitrogen (N) management practices over the course of a four-year canola-wheat rotation on N availability in subsequent growing seasons. Nitrogen availability following a crop failure versus a "bumper crop" is also being assessed.
PROGRESS: Year 2 of 2. Initial results suggest that N availability was influenced more by the productivity of the preceding crop than by preceding N management. In 2014, unfertilized wheat grown after a poor canola crop yielded 115 percent of unfertilized wheat grown after a high-yielding wheat crop. Higher Greenseeker readings and grain protein levels suggested these higher yields were associated with greater N availability.

Assessing current soil test-based fertilizer recommendations for direct seeding systems to optimize crop production and contribution margin

LEAD RESEARCHER: Kabal S. Gill, SARDA
FUNDING: ACPC, ABC, AAF, local municipalities, SARDA
PURPOSE: Starting from 2010, cereal (wheat or barley) and canola responses to fertilizer rates (0, 60, 100 and 140 percent of soil-test based fertilizer recommendations) were assessed under conventional (CN) and direct seeding (DS) systems.
PROGRESS: From 2010 to 2014, crop yields always increased significantly with 60 percent rates while differences between 60 and 140 percent rates were not always significant. Maximum yields were observed at 100 or 140 percent fertilizer rates. Crop yields were usually higher from the DS system in dry years while no consistent differences between DS or CN systems were observed in years with normal rainfall. No consistent interactions were observed between the seeding systems and fertilizer recommendations. Compared to the cereals, canola yield with no fertilizer showed relatively steeper decline resulting in increased response to fertilizer with passage of years.

Identification of superior crop rotations to minimize inputs, optimize crop production and maximize contribution margin

LEAD RESEARCHER: Kabal S. Gill, SARDA
FUNDING: ACPC, APG, ABC, AAF, local municipalities, SARDA
PURPOSE: This study compared canola and wheat monocultures to two- and three-year crop rotations that included peas, barley and flax. The study began in 2009. Maximum amounts of N, P, K and S fertilizers were used in the canola monoculture.

INTEGRATED PEST MANAGEMENT

PROGRESS: Including peas in a rotation reduced N use while absence of canola in a rotation reduced S use. Compared to crop rotations, canola monoculture was more sensitive to yield loss than the wheat monoculture. The 2010 to 2014 results showed average crop rotation benefits of 11.3 bu./ac. (20 percent) over the canola monoculture and 5.7 bu./ac. (nine percent) over the wheat monoculture.

Field proofing the use of plant hormones to increase canola, wheat and pea yields

LEAD RESEARCHER: Jocelyn Ozga, University of Alberta
FUNDING: ACPC, APG, AFC, University of Alberta, Syngenta
PURPOSE: Among the classes of plant growth regulators, auxins show some promise for enhancing the vegetative growth and yielding ability of specific crops. The project tested foliar application of the auxins 4-chloroindole-3-acetic acid (4-Cl-IAA) and 4-methylindole-3-acetic acid (4-Me-IAA) at an early reproductive development stage of canola, wheat and field pea.
PROGRESS: Overall, data suggest that one application of the auxins 4-Cl-IAA or 4-Me-IAA prior to or at flowering has the ability to increase seed yield of canola, wheat and field pea crops. Further testing is required to broaden our knowledge of the conditions and genotypes necessary to obtain optimal auxin response for increased seed yield under a variety of environmental conditions.

Development and implementation of a weather-based, near real time, crop insect pest monitoring/ prediction model and program for Alberta

LEAD RESEARCHER: Daniel Itenfisu, AAF Edmonton
FUNDING: ACPC, AAF
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 pest phenology across Alberta and assist in devising effective pest management practices.
PROGRESS: Year 2 of 3. Progress includes a thorough literature review on pest forecasting systems, identification of appropriate pest models, design and implementation of pest phenology surveys and monitoring protocols across 100+ sites in 2014 and 2015. The researcher also made progress to design, deploy and operate near-real-time portable weather stations, and disseminated results through biweekly pest prediction maps.

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A portable near-real-time weather station monitors weather variables in a field near Brooks, AB. Data will be used to develop a weather-based insect prediction model.

PHOTO: Swaroop Kher

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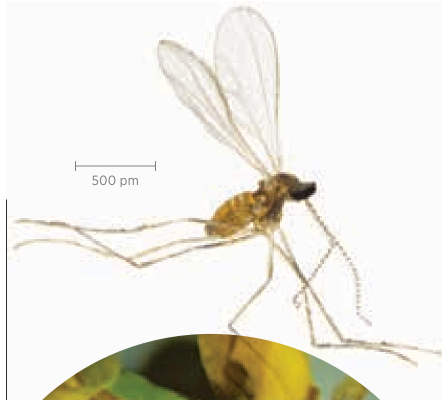

Swede midge is the focus for three ongoing studies. Damage has been low in most regions so far, but the range continues to expand. Swede midge was confirmed in two Alberta fields in 2015. These photos show the swede midge adult, larvae inside a canola floret, and one example of midge damage symptoms.

PHOTOS: Left: Owen Olfert, AAFC Saskatoon; Top right: Tyler Wist, AAFC Saskatoon; Lower right: Larry Grenkow, AAFC Saskatoon

Aster yellows (AY) and swede midge: New threats to Prairie canola production

LEAD RESEARCHERS: Tyler Wist, Chrystel Olivier, Owen Olfert, Julie Soroka, Tim Dumonceaux, AAFC Saskatoon
FUNDING: ACPC, WGRF, ACIDF
PURPOSE: The purposes are to: determine the extent of infestation, evaluate yield losses, develop economic thresholds and forecast warnings, and identify resistant canola lines for AY and swede midge. AY: In the study years, the number of aster leafhoppers in canola across Saskatchewan was low and corresponded to a negligible incidence of AY symptoms in canola fields and commercial cultivar trials. However, aster leafhoppers were present and reproducing in cereal crops so "spillover" of adult leafhoppers at the edges of canola fields is probable.
PROGRESS: Year 3 of 3. AY: Several promising new techniques for the determination of AY infection in plants and leafhoppers have been developed, including a field test that yields results in less than one hour and is nearly ready for field testing. Swede midge: Although pheromone traps from only three of 150 locations across the Prairies tested positive for adult swede midge in 2015, damage surveys from Yorkton to west of Lloydminster found swede midge larvae in 15 canola fields. Two fields were in Alberta, the first record of the pest in that province.

Monitoring of swede midge populations in Saskatchewan and determining the impact of swede midge in different growth stages in canola

LEAD RESEARCHERS: Owen Olfert, Julie Soroka, AAFC Saskatoon
FUNDING: SaskCanola
PURPOSE: The purpose is to investigate the correlation between swede midge infestation and canola growth stage by determining the effects of early and late seeding on canola seed yields in midge-infested commercial canola fields.
PROGRESS: Year 2 of 3. Swede midge injury to canola was again light in 2015, but varied by location. One location — the driest site — had less injury than in 2014; one site had similar injury levels both years; and two sites had more injury in 2015 than in 2014. Few differences were found in injury between early and late seeded plots, and among plots using seed treated or not treated for flea beetle control.

Ecology of swede midge — host plant interactions

LEAD RESEARCHERS: Owen Olfert, Julie Soroka, AAFC Saskatoon
FUNDING: ADF, WGRF, SaskCanola
PURPOSE: The purpose is to investigate host plant susceptibility or resistance factors to swede midge, with the ultimate aim of identifying host plant resistance to the pest.
PROGRESS: Year 1 of 4. Researchers are currently compiling lists of plant species known to be swede midge hosts or non-hosts, collecting seeds of plants on the lists, and developing bioassay techniques in order to start experiments on midge-plant interactions.

Detection, identification and control strategies for cutworms on the Prairies

LEAD RESEARCHER: Kevin Floate, AAFC Lethbridge
FUNDING: ACPC, SaskCanola, AAFC
PURPOSE: This project was initiated to facilitate methods to identify and control species of cutworms that are pests of canola.
PROGRESS: Year 4 of 4. Results include: (1) the development of a molecular-based tool to identify key species of pest cutworms; (2) surveys of cutworms across the Prairie provinces; (3) identification of wasps and flies parasitic on these cutworms; (4) laboratory studies to assess the ability of select parasitoid species to develop on different cutworm pest species; (5) studies to assess the effect of seed cultivar, seed treatment and fertilizer regime on cutworm development; and (6) a cutworm identification guide (in preparation) for use by the agriculture sector.

Seed treatment as an alternative method to control aster yellows

LEAD RESEARCHERS: Bob Elliott and Chrystel Olivier, AAFC Saskatoon
FUNDING: SaskCanola
PURPOSE: The purpose is to evaluate seed treatments for control of leafhoppers and aster yellows (AY).
PROGRESS: Year 3 of 3. Laboratory assays on AY-infected leafhoppers at the cotyledon and early true-leaf stages identified treatments that provide the best leafhopper control and suppression of AY symptoms. In field trials on two canola types, leafhopper populations were very low whereas flea beetle populations were extremely high. Evaluations focused on identifying seed treatments that provide the best protection against flea beetle damage and the greatest improvement in seedling establishment, plant growth and seed yield.

Pollination management to maximize canola yield

LEAD RESEARCHERS: Shelley Hoover, AAF, Steve Pernal, AAFC Beaverlodge, Ralph Cartar, University of Calgary
FUNDING: Alberta Beekeepers Commission, ASCA, ACIDF, CCC
PURPOSE: The goal of 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 2 of 3. Preliminary results indicate that insect visitation to 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. In addition, data on honey bee hive management indicates a strong relationship between population size and honey production, however colonies managed as single brood boxes collected equivalent pollen to those managed in two brood boxes. Preliminary results from comparisons of honeybee hives used to pollinate hybrid seed production crops indicate that they produced less honey than those used strictly for honey production. Data on comparisons of colony health are ongoing. Observations in hybrid seed fields indicate that there are numerous behavioural interactions within and among pollinator species. Data also indicate that nectar resources are limited in these crops due to the high abundance of bees.

Coordinated surveillance, forecasting and risk warning systems for field crop insect pests of the Prairie ecosystem

LEAD RESEARCHER: Owen Olfert, AAFC Saskatoon
FUNDING: ACPC, SaskCanola, MCGA, WGRF
PURPOSE: The aim is to develop and implement insect surveillance programs to keep the Canadian agriculture industry informed of the risks to crop production from pest species and to highlight and conserve their natural enemies.
PROGRESS: Year 2 of 5. Sampling protocols have been developed or adapted for large-scale monitoring of a number of the major pests, and spatial analysis techniques have been developed and implemented to forecast their risks to crop production. Weekly updates were provided during the 2015 growing season and a new blog was developed for the Prairie Pest Monitoring Network: http://prairiepestmonitoring.blogspot.ca/.

Improving lygus management for current canola and faba bean cultivars

LEAD RESEARCHER: Hector Carcamo, AAFC Lethbridge
FUNDING: ACPC, ACIDF, APG
PURPOSE AND PROGRESS: Year 4 of 4. Lygus density treatments in the cages at all three sites — Lethbridge, Lacombe and Beaverlodge — seem to have succeeded in creating the variable insect pressures required to validate the thresholds using current hybrid cultivars. The cage study was supplemented with a plot spray trial. Preliminary regression analysis suggests a stronger negative relationship between lygus and yield during dry years. Yield and insect data are being processed for year four. Results will be presented at extension meetings in the winter.

Biology and management of glyphosate-resistant kochia

LEAD RESEARCHER: Bob Blackshaw, AAFC Lethbridge
FUNDING: ACPC, AWC, ABC, ACIDF, WGRF
PURPOSE: This study aims to identify cost-effective alternative herbicides to control glyphosate-resistant kochia in pre-seed, chemfallow, in-crop and post-harvest applications. It also looks to determine the timing of seed maturity, seed production potential, and seed dormancy characteristics of glyphosate-resistant kochia.
PROGRESS: The most effective rate of existing herbicides has been determined and conveyed to growers. Several

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unregistered herbicides show potential to control glyphosate-resistant kochia and data has been forwarded to the respective crop protection companies. Kochia emerging as late as mid-August can set viable seed before a killing frost. Seed loses dormancy a few weeks after maturity.

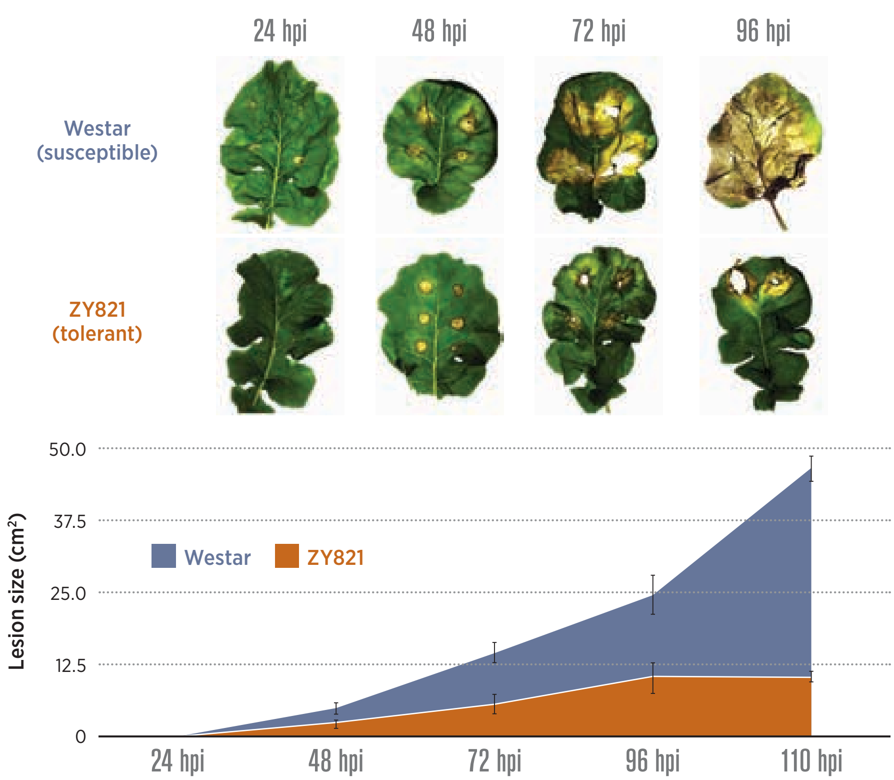
Emergence timing and management of cleavers in Saskatchewan canola crops

LEAD RESEARCHER: Chris Willenborg, University of Saskatchewan
FUNDING: SaskCanola, ADF
PURPOSE: Emergence timing of cleavers varies by population and most populations exhibit some level of spring and fall emergence. This study will work on differentiating speciation within the cleavers population, and look for potential herbicide solutions to cleavers management.
PROGRESS: Work is nearly complete. One of the products studied, clomazone, should soon be registered ahead of canola, and quinclorac is registered but does not have MRLs yet. Both of these provide excellent cleaver control when tank-mixed with glyphosate, glufosinate or imazapyr and imazamox.

Performance and cost of field scouting for weeds and diseases using imagery obtained with an unmanned aerial vehicle

LEAD RESEARCHER: Christoph Neeser, AAF
FUNDING: ACPC, AAF, ACIDF, WGRF, APG, AWC, ASCA, PGA
PURPOSE: The aim is to assess the usefulness of small, unmanned aerial vehicles (UAVs) for field scouting of weeds and diseases in major field crops.
PROGRESS: Images of alfalfa, barley, canola, peas, potatoes and wheat were captured over the 2014 growing season. For verification, selected areas were photographed from the ground following the capture of the UAV images. The image analysis is still in progress, but it is already clear that the 5 to 6 cm/pixel ground resolution is insufficient to substitute for in-person field scouting. Adjustments to the recommended protocol will focus on a two-stage approach, which will consist of identifying general areas of interest that will be inspected at close range with the use of a multi-rotor type of UAV.

*University of Manitoba researchers sequenced leaf tissue in tolerant and universally susceptible cultivars of **Brassica napus** to identify genes and plant defence pathways responsible for tolerance against the sclerotinia pathogen.*



Proof of concept to build a nano and antibody based pathogen-specific plant disease monitoring device for agricultural pest management

LEAD RESEARCHER: Xiujie Li, Alberta Innovates
FUNDING: ACIDF, ACPC, AITF
PURPOSE: The long-term goal is to develop an in-field sensor for the detection of plant disease pathogen levels (for disease prevention) and transfer the results to an electronic device in real-time fashion. The purpose is to prove that the potential sensor is feasible for spore detection.
PROGRESS: The study proved that lab nano-sensing technology could detect *S. sclerotiorum* ascospores and *Leptosphaeria maculans* with specificity. The spores and the impedance measurement on the sensor have a linear relationship. An in-field device is in progress.

Getting one step closer to sclerotinia control through cultivar resistance and biological applications

LEAD RESEARCHERS: Mark Belmonte, Dilantha Fernando and Teresa deKievit, University of Manitoba
FUNDING: ACPC, SaskCanola, MCGA
PURPOSE: This study aims to identify genes and gene regulatory networks responsible for canola tolerance to sclerotinia in the presence of a bacterial biocontrol agent *Pseudomonas chlororaphis*. Tools include laser micro-dissection, next generation RNA sequencing and robust bioinformatics strategies.

Researchers have developed a PCR-based method to measure the amount of DNA of the sclerotinia stem rot pathogen in canola petals.

PROGRESS: Researchers sequenced leaf tissue in tolerant and universally susceptible cultivars of *Brassica napus* in the presence of the fungus, the bacteria or both. They identified a suite of genes and plant defence pathways responsible for tolerance against the sclerotinia pathogen.

Improving sclerotinia disease control in edible beans and canola

LEAD RESEARCHER: Michael Harding, AAF
FUNDING: ACPC, WGRF, APG
PURPOSE: The objectives are 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 3 of 4. A few synergistic combinations have appeared with the hope they will be verified to be consistent in all years tested. One of the resistance priming chemicals applied to seed has shown significant white mold 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.

Effects of genetic sclerotinia tolerance, foliar fungicide applications and their interactions on the incidence and severity of sclerotinia stem rot infection in Argentine canola

LEAD RESEARCHER:
Chris Holzapfel, IHARF
FUNDING: SaskCanola
PURPOSE: A three-year field study was initiated at five locations in 2013 to evaluate the merits of genetic tolerance and foliar fungicide applications for reducing sclerotinia stem rot infection in *Brassica napus* under field conditions. A secondary objective was to determine if, and under what conditions, foliar fungicide applications might be required when growing a cultivar with genetic tolerance to this important disease.
PROGRESS: While foliar fungicides tended to provide less consistent benefits with the tolerant hybrid, the results are not necessarily conclusive. At locations where disease was observed, foliar fungicides reduced sclerotinia incidence but only significantly increased seed yields for 45H29 at Melita in 2013 (according to the overall F-tests). So far, this study shows there is no benefit to a dual fungicide application over a single application, but this may not be the case under extremely high disease pressure. Field trials were conducted at all five locations again in 2015, the final growing season of the study.

Development of a rapid quantitative detection method for sclerotinia stem rot inoculum to aid disease risk assessments and fungicide spray decisions

LEAD RESEARCHER: Stephen Strelkov, University of Alberta
FUNDING: SaskCanola, ACPC, MCGA
PURPOSE: The purpose is to develop and refine a rapid quantitative method for pathogen detection on canola and flower petals.
PROGRESS: Final year. A quantitative PCR-based (molecular) method to measure the amount of DNA of the sclerotinia stem rot pathogen in canola petals has been developed. This method is both highly specific and highly sensitive for the stem rot pathogen. The relationship between the amount of pathogen DNA on the canola petals and final disease incidence and severity was investigated by collecting samples and monitoring disease development in fields in central Alberta and across the Prairies. Various parameters such as seeding date were also monitored and recorded. Analysis of this large dataset is nearing completion and will allow validation of the predictive potential of the test.

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Analysis and monitoring of *Leptosphaeria maculans* race dynamics in Western Canada for effective use of cultivar resistance in management of blackleg on canola

LEAD RESEARCHER: Gary Peng, AAFC Saskatoon
FUNDING: SaskCanola, ACPC, MCGA, WGRF, ACIDF, ARDI and seed companies
PURPOSE: Analyze and monitor the blackleg pathogen population using Westar trap plots scattered on the Prairies to 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. Additionally, certain severely diseased fields will be investigated to understand the role of *L. maculans* race changes in causing the cultivar to lose resistance to blackleg.
PROGRESS: Counts of 196 and 146 *L. maculans* isolates were collected from trap plots in 2012 and 2013 respectively, and tested on 14 host differentials for the presence or absence of avirulence (*Avr*) genes in the pathogen population. Overall, *AvrLm1*, *AvrLm3*, *AvrLm9*, *AvrLep1* and *AvrLep2* were found at low frequencies while *AvrLm2*, *AvrLm4*, *AvrLm6* and *AvrLm7* were found at higher frequencies. The pathogen population changed noticeably from that of 2007. *AvrLm1*, *AvrLm3* and *AvrLm9* almost disappeared while *AvrLm7* increased substantially. Testing of 2014 samples is continuing.

Biocontrol of clubroot and blackleg by the endophytic microorganisms of canola

LEAD RESEARCHER: Paul Holloway, University of Winnipeg
FUNDING: ACPC, SaskCanola, MCGA
PURPOSE: Endophytes are bacteria and fungi that inhabit the tissue of plants without causing any harm to the plant. The goal is to find endophytes that may provide a benefit to canola.
PROGRESS: Researchers have isolated and purified a number of endophytic fungi and bacteria with several promising anti-bacterial and anti-fungal activities. Further testing will determine whether these endophytes also have activity against clubroot and blackleg pathogens and whether they can be used to protect canola plants.

Development and application of rapidly deployable in-field molecular diagnostics for plant diseases

LEAD RESEARCHER: Tim Dumonceaux, AAFC Saskatoon
FUNDING: ADF, SaskCanola
PURPOSE: The study will develop rapid diagnostic methods for a range of pathogens along with methods for rapid DNA extraction in a non-laboratory setting and apply these methods to the detection of crop pathogen DNA in agricultural products. We have targeted three diverse pathogens for initial development: aster yellows (phytoplasma), clubroot and blackleg.
PROGRESS: Field-deployable assays based on LAMP (loop-mediated isothermal DNA amplification) have been developed and validated for all of the targeted pathogens. The expertise developed while designing and validating these assays led the researchers to develop rapid diagnostic assays for other pathogens. They have also begun to perfect field-based DNA extraction methods for rapid and mobile pathogen detection.

Development of canola cultivar blackleg resistance groups: feasibility evaluation

LEAD RESEARCHER: Ralph Lange, Alberta Innovates
FUNDING: ACPC, 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: To date, researchers have adapted the Australian procedure by inducing ascospore formation in the residues. Early indications are that the number of resistance groups in Canada may be limited, so researchers have significantly increased the number of residue collection sites to decrease the chances of missing potential groups. They are currently collecting residues from blackleg-infested fields and strip trials. The procedure is to collect from fields and strip trials, transport residues to overwinter at Vegreville, and then inoculate field trials with the residues in the spring. They also test the residues indoors to further seek out putative resistance groups.

Toward a strategy for reducing the spore density and dissemination of clubroot of canola in Alberta

LEAD RESEARCHER: Sheau-Fang Hwang, AAF
FUNDING: ACPC, ACIDF, WGRF
PURPOSE: The purpose is to develop a better understanding of the distribution and dispersal of clubroot and to develop methods to eradicate or reduce newly established infestations, both within fields and on a regional basis.
PROGRESS: Year 2 of 4. Resistant cultivars had very low indices of disease (0 to 6 percent) in most crops, however ID values of up to 20 percent were detected in some crops. In field experiments, susceptible cultivars contributed 2 x 10^8 spores/gram of soil, while resistant cultivars contributed 1.2 x 10^7 spores/gram of soil. Use of Vapam soil fumigant on clubroot-infested land improved crop establishment, plant height and seed production of plants and reduced clubroot severity.

HARVEST MANAGEMENT

Extent of infestation and potential for eradication of clubroot at sites in Saskatchewan

LEAD RESEARCHER: Bruce Gossen, AAFC Saskatoon
FUNDING: SaskCanola, ADF, WGRF
PURPOSE: This study assesses the potential for using fumigation to reduce or eliminate the resting spores of *Plasmodiophora brassicae* (the cause of clubroot) in new infestations and other situations where relatively small volumes of soil need to be treated.
PROGRESS: Two fumigants had good efficacy against clubroot under controlled conditions, but were less effective in the field. One issue that affects efficacy is that the spores of the pathogen are present at least one metre deep in the soil profile. Other factors that affect pathogen detection and fumigation efficacy are being examined.

Supporting continued development of clubroot resistant canola and early detection of clubroot outbreaks

LEAD RESEARCHER: Michael Harding, AAF
FUNDING: ACPC, 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 3 of 4. Dozens of new lines/cultivars have been screened, many of which have strong resistance to pathotype 5. Soil amendments and treatments have demonstrated limited ability to manage clubroot in areas with high resting spore populations. Clubroot surveillance has not discovered any new infestations south of Highway 1.

Developing a rapid method to evaluate pod-crop in canola

LEAD RESEARCHER: Rob Gulden, University of Manitoba
FUNDING: ACPC, SaskCanola, MCGA
PURPOSE: Pod retention-resistance is a new method under development to estimate pod drop potential among canola varieties. The method uses a digital force gauge to measure the force required to break the petiole of the pod at the rachis — the weakest point of attachment — and correlates this with pod drop measurements.
PROGRESS: Results among site-years showed consistent and significantly higher force was required to break petioles from the lower sections of the plant compared with the upper sections, while no differences were observed between the main rachis and branches. Twelve to 15 pod retention resistance measurements per section are necessary for consistent results and differences among cultivars are observed.

Canola direct-cut harvest systems

LEAD RESEARCHER: Nathan Gregg, PAMI
FUNDING: SaskCanola, ADF, WGRF
PURPOSE: This study is examining headers for direct-combining canola, including comparisons of yield, seed quality, header shatter loss and environmental shatter loss. Draper, rigid and extendable cutter bar headers and a swath-based system are being compared. The three-year study has two test locations: Indian Head and Swift Current.
PROGRESS: Year 2 of 3. No conclusive loss advantage was apparent with any of the headers. However, crop conditions and material flow characteristics of the different headers had a large effect on combine and header performance. Green plant material at Swift Current resulted in lower header loss, higher combine loss and increase power utilization. The more mature crop at Indian Head resulted in slightly higher header loss, but lower combine loss and power requirements.

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GENETICS

Development of a germplasm resource to dissect complex traits in *Brassica napus*

LEAD RESEARCHER: Isobel Parkin, AAFC Saskatoon/University of Saskatchewan
FUNDING: SaskCanola, ADF, ACPC, 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: Year 3 of 4. 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.

Developing canola germplasm with diverse mechanisms to enhance the durability of clubroot resistance

LEAD RESEARCHER: Gary Peng, AAFC Saskatoon
FUNDING: SaskCanola, WGRF
PURPOSE: To assess AAFC clubroot-resistant germplasm against the newly reported pathotype 5X of *Plasmodiophora brassicae* (clubroot) for the source of resistance, understand the resistance spectrum (against different pathotypes) and mechanisms of selected genes or genotypes, and incorporate effective clubroot resistance genes into elite canola germplasm or breeding lines.
PROGRESS: Preliminary screening of 17 clubroot resistant genotypes identified several candidates against a mixed population of pathotype 5X isolates. Further testing showed variations in resistance against different isolates of pathotype 5X, indicating the group likely has more races. One of the candidate genes, with resistance to most of the 5X isolates, is being incorporated into canola germplasm as well as commercial breeding lines. Modes of action are being studied for two of the candidate genes and it is hoped that R genes with different resistance mechanisms will be introduced into commercial cultivars.

Developing near-isogenic *Brassica napus* lines for differentiating pathotypes of *Plasmodiophora brassicae*

LEAD RESEARCHER: Fengqun Yu, AAFC Saskatoon
FUNDING: WGRF, ADF, SaskCanola
PURPOSE: This project aims to develop *Brassica 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: Year 2 of 4. Researchers have obtained BC1 and BC2 introgressed *B. napus* lines containing eight single clubroot resistance genes.

Identification and mapping of clubroot resistance genes in *Brassica rapa* and development of SNP markers tightly linked to resistance genes

LEAD RESEARCHER: Fengqun Yu, AAFC Saskatoon
FUNDING: ACPC, WGRF
PURPOSE: This project aims to identify clubroot resistance genes in *Brassica rapa* and develop molecular markers for rapid introgression of the clubroot resistance into canola.
PROGRESS: Year 3 of 3. Researchers have identified five clubroot resistance genes and developed SNP markers tightly linked to them. Some of the markers and genes have been used by the Canadian canola industry for incorporation into their canola varieties.

Introgression of disease resistance from *Brassica nigra* into canola using new-type *Brassica napus*

LEAD RESEARCHER: Fengqun Yu, AAFC Saskatoon
FUNDING: ADF, ACPC
PURPOSE: The project aims to identify clubroot resistance and blackleg resistance genes in *B. nigra* and transfer the genes into canola.
PROGRESS: Year 1 of 4. Researchers have developed a segregating population for genetic mapping of clubroot resistance genes and obtained F1 progenies from the interspecific crosses between *B. napus* and *B. nigra*. Inheritance of clubroot resistance in the *B. nigra* has been determined.

Molecular cytogenetics of blackleg resistance in the *Brassica* B-genome and introgression of resistance into *B. napus* through recurrent backcrossing

LEAD RESEARCHER: Habibur Rahman, University of Alberta
FUNDING: ACIDF, ACPC
PURPOSE: This study aims 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 such as PG3, PG4 and PGt, 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.

U of S researchers are looking for clubroot resistance in non-host species like this grass, ***Brachypodium distachyon.*** *The image shows uninfected* ***B. distachyon*** *on the right (C for control) and infected (I) on the left.*

Using non-host species to identify novel genes for durable clubroot resistance in canola

LEAD RESEARCHER: Peta Bonham-Smith, University of Saskatchewan
FUNDING: SaskCanola, ADF
PURPOSE: This study explores a different genetic resource, a non-host species such as the small grass *Brachypodium distachyon*, to identify genes that can confer durable, broad-spectrum resistance to *Plasmodiophora brassicae*, the pathogen responsible for clubroot.
PROGRESS: Researchers have confirmed that *B. distachyon* can be infected with *P. brassicae* but, similar to wheat and winter rye, it is a non-host and does not develop clubroot. They observed that the resistance, seen as a significant regression of the number of infected cells in the root inner tissues, develops in the non-host plant within a few days after the infection. They are currently analyzing the transcriptome in roots sampled from the *P. brassicae*-infected and mock-treated non-host plants within this time window in order to identify the differentially regulated genes in response to the infection by *P. brassicae*.

Building durable resistance to clubroot disease in canola: Identification of multiple clubroot resistance genes from *Brassica napus* and *B. rapa* for marker-assisted gene stacking in canola breeding

LEAD RESEARCHER: Gopalan Selvaraj, National Research Centre, Saskatoon
FUNDING: SaskCanola, ADF, WGRF
PURPOSE AND PROGRESS: This project accomplished genetic mapping for clubroot resistance for P3 pathotype (single spore isolate) in collaboration with Habibur Rahman's group at the University of Alberta. Transcriptome and microRNA sequencing at various disease developmental stages, and pathogen transcriptomics were also completed for gene and marker discovery. Biochemical analyses are underway. ●

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