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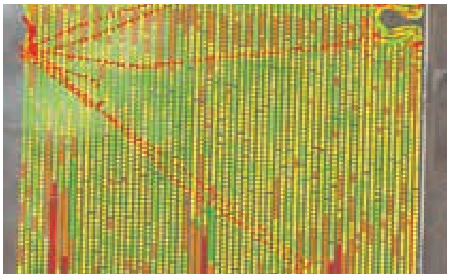


SCIENCE SPECIAL: TOP SCIENCE FOR THE BOTTOM LINE

2014




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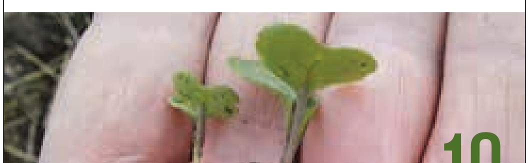

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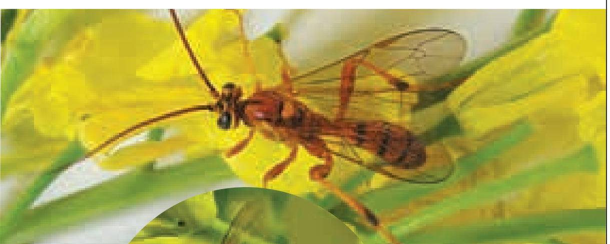

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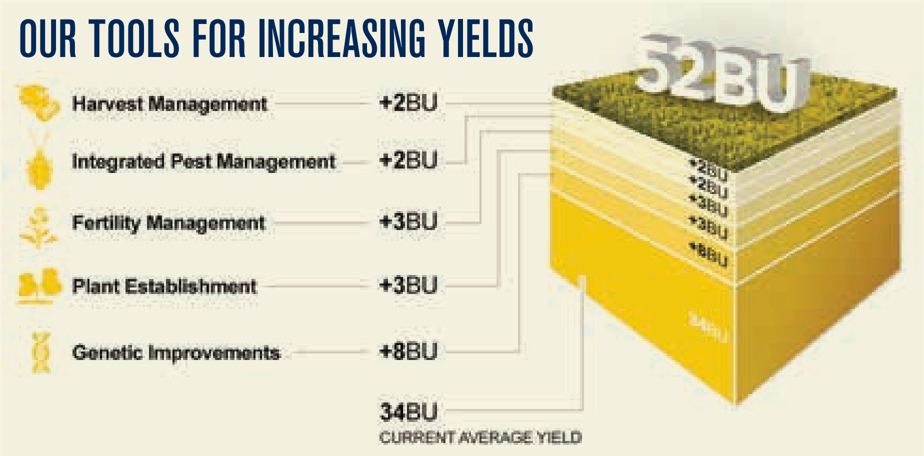
Launchpad to more productivity and profits

The Canola Council of Canada's strategic plan challenges canola growers to increase average yields by 50 percent by 2025 — and maintain profitability and sustainability at the same time. The goal is ambitious, but with improved agronomy, new research, new genetics, and a concentrated effort to provide information tailored to each region, we believe it can be done.

The strategic plan targets an average Canadian canola yield of 52 bu./ac. by 2025, up from the three-year average of around 34 bu./ac. when the plan was hatched. This target is broken down into five components — a 3 bu./ac. increase from improvements in plant establishment, 3 bu./ac. from fertility management, 2 bu./ac. from more timely and economic integrated pest management decisions, 2 bu./ac. from harvest management, and 8 bu./ac. from improved genetics.

This Science Edition of *Canola Digest* explores these five themes, starting with detailed summaries of best management practices in the four agronomy categories. And because this is a "science" edition, each article provides the key science behind each best practice.

In another article, representatives from the canola seed industry describe the strategic goal from their perspective, explaining what it will take to improve harvested yields by 8 bu./ac. from genetics alone.



This magazine also previews 16 new canola agronomy studies, funded through Growing Forward 2, a five-year arrangement with $15 million from the Government of Canada and $5 million from the canola industry. An eight-page spread provides quick purpose and progress reports for 68 new and ongoing studies that received direct funding from the provincial canola grower organizations: Saskatchewan Canola Development Commission (SCDC), Alberta Canola Producers Commission (ACPC) and Manitoba Canola Growers Association (MCGA). That is an impressive amount of new research, which will help growers and agronomists better understand how to manage plant populations, nitrogen use efficiency, clubroot, blackleg, lygus bugs, herbicide-resistant weeds, harvest losses and many other production challenges.

Canola Digest Science Edition 2014 is a snapshot of where we are now, with best practices that — when applied — can move us well on our way toward our goals. And with more than a decade until 2025, critical analysis of current practices described in these pages may identify gaps that can be refined with new research and discovery.

This will be one of the most valuable magazines in farm mailboxes this year, and one to keep handy for years to come. Thanks to SCDC, ACPC, MCGA and Agriculture and Agri-Food Canada for contributing the funding to make this Science Edition possible. •

Target seven to 10 plants per square foot

KEY PRACTICE: Target a population of at least seven plants per square foot to maintain yield potential for canola. This target will allow for some plant mortality due to post-seeding stresses without dropping below the minimum five plants per square foot required for canola yield potential.

KEY RESEARCH: Leeson, Julia, Agriculture and Agri-Food Canada (AAFC). "Impact of Management and Environment on Canola Establishment Based on Survey Data." *Canola Digest Science Edition* (2013).

Shirtliffe, Steve, University of Saskatchewan. "Determining the Economic Plant Density in Canola." Canola Agronomic Research Program based on summary data from 35 experiments (2009).

Canola growers are losing yield potential through reduced plant population. Crops with low stand densities are more vulnerable to losses from disease, insects, weed competition, uneven maturity and environmental stresses. Although crops with low stand densities are forced to compensate through increased pod and seed production per plant, current research shows that improving stand density targets may result in significant yield gains.

Through his 2009 meta-analysis of 35 canola studies, Steve Shirtliffe with the University of Saskatchewan studied the correlations between seeding rates, plant density and yield in both hybrid and open-pollinated canola. On average, he found that canola seeded at the recommended 5 lb./ac. yielded higher than canola seeded at 3 lb./ac.

Shirtliffe also found that many canola growers reduce seeding rates in response to high seed costs. A grower who wants to economize on seed should only consider lower rates for fields that are expected to have optimum emergence, and maintain or increase seeding rates for fields with poorer expected emergence. However, given the larger thousand seed weight (TSW) of some seed lots and typical survival rates, even a 5 lb./ac. seeding rate may not produce the target stand.

Once optimum seeding rate is calculated, the greatest factor under the farmer's control becomes seed placement. Seed slow enough to ensure good and even seed depth from all openers. "Using an accurate air drill with precise seed depth control operated at low field speeds will ensure that farmers can achieve the best possible emergence," writes Shirtliffe.

In his final report "Determining the Economic Plant Density in Canola," prepared for the Saskatchewan Canola Development Commission, Shirtliffe concluded, "Canola farmers seeking to maximize returns should target populations greater than five plants per square foot. Plant populations lower than this will almost always have yield loss."

Data from surveys conducted in Prairie canola fields between 2000 and 2012 show that, in all years surveyed, an average of 60 percent of fields had at least some patches where the crop count was less than four plants per square foot. This translates to an average of approximately 30 percent of all Prairie acreage with too few plants to reach yield potential.

Julia Leeson, biologist with Agriculture and Agri-Food Canada in Saskatoon, led these surveys, which included grower interviews and in-field assessment. Of the growers surveyed, all fields seeded at rates greater than 5 lb./ac. had crop stands within or above the recommended range.

Establishing a relatively thick stand gives a canola crop the best chance of success. Large-size seed may or may not provide increased early season vigour compared to smaller seed, but the minimum stand to reach yield potential is ultimately five plants per square foot, regardless of thousand seed weight (TSW). Targeting a population of at least seven healthy plants per square foot allows for some plant mortality without dropping below this density. ●

Estimated plant populations under various seeding conditions
Seed survival (%) = 60%

Thousand seed weight (grams)	Seedling rates (lb./ac.)					
	3	4	5	6	7	8
2.5	7.5	10.0	12.5	15.0	17.5	20.0
3	6.3	8.3	10.4	12.5	14.6	16.7
3.5	5.4	7.1	8.9	10.7	12.5	14.3
4	4.7	6.3	7.8	9.4	10.9	12.5
4.5	4.2	5.6	6.9	8.3	9.7	11.1
5	3.8	5.0	6.3	7.5	8.8	10.0
5.5	3.4	4.5	5.7	6.8	8.0	9.1
6	3.1	4.2	5.2	6.3	7.3	8.3

At 60 percent seed survival, seed with a thousand seed weight of 4g seeded at 5 lb./ac. will produce 7.8 plants per square foot. Adjustments to seeding rate and seed weight change the result. For more tables, go to www.canolawatch.org and search for the article "Wide range of seed weights."

Aim for uniform stands

KEY PRACTICE: Uniform stands, with the same number of plants per square foot across the field and with plants at the same growth stage, are proven to increase yields.

KEY RESEARCH: Angadi, S.V., Agriculture and Agri-Food Canada (AAFC), et al. "Yield Adjustment by Canola Grown at Different Plant Populations under Semiarid Conditions." *Crop Science* 43 (2003): 1358-1366.

Gan, Yantai, AAFC. "Improving Canola Establishment and Uniformity Across Various Soil-Climatic Zones of Western Canada." *Canola Digest Science Edition* (2013).

Yang, C., Gan, Y., AAFC, et al. "Up to 32% Yield Increase with Uniform Canola Stands in Western Canada." *Agronomy for Sustainable Development* (2014).

Canola stands with a consistent number of plants per square foot across the field and with plants at the same growth stage produce significantly higher yields. The benefit of a uniform stand is especially evident when overall plant populations are less than ideal or when moisture is limited.

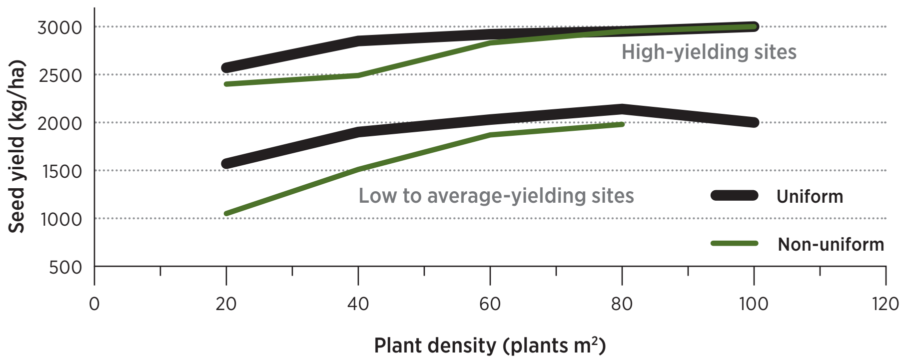
Chao Yang and Yantai Gan of Agriculture and Agri-Food Canada (AAFC) et al published a March 2014 paper in *Agronomy for Sustainable Development* titled, "Up to 32% Yield Increase with Uniform Canola Stand in Western Canada." The paper details a three-year Canola-Flax Agri-Science Cluster study in which field experiments were conducted at 16 site-years across the different Canadian Prairie zones to review the impact of stand uniformity on canola pod formation, seed set and crop yield. Each test consisted of the same glufosinate-resistant hybrid cultivar sown at 100, 80, 60, 40 and 20 plants per square metre (approximately 10, 8, 6, 4 and 2 plants per square foot) with both uniform and non-uniform stands.

Yang and Gan found that spatially uniform stands increased seed yield by up to 32 percent at low-yielding sites and by up to 20 percent at high-yielding sites (see the figure). Ensuring a uniform growth stage will improve the ability to time in-crop applications and harvest to optimize both crop quality and yield.

Yang and Gan conclude, "...canola yield can be increased by improving the uniformity of plant spatial distribution patterns in the field regardless of environmental conditions."

"Yield Adjustment by Canola Grown at Different Plant Populations under Semiarid Conditions," published by S.V. Angadi in *Crop Science* (2003), reports similar results from a 1999 to 2001 field study at Swift Current, SK. Here it was found that even reducing plant population by half from 80 to 40 plants per square metre, which is just below the recommended minimum for optimum canola yield potential, did not reduce seed yield when the reduced plant population was uniformly distributed. However, seed yield at this lower density was significantly reduced by non-uniform distribution.

Uniform stands yield more, especially at lower plant densities.



How to improve uniformity

A number of factors contribute to poor uniformity in canola plant stands, including uneven seeding depth, insect damage, excessive seed-placed fertilizer, late spring frost or other environmental conditions, and improper management of previous crop residues.

For uniform stand establishment under a wide variety of conditions, use a seeder that can consistently place seed 1.25 to 2.5 cm (1/2" to 1") deep. The seeding tool has to be set properly for a grower to achieve the target seeding depth and seed-to-soil contact for all seed rows.

Slowing down while seeding allows for accurate seed placement and consistent seeding depth, resulting in more uniform emergence. Ideal speed varies by the type of drill, soil type and moisture, as well as amount and type of crop residue. It is important to find a seeding speed that is right for both the equipment and conditions. ●

Earlier seeding generally increases yield

KEY PRACTICE: Crops seeded early (in late April or early May, depending on the region) will out-yield canola seeded in late May to early June most years. Not all years, but most years.

KEY RESEARCH: Angadi, S.V., Agriculture and Agri-Food Canada (AAFC), et al. "Early Seeding Improves the Sustainability of Canola and Mustard Production on the Canadian Semiarid Prairie." *Canadian Journal of Plant Science* (2004).

Brandt, Stewart, AAFC, et al. "Evaluating the Agronomic and Economic Value of High Quality Canola Seed." Canola Agronomic Research Program (CARP) (11-01-08).

Kirkland, Ken J., AAFC and Johnson, Eric N., AAFC. "Alternative Seeding Dates (Fall and April) Affect *Brassica napus* Canola Yield and Quality." *Canadian Journal of Plant Science* (2000).

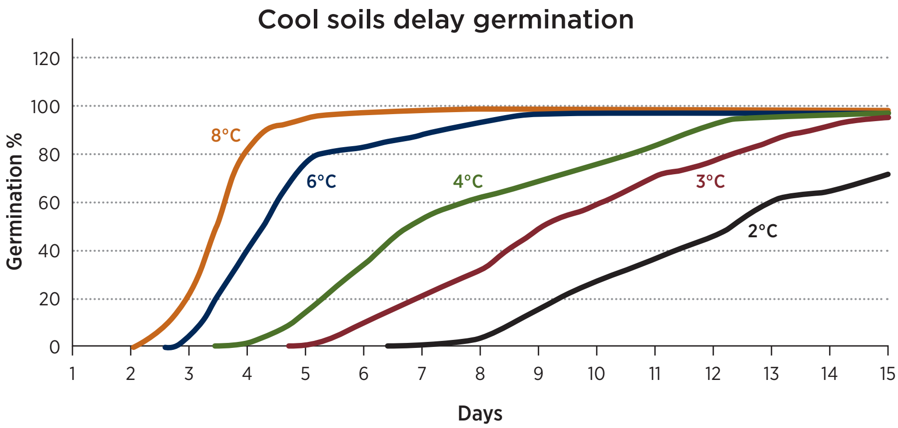
Capo-chichi, Ludovic J.A., Alberta Innovates, et al. "Assessment of Seed Germination and Seedling Performance of Spring Canola at Low Temperatures." CARP (2011-7).

Early spring seeding typically benefits canola yield and quality. An early planting date enables the crop to take advantage of good spring moisture, avoid some heat stress at flowering, and reduce the risk of fall frost damage.

Generally, soil temperatures below 8 to 10°C result in progressively poorer germination and emergence. However, early seeding in late April or early May often provides yield benefits in spite of this — as long as an adequate plant population survives. Starting to seed when soil temperatures in the zone reach 5°C is a reasonable compromise, or even earlier if the forecast is for temperatures to rise the week following seeding.

It is important, therefore, to consider local weather history and frost risk when choosing a seeding date. The frost-free period varies considerably from location to location in Canada and the actual dates of final spring frost and first fall frost are different each year.

Through a four-year study conducted at the AAFC research farm near Scott, SK, Ken Kirkland and Eric Johnson found that canola seeded late fall or early spring yielded up to 38 percent more compared to traditional mid-May seeding. Fall seeding canola is a high-risk practice and is not recommended, but this study does support early spring seeding.



This shows the effect of soil temperature on days to emergence, and on uniformity.

S.V. Angadi of AAFC et al, referenced those findings in the 2004 paper "Early Seeding Improves the Sustainability of Canola and Mustard Production on the Canadian Semiarid Prairie." Angadi also summarized a four-yield field study at the Semiarid Prairie Agricultural Research Centre in Swift Current to examine the effect of fall and spring seeding on the growth and water-use characteristics of three canola species.

In the Swift Current study, seeding dates were late fall (November 2 to 23 just before soil freezing), early spring (April 24 to 26) and late spring (May 23 to 25). The lowest plant populations occurred with fall seeding, but early seeding generally resulted in earlier flowering, avoiding mid- to late-summer heat stress.

The effect of seeding date on yield was very dependent on available water throughout the growing season. In the year with the most typical moisture conditions, early spring seeded crops produced the highest yield, followed by fall seeded and then late spring seeded. Planned comparisons also showed higher water-use efficiency with early spring seeding compared to late spring seeding.

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Seed at 1/2″ to 1″ deep

KEY PRACTICE: Optimum seeding depth is ½″ to 1″ below the press wheel furrow. This reduces days to emergence and improves plant population and uniformity, which produce season-long benefits.

KEY RESEARCH: Harker, K. Neil, Agriculture and Agri-Food Canada (AAFC). "Seeding Depth and Seeding Speed Effects on No-Till Canola Emergence, Maturity, Yield and Seed Quality." *Canola Journal of Plant Science* (2012). Harker, K. Neil , AAFC. "Factors Influencing Canola Emergence." *Canola Digest Science Edition* (2013).

Canola growers who consistently seed at a shallow depth of 1.2 to 2.5 cm (½″ to 1″) can reap significant benefits. These include improved plant density, superior competition with weeds, decreased days to emergence, increased canola ground cover, decreased days to flowering and maturity, decreased green seed levels and higher yields.

Shallow seeding of canola into a firm, moist, warm seedbed helps ensure rapid, uniform germination with a high percentage of emergence. Deeply sown seeds require several days longer to emerge and have reduced survival rates due to the insufficient stored energy in canola required to push cotyledons to the surface.

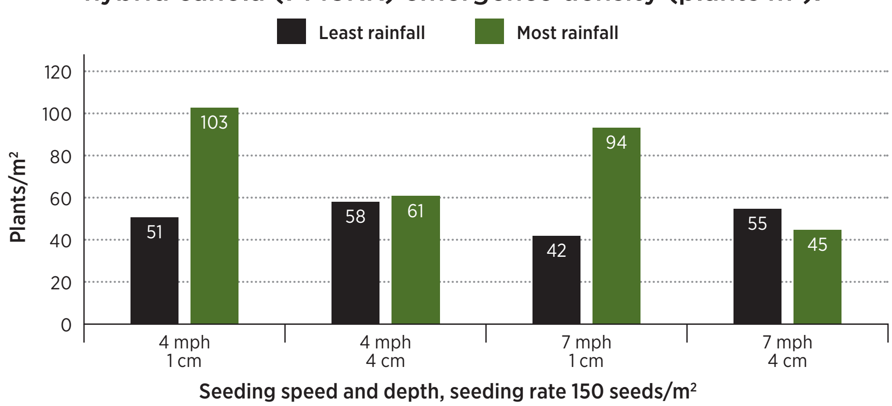
Canola seed is a substantial input cost and poor crop establishment is a continuing concern for growers. Estimates suggest that, on average, only 50 percent of planted seeds emerge — even for seed with a very high germination analysis.

Neil Harker with Agriculture and Agri-Food Canada (AAFC) in Lacombe, AB led a three-year project titled: "Factors Influencing Canola Emergence." Direct-seeding experiments were conducted at four sites in Western Canada from 2008 to 2011 with data collected from 10 site years. Hybrid or open-pollinated gylphosate-resistant canola was seeded at speeds of four or seven miles per hour and at depths of 1 cm (approximately 1/2″) or 4 cm (approximately 1.5″), in replicated trials.

The researchers found that emergence was greater for canola seeded at a depth of 1 cm compared to 4 cm, with soil moisture being a key influence on results. Canola emergence averaged 35 percent for both seeding depths when precipitation levels were low. With ample moisture, the differences became more significant, with an average emergence level of 66 percent when seeding depth was 1 cm.

Canola seeded at 1 cm also performed better across nearly all measured variables in comparison to canola seeded at 4 cm. Harker concluded that, although taking a "recipe" approach to seeding depth is not appropriate for all conditions, "…in most Canadian Prairie production areas, seeding at a depth of 1 cm will not only improve canola emergence density, but will also decrease days to emergence, increase canola ground cover, decrease days to flowering and days to maturity and tend to decrease green seed levels."

The effect of seeding depth and seeding speed on hybrid canola (7145RR) emergence density (plants m²).



Means were estimated based on the PROC PLS analyses, which grouped sites according to environmental conditions; in this case the dominant factor was precipitation levels surrounding the time of seeding.

Machinery considerations

Openers that leave a trench or furrow are prone to filling in with soil after rain, which increases the true seeding depth. Opener wear, soil type, moisture and ground speed will influence opener performance. Therefore, seeding depth should be measured carefully during the first few passes in each field and again randomly throughout, or when conditions change.

Seeding speed also influenced canola variables in Harker's study. Slowing down while seeding allows for accurate seed placement and consistent seeding depth, resulting in more uniform emergence. Ideal speed varies by the type of drill, soil type and moisture, as well as amount and type of crop residue, so it is important to find the speed that is right for both the equipment and conditions. ●

Put only phosphate in the seed row

KEY PRACTICE: Ensure safe rates of seed-placed fertilizer to improve nutrient-deficient soil conditions without increasing seedling mortality. The safest step is to put only phosphate in the seed row, and all other fertilizer outside the seed row.

KEY RESEARCH: Grant, Cynthia, Agriculture and Agri-Food Canada (AAFC). "Improving Nutrient Management in Canola and Canola-Based Cropping Systems." *Canola Digest Science Edition* (2013).

Grenkow, Laryssa, University of Manitoba. "Seed-Placed Phosphorus and Sulphur Fertlizers: Effect on Canola Plant Stand and Yield." Oral Presentations, Soils and Crops (2013).

The success of a canola crop relies on meeting high nutrient requirements, particularly those of nitrogen (N), phosphorus (P) and sulphur (S), as well as establishing a strong, dense plant stand. Putting down seed and fertilizer in one pass is common practice on the Prairies, but for canola, most of that fertilizer should go in the side band or mid-row band to avoid seed damage and seedling mortality.

Safe seed placement rates depend on row spacing, seed and fertilizer placement and separation, soil moisture and soil type. Phosphorus is the most important nutrient to place in the seed row, due to its limited mobility and the importance of early uptake.

Seed row placement is best for the first 15 to 20 lb./ac. of phosphate as it may improve emergence and seedling vigour on deficient or cool soils where availability is reduced.

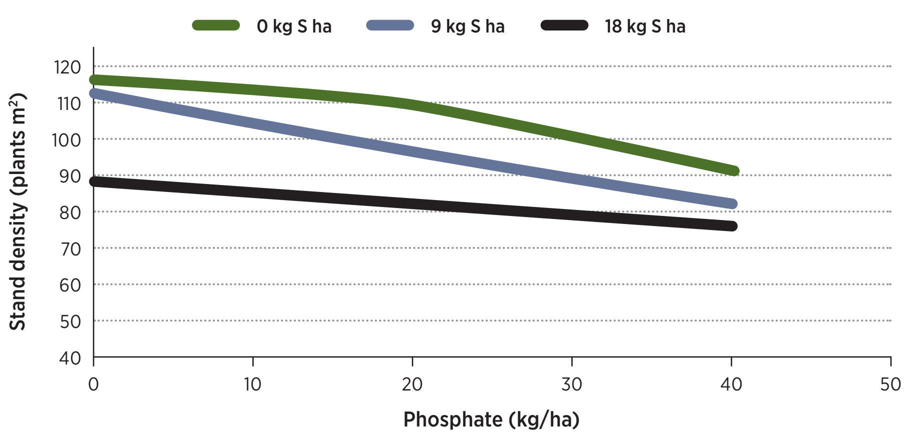
Laryssa Grenkow, then with the University of Manitoba, presented, "Seed-Placed Phosphorus and Sulphur Fertilizers: Effect on Canola Plant Stand and Yield," at Soils and Crops 2013. This presentation was based on the findings of a Canola-Flax Agri-Science Cluster study led by Cynthia Grant of AAFC, Brandon, MB. The study evaluated improved practices for P, S and N management in canola. Field, growth chamber and laboratory trials were used to determine safe rates of seed-placed P and S blends in various environments and the effects of traditional versus enhanced-efficiency P and S fertilizers on canola variables.

For most site years, the field study application of traditional ammonium sulphate (AS) or monoammonium phosphate (MAP) alone at either rate did not affect stand establishment. Applying P and S fertilizers in a blend increased the frequency and severity of damage with plant stand reduction by as much as 57 percent and by an average of 18 percent overall. The high-AS blends caused the most damage, resulting in an overall average plant stand reduction near 20 percent (see the figure).

As for yield, the greatest and most consistent yield increase resulted from the combination high-MAP/low-AS treatment. However, due to a high salt index, seed row application that includes AS does come with a high risk of ammonia toxicity.

Grenkow concluded that, "In order to maximize the benefits and minimize the risks of applying highly available P and S, farmers with single shoot, low SBU seeding equipment should reserve the limited tolerance of canola for seed row fertilizer for P." ●

Seed-placed sulphate and phosphate fertilizers can reduce canola stand density



Use seed treatment to minimize early disease

KEY PRACTICE: A registered seed treatment with multiple fungicide active ingredients can minimize the threat of seed and seedling diseases. Seeding early, shallow and with good seed to soil contact for quick emergence also helps prevent early disease infection. Start field scouting 10 to 14 days after seeding.

KEY RESEARCH: Hwang, S.F., Alberta Agriculture and Rural Development (AARD). "The Effect of Seed Size, Seed Treatment, Seeding Date and Depth on Rhizoctonia Seedling Blight of Canola." *Canadian Journal of Plant Science* (2014).
Hwang, S.F., AARD. "Reducing Seedling Blight to Improve Stand Establishment in Hybrid Canola." Canola Agronomic Research Program (CARP) project (2007-1).

Canola is vulnerable to a number of seed and seedling diseases. A registered seed treatment with multiple fungicide active ingredients can minimize this threat. While early seeding is best for yield in general, shallow seeding and good seed to soil contact allow the crop to establish as quickly as possible, making it less susceptible to disease. It's also important to start field scouting 10 to 14 days after seeding, looking for diseased seed as well as dying or dead plants.

Canola seeded too deep is at higher risk of seedling diseases. Deep seeding requires a long hypocotyl for the plant to reach the soil surface, which exposes more of the plant to soil-borne disease pathogens. Deep seeding also extends the days to emergence, which means the plant is at its vulnerable stage for longer.

Sheau-Fang Hwang of AARD in Edmonton has led a number of studies on reducing seedling blight in canola. These studies examined the efficacy of fungicide seed treatments on suppressing various diseases in canola, and evaluated the effects of factors such as seeding date, seeding depth, seed size and soil temperatures.

Hwang's 2014 paper "The Effect of Seed Size, Seed Treatment, Seeding Date and Depth on Rhizoctonia Seedling Blight of Canola," summarizes greenhouse and field experiments on canola inoculated with *R. solani*, the most commonly isolated pathogen associated with the canola seedling blight complex.

Two seed treatments commonly used against the seedling blight complex were applied to canola for seeding in both the greenhouse and field-plot studies. Both treatments were applied at the labeled rate and each consisted of both a broad-spectrum fungicide and an insecticide.

Under greenhouse conditions, inoculations with *R. solani* reduced seedling emergence, plant height and shoot weight by an average of 35 percent compared with the non-inoculated control. In the field trials, inoculation reduced plant emergence by 88 to 91 percent and seed yield by 62 to 84 percent compared with the control.

Over three of the trial years, inoculation with *R. solani* reduced seedling emergence by an average of 95 percent with corresponding yield reductions averaging 87 percent in comparison with the non-inoculated control. Throughout this study, seed yield was greater for the early and mid-seeding dates and seed treatment consistently improved both seedling emergence and seed yield under high inoculum pressure.

Although early seeding generally improved seedling emergence in inoculated trials, seed size and seeding depth had very little effect on emergence and yield in this study. However, Hwang concludes that fungicidal seed treatments can play an important role in stabilizing canola stand establishment under heavy disease pressure by *R. solani*. ●

Rhizoctonia or "wirestem" often results with deep seeding (as shown in the seedling on the left), which increases exposure of the very sensitive hypocotyl.

Protect canola from early insect feeding

KEY PRACTICE: Use seed treatments and early in-crop treatments, if scouting deems them necessary, to protect young plants from flea beetles.

KEY RESEARCH: Hallett, Rebecca, University of Guelph. "Assessing the Impact of Swede Midge on Canola Production in the Prairies & Ontario." Canola Agronomic Research Program (CARP 2005-14).

Olfert, Owen and Elliott, Bob, Agriculture and Agri-Food Canada (AAFC). "Detection, Surveillance and Management of Weed, Insect and Disease Pests that Threaten the Economic Viability of Crop Production and the Environmental Health of Prairie Agro-Ecosystems." *Canola Digest Science Edition* (2013).

Soroka, Julie, AAFC. "Mitigation of Risk to Canola from Spring Flea Beetle Injury." *Canola Digest Science Edition* (2013).

Flea beetles and cutworms are the most common early-season insect pests of canola. Despite canola's ability to branch out and recover from thinned stands, early insect feeding will reduce canola biomass and delay maturity, increasing the risk of lower yield and quality. The key to minimizing damage is early detection and the use of an insecticidal seed treatment to control flea beetles.

Rapid emergence and early growth is also very important to offset insect feeding, along with frequent scouting for feeding damage from germination through the early rosette stage. This will allow growers to intervene before significant plant losses occur.

Studies have shown annual canola yield losses from flea beetle damage ranging from eight to 10 percent, with insecticidal control being the principal management method. A three-year Canola-Flax Agri-Science Cluster study, led by Julie Soroka of AAFC Saskatoon, investigated flea beetles across the Prairies to determine factors affecting distribution and feeding and to analyze control methods.

Soroka found that striped flea beetles typically emerge first and are more active at temperatures lower than crucifer flea beetles. Crucifer flea beetles emerge at temperatures closer to 15°C and both species are more likely to fly from field to field when temperatures exceed 15°C.

Damage from both striped and crucifer flea beetles increased as the temperature increased. Crucifer flea beetle damage to cotyledons nearly doubled with each 5°C increase in temperature from 5°C to 25°C. Soroka advises growers to inspect canola daily when temperatures reach 20 to 25°C due to the rapid increase in damage at higher temperatures.

Frequent scouting from germination through the early rosette stage will determine whether further flea beetle control is required.

Researchers in this study found that current seed treatments provided substantially better control and protection against crucifer flea beetles than striped flea beetles. Also, seed treatments provided excellent flea beetle protection when warm, dry conditions occurred during germination and stand establishment. Seed treatments may be less effective when above-average rainfall causes saturated soil conditions or when striped flea beetles are the most abundant species.

Most flea beetle damage occurs at the cotyledon and early true leaf stages, with feeding after the fourth leaf stage having minimal impact on yield. An earlier seeding date takes advantage of the lower early spring temperatures during these growth stages and has proven to reduce injury.

Owen Olfert of AAFC conducted field tests over a three-year period to investigate the effect of seeding date on flea beetle damage, beetle emergence and agronomic performance of six canola and mustard cultivars, in the Canola-Flax Agri-Science Cluster study 3.7.8.

Olfert et al found that overall damage was lower in early seeded plots (14.6 percent) than in late seeded plots (21.4 percent). Seed yields were also 12 percent higher in early seeded plots than in late seeded plots, with early seeding improving overall yield by five to 20 percent depending on the cultivar.

Early seeding is also effective in mitigating damage from other insects, including cabbage seedpod weevil and swede midge. Swede midge is responsible for heavy losses in the Ontario canola growing region, and it was first found on the Prairies in Saskatchewan in 2007. This insect's flexible biology could make it well adapted to the Prairies.

Rebecca Hallett of the University of Guelph has studied swede midge on canola in Ontario, and says canola must be planted early in areas of swede midge infestation. "By mid to late June, it may be best not to plant at all as damage will be very high, the crop will likely be unharvestable and resulting overwintering midge populations will present a risk to the following year's crop," says Hallett. •

Apply enough nitrogen

EARLIER SEEDING GENERALLY INCREASES YIELD
continued from page 7

Angadi concluded with a recommendation to seed canola as early in spring as practical, because this seeding date is most likely to produce the highest seed yields.

Stewart Brandt et al of AAFC also conducted a two-year seed timing study for Saskatchewan Canola Development Commission (SCDC), “Evaluating the Agronomic and Economic Value of High Quality Canola Seed.” The study found that plots seeded prior to May 20 resulted in higher seedling establishment, canola biomass and seed yield compared to those seeded on June 3. “Seed growers should try to seed their canola in early to mid-May to produce high vigour seed,” reported Brandt.

Some gains may also be made through breeding canola for low temperature tolerance, but this can be very challenging. J.A. Ludovic Capo-chichi of Alberta Innovates completed the study, “Assessment of Seed Germination and Seeding Performance of Spring Canola at Low Temperatures,” in March 2014. He concluded: “To improve efficiency and increase the tolerance of low temperature, canola breeders must exploit new screen techniques to complete previously used methods. This project has generated a huge amount of information and tools that will be useful in breeding programs and other projects aimed at understanding the physiology and genomics of low temperature tolerance in spring canola.” ●

KEY PRACTICE: Use soil tests, ideally taken at consistent locations (GPS helps), and base rate decisions on soil test recommendations.

KEY RESEARCH: S.A. Brandt, Agriculture and Agri-Food Canada (AAFC), et al.“Seeding rate, fertilizer level and disease management effects on hybrid versus open pollinated canola (*Brassica napus* L.)” *Canadian Journal of Plant Science*, 2007.

R.E. Blackshaw, AAFC, et al. “Canola response to ESN and Urea in a four-year no-till cropping system”, *Agronomy Journal*, 2011.

Nitrogen is the most common limiting nutrient for canola production. The challenge is to choose a nitrogen rate that balances the high yield potential of hybrid canola with the economic return from the extra pounds of nitrogen required to meet that potential. Applying enough fertilizer to meet the crop’s yield potential is not always the most economic decision.

The first step in making the decision is to understand how much nitrogen canola needs. The Canadian Fertilizer Institute (CFI) has a nutrient uptake and removal table (developed based on a culmination of science from the 1990s) that can be used to demonstrate typical nutrient needs. The CFI table says a 35 bu./ac. canola crop takes up 100 to 123 lb./ac. of nitrogen, or roughly 3 to 3.5 pounds for each bushel. A 50 bu./ac. crop would need 150 to 175 lb./ac. of available nitrogen.

Not all of this has to come from fertilizer, given that soil reserves and organic matter mineralization will provide some of that total. This brings us to the second step in decision-making: a soil test.

A benchmark sample is an effective and economical way to test every field every year. Select one or more small representative areas in a field. Take 15 to 20 soil cores from each area and mix them to create a composite sample to submit for analysis. Use GPS to return to the benchmark location year after year to get a better indication of soil nutrient trends over time. These trends can be used to assess whether fertilizer application rates for crops throughout the rotation are adequate, excessive or deficient. (For more on soil sampling techniques, go to www.canolawatch.org and search for the article “How to take a good soil sample.”)

Various studies have looked at nitrogen rates for hybrid canola. S.A. Brandt of of Agriculture and Agri-Food Canada (AAFC) et al, published: “Seeding rate, fertilizer level and disease management effects on hybrid versus open pollinated canola (*Brassica napus* L.)” in the *Canadian Journal of Plant Science* in 2007. In that study, Brandt compared three nitrogen levels — 67, 100 and 133 percent of the commercial recommended rate — and concluded that the high rate generally increased the total yield of biomass and seed.

R.E. Blackshaw of AAFC et al published: “Canola response to ESN and Urea in a four-year no-till cropping system” in Agronomy Journal in 2011. In that study, Blackshaw compared various inputs, including nitrogen at 50, 100 and 150 percent of the recommended rate. The study concluded that canola responded positively to the 150 percent rate compared to the 100 percent rate about half the time.

Finding a practical balance will depend on the potential economic return from added nitrogen for each field, as well as consideration of the moisture situation, equipment logistics and grower appetite for risk.

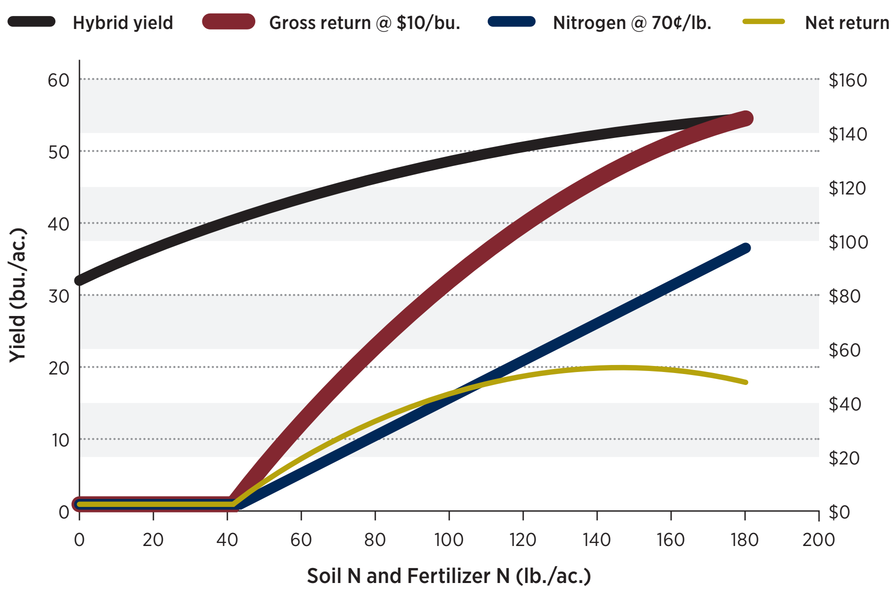
In both the Brandt and Blackshaw studies, the yield jump when going from the recommended nitrogen rate to 133 percent (Brandt) or 150 percent (Blackshaw) of the recommended rate was not huge. Both of these studies reflect the long-accepted economic response curve for nitrogen, which shows a fairly flat top to the curve over a wide range of rates.

The following information refers to the graph, which was generated using information from the nitrogen calculator (available here: www.gov.mb.ca/agriculture/online-resources/decision-making-tools.html). The point at which the net return (NR) line is greatest (goes flat) represents the maximum economical rate of N (MERN) — $1 invested in N will return $1 in revenue.

Whether a grower wants to apply this rate will depend on risk factors. For example:

- Moisture conditions during the growing season greatly affect the response to fertilizer N, but growing season weather isn't predictable. Dry conditions may reduce yield potential, which will drop the gross revenue (GR) line and shift the NR line to the left. The most economic nitrogen rate may be lower in that case.
- Ideal moisture conditions and better price prospects may increase the GR line's potential, shifting the NR line to the right and improving the return on investment for extra nitrogen. Growers with a higher appetite for risk may apply nitrogen rates at or above the current MERN (the last 10 lb./ac. of N provides a 1:1 return on investment according to the model) expecting the model conditions to improve and the MERN to increase.
- Growers with a lower appetite for risk will notice that the NR line is fairly flat over a wide range of nitrogen rates. They may opt for a rate lower than the MERN. They may prefer a rate where the last 10 lb./ac. of nitrogen applied will provide $1.25 or $1.50 return on each $1 invested instead of a 1:1 return. ●

Hybrid canola response to Nitrogen



The yellow represents the net return (NR) from nitrogen fertilizer. When the line goes flat, this indicates the point where $1 in nitrogen fertilizer provides a $1 increase in return.

THE 4 RS FOR NITROGEN

The 4 Rs for fertilizer decision-making are: the right fertilizer source, at the right rate, at the right time, and in the right place. The 4 Rs for nitrogen depend a lot on the individual grower's system and appetite for risk, but here are a few rough guidelines:

Right source: Urea, UAN or anhydrous ammonia. Each has its benefits and most farms have made a choice based on which fits best with their seeding systems.

Right rate: It might be higher than you think, but the decision to increase rates depends on the rate of return for that next 10 lb./ac. of nitrogen.

Right time: Spring placement has the lowest risk for loss compared to fall, however fall application can present an economic advantage. Time, supply, logistics and weather influence the decision for each grower.

Right place: Limit nitrogen in the seed row, and make sure it's available when and where the crop needs it.

Improve nitrogen use efficiency

KEY PRACTICE: Investment in enhanced-efficiency fertilizer products may provide an economic benefit when spring timing and band placement are not possible.

KEY RESEARCH: Grant, Cindy, Malhi, S.S. and Schoenau, Jeff. "Improving Nutrient Use Efficiency with Enhanced Efficiency Fertilizers in the Northern Great Plains of North America." *Recent Trends in Soil Science and Agronomy Research in the Northern Great Plains of North America* (2010).

Improved nitrogen use efficiency could provide a significant economic gain, given that nitrogen is one of canola growers' single biggest input costs.

"Nutrient use efficiency from fertilizer application is generally less than 50 percent in the year it is applied. Improvements in nutrient use efficiency are therefore critical, both to improve the economics of crop production and to minimize the movement of nutrients into the air or water," wrote Cindy Grant, S.S. Malhi and Jeff Schoenau in their 2010 review, "Improving nutrient use efficiency with enhanced efficiency fertilizers in the Northern Great Plains of North America."

If growers follow the traditional efficiency methods of in-soil banding (4R right placement) nitrogen in the spring (4R right timing), they will see limited benefit from an investment in enhanced efficiency products.

The benefit from enhanced efficiency products tends to increase when growers cannot — due to logistics, timing, weather or equipment — apply using traditional methods. In their review, Grant, Malhi and Schoenau provide the following examples:

1. Seeding equipment with banders that can apply fertilizer separately from the seed row can be costly and may also increase draft requirements, soil disturbance and moisture loss. Enhanced efficiency fertilizers that allow the use of simplified, less expensive equipment or practices (for example, seed-placed as compared to mid-row or side-band systems; surface applications rather than in-soil band) may be economically and operationally attractive.

2. By reducing the potential for nutrient loss, enhanced efficiency fertilizers allow a single efficient application of fertilizer that becomes available over a longer period, increasing application timing flexibility. They can also be applied in the fall so growers don't miss the spring window of application for split applications due to poor weather, physical conditions in the field, or time constraints.

Enhanced efficiency fertilizers

The three most widely available novel fertilizer formulations to improve N use efficiency are urease inhibitors, controlled release nitrogen and nitrification inhibitors. The following information on each is taken from the Grant, Malhi and Schoenau review.

Urease inhibitors. Urease inhibitors can be used in place of traditional management practices to decrease ammonia volatilization from surface applications and seedling damage from seed-placed ammonium or ammonium-producing N fertilizer. This could help growers reduce soil disturbance and application costs.

Urea will not volatilize or cause seedling damage until after it has been hydrolyzed to ammonium in a reaction catalyzed by the urease enzyme. Urease inhibitors slow the rate of hydrolysis to reduce the concentration of ammonium and ammonia present in the soil solution. This allows time for rainfall to move urea into the soil where the released ammonia will be less subject to volatilization, or for the urea to move away from the germinating seedling, reducing the risk of seedling damage.

Use of urease inhibitors with fall-banded urea may slow the release of ammonia and its subsequent conversion to nitrate, reducing the risk of nitrate leaching or denitrification.

Urease inhibitors are most likely to increase crop yield where yield potential is high, soil N levels are low, and soil and environmental conditions promote extensive volatilization. Potential volatilization, and hence potential benefits from the use of urease inhibitors, will be higher where: incorporation is difficult; where there is little opportunity for urea to move into the soil with infiltrating water; or where the soil has a high urease activity because of lack of cultivation or the accumulation of organic material. The risk of volatilization and seedling damage is higher on high pH, calcareous soils.

Controlled release nitrogen. The product currently available is polymer-coated urea, which releases urea fertilizer into the soil solution at a rate limited by moisture and controlled by soil temper-ature. Controlled release urea provides its greatest benefit under warm, moist conditions that promote high loss. The potential benefits will also increase if the fertilizer is in the soil for a longer period of time before crop uptake.

If conditions are dry and losses of conventional urea are low, controlled release urea may not increase yield compared to in-soil banded uncoated urea. Under wet conditions, controlled release urea should reduce the risk of leaching and/or denitrification, by more closely matching uptake with supply, hence reducing losses.

Controlled release urea can also be used to reduce seedling toxicity.

Nitrification inhibitors. These products slow nitrification of ammonium-producing fertilizers by interfering with the action of *Nitrosomonas* bacteria. Slowing nitrification allows the fertilizer to maintain the ammonium form longer, reducing the concentration of NO_3- in the soil solution and thus reducing the risk of leaching, denitrification, and N_2O emission release.

Both agronomic and environmental benefits of nitrification inhibition will be greatest where potential losses through leaching and denitrification are high, for example under wet soil conditions. Benefits are unlikely in dry or well-drained soils, since leaching and denitrification losses are limited by a lack of moisture. ●

FOUR MAIN PATHWAYS OF N LOSS FROM THE SOIL-PLANT SYSTEM:

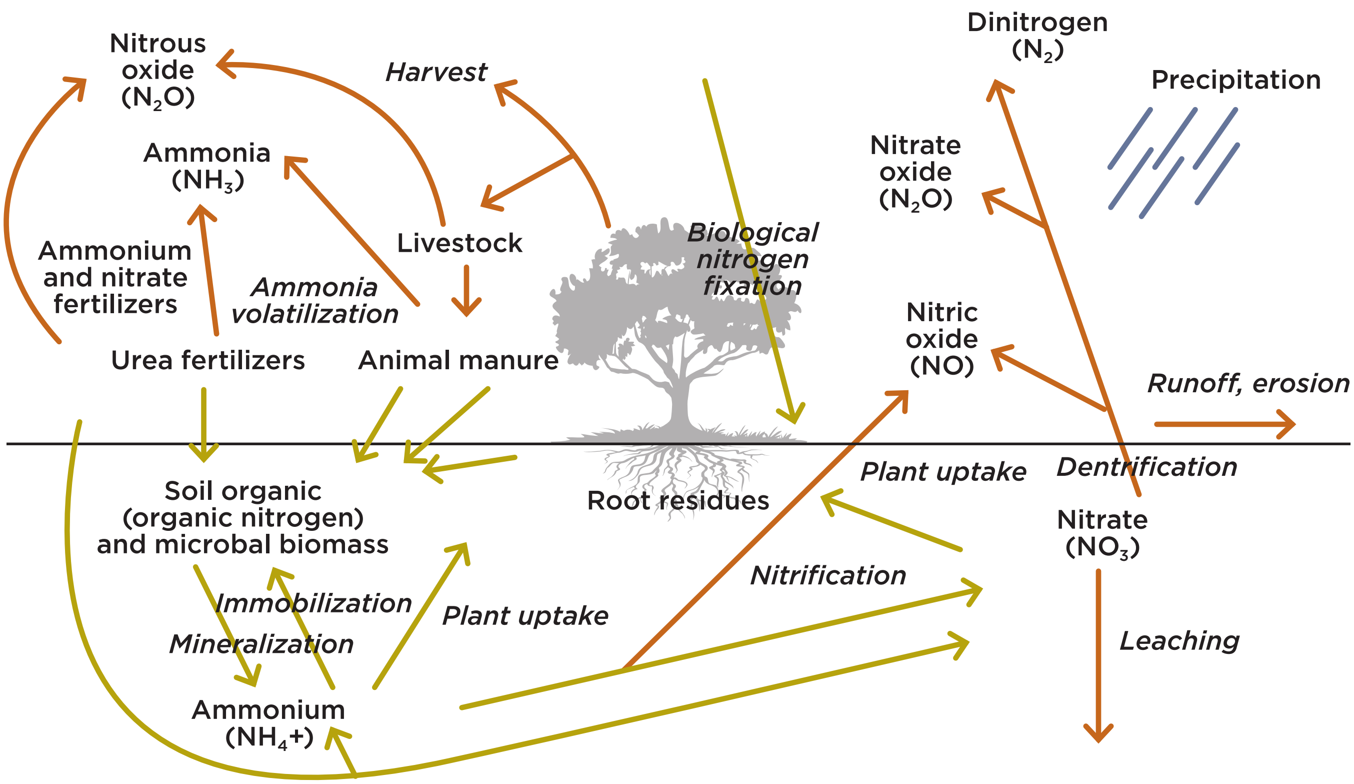
Volatilization: If ammonium ($NH+_4$) or ammonium-producing fertilizers are applied on or near the soil surface, they may be lost from the plant-soil system through ammonia volatilization.

Immobilization: Both ammonium and nitrate may be utilized by soil microorganisms and converted to organic forms through immobilization. Immobilization can be particularly high when the nutrients are in contact with crop residues with a low N concentration.

Denitrification and leaching: Nitrate (NO_3) nutrient sources can be lost by leaching (movement down into groundwater) and denitrification (losses to atmosphere) as soon as they enter the soil. However, if an ammonium or ammonium-producing source of N is used, such as anhydrous ammonia or urea, the ammonium must convert to nitrate before significant losses occur. As soil temperature and soil moisture increase, the rate of conversion from ammonium to nitrate increases, increasing the risk of denitrification and leaching. ●

Simplified nitrogen cycle. This includes the four ways nitrogen can be lost.

Source: OECD, 2001.



Phosphorus is often under-applied

KEY PRACTICE: In the seed row is the best time and place for the first 15 to 20 lb./ac. of phosphate — which is the amount most likely to produce an economic return in the year of application. However, this rate is not enough to match crop removal, which may lead to phosphorus shortages over time.

KEY RESEARCH: Grant, C.A., Agriculture and Agri-Food Canada (AAFC), et al. "The importance of early season phosphorus nutrition," 2001, *Canadian Journal of Plant Science*, 81(2): 211-224.

M. Nyborg and A.M.F. Hennig, AAFC. "Field experiments with different placements of fertilizers for barley, flax and rapeseed," 1969, *Can. J. Soil Sci*. 49: 79-88.

Phosphate applied in the seed row at rates of 15 to 20 lb./ac. (equivalent to 30 to 40 lb./ac. of monoammonium phosphate) should give each seed equal access to a droplet or prill without compromising seed safety. Seed safety, even at these rates, can be at risk in sandy soils using drills with very low seedbed utilization.

Nyborg and Hennig's 1969 paper showed plant stand and yield benefits from seed-placed rates around 10 lb./ac. compared to no seed-placed phosphate. However, they also found that yield and plant stand started to fall at seed-placed rates above 20 lb./ac.

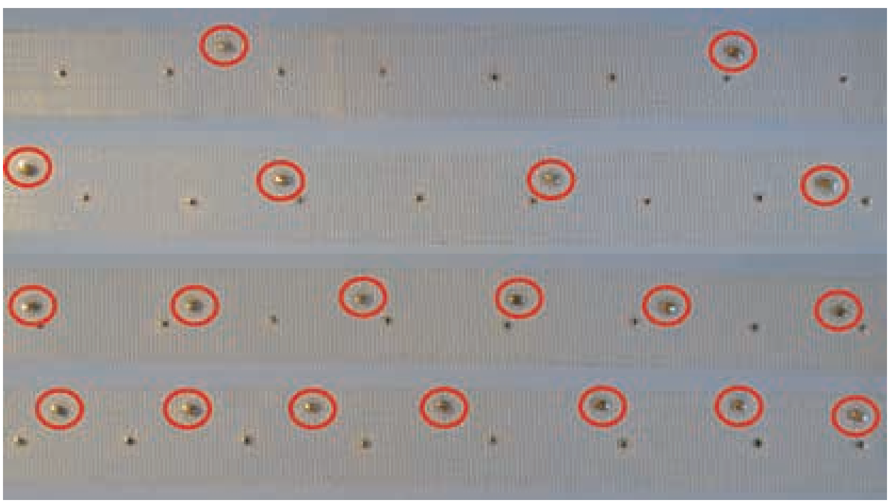
Cindy Grant et al, in the *Canadian Journal of Plant Science* review article "The importance of early season phosphorus nutrition," emphasized the benefit to having phosphate available early in the season. "Early season limitations in P availability can result in restrictions in crop growth from which the plant will not recover," they wrote.

Seed placement of phosphate addresses this early requirement, and is especially valuable in cool soils. That's because temperature may influence the ability of the plant to access phosphorus during the early stages of crop growth. In cool temperatures, diffusion of phosphorus in the soil is slower, root growth is restricted, and phosphorus is less soluble.

Grant et all add that, "Since P will not move through the soil, it must be placed in a position where the plant roots can contact it early in the season. Placing the P in a band in or near the seed row allows the highest possible concentration of roots to contact and utilize the band soon after emergence."

Grant also led a recent study called "Improving nutrient management in canola and canola-based cropping systems," which was reported in the 2013 *Canola Digest Science Edition*. This study found that canola stand establishment was highest when only ammonium phosphate was placed in the seed row. Ammonium sulphate tended to increase seedling mortality, as did a combination of ammonium sulphate and ammonium phosphate. This study found that rates up to 20 kg/ha (roughly 20 lb./ac.) of phosphate seem to be the safest for stand establishment, which supports earlier work by Nyborg and Hennig.

The long-term management challenge for growers is that these seed-placed rates do not come close to matching the removal rates of current canola yields. Canola takes up 1.25 to 1.5 pounds of phosphate per bushel of yield, of which around 1 lb./bu. is removed with the seed, according to Canadian Fertilizer Institute estimates. A crop that yields 40 bu./ac. removes 40 lb./ac. of phosphate. Therefore seed-placed application rates of 15 to 20 lb./ac. are only meeting half the crop removal. Growers could apply the other half as a maintenance rate with their fertilizer blend applied outside the seed row or apply higher rates with cereal crops in the rotation. ●



These demonstration strips from Agvise Laboratories show how lower rates of seed-placed phosphate will not provide equal access for all canola seeds. Dots down the middle indicate canola seeds while dots circled in red are monoammonium phosphate (MAP) particles. The top strip has phosphate at 5 lb./ac., followed by 10, 15 and 20 lb./ac. for subsequent strips. Rates of 15 to 20 lb./ac. of phosphate improve proximity.

Top dress if deficiencies are likely

KEY PRACTICE: In Western Canada where the growing season is short, the ideal practice is to apply all fertilizer at the time of seeding. However, if shortages are expected or crops are showing deficiencies, soil-applied applications of nitrogen or sulphur fertilizer after emergence will likely provide an economic benefit.

KEY RESEARCH: Guy Lafond, Agriculture and Agri-Food Canada (AAFC). "Post Emergent Options for N Fertilization in Western Canada for Wheat and Canola" Manitoba Agronomists Conference proceedings, 2004, pp. 35-40.

S.S. Malhi, AAFC. "Restoring canola yield by applying suphur fertilizer during the growing season," Lee, D.W. (Ed.), Agrium Symposium: Sulfur Fertility and Fertilizers, Agrium New Products R & D, Calgary, pp. 51-55.

Spring applied fertilizer, ideally applied at the time of seeding in a one-pass system, is generally considered the most timely and economical for Western Canada. Cindy Grant, research scientist with Agriculture and Agri-Food Canada (AAFC) in Brandon, MB, tested various nitrogen products and application timings and found that urea applied at the time of seeding achieved yields equal to or better than the same rates applied in a split application (some at seeding, some as an in-season top dress.) In a study titled "Post Emergent Options for N Fertilization in Western Canada for Wheat and Canola," AAFC research scientist Guy Lafond concluded that, when moisture is adequate at seeding, the best practice is to apply all fertilizer at the time of seeding rather than use a split application with some at seeding and the rest added as a top dress.

However, over the years Lafond and other researchers have discovered some cases where top dressing does help. For canola, nitrogen and sulphur are the only two nutrients likely to provide a return on investment when applied as a top dress. It can make economic sense to top dress if:

- **Growing conditions improve after seeding.** If conditions were too wet or too dry at the time of seeding, growers may have cut back fertilizer rates in response to lower yield projections. If conditions improve in June and a good stand emerges, growers may see a yield benefit from splitting the recommended rate, applying some at seeding and some as a top dress.
- **Saturated soils impede good seed placement.** This expands on the previous point. When the only choices to get canola seeded are mudding in or broadcast, cutting back nitrogen rates at seeding may be a good practice to reduce nutrient losses and to assess stand establishment. If the crop becomes well established, an investment in more nitrogen fertilizer would be warranted.
- **High losses are likely to have occurred.** Wet soil conditions can accelerate nitrogen losses through leaching and denitrification and sulphur losses through leaching. Fields may need a top up to reach their yield potential, but make sure canola survived the wet conditions before investing in the fertilizer.
- **The crop is showing signs of deficiency.** Nitrogen deficiency symptoms first show up in older leaves as pale green to yellow colouring, and sometimes purpling. Tissue analysis may confirm these observations, but be sure to follow lab rules for sampling. Turnaround time is another hurdle. Results may not come back in time to take action. As an alternative, growers or agronomists could do a small experiment by spreading fertilizer on the surface and watering it in to see how plants respond. A small patch could be done by hand. If the plants in the patch green up, this suggests a nitrogen deficiency.
- **A grower cannot efficiently place all the fertilizer needed through the seeding tool.** Some growers will address this with a top dress application of nitrogen after crop emergence.

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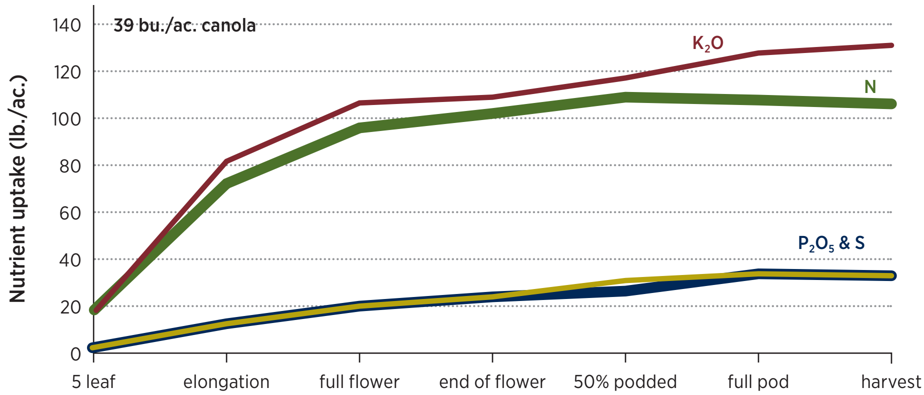
How much N, P, K and S does canola take up?



This graph shows nutrient uptake through the season for nitrogen, sulphur, phosphorus and potassium. Top dress nitrogen and sulphur is ideally applied before uptake peaks. Based on research by Adrian Johnston et al, 1999.

TOP DRESS IF DEFICIENCIES ARE LIKELY

continued from page 17

- **In cases of poor root growth.** Plants may be able to reach leached nitrogen later in the season as their root systems fully develop, but canola in fields with excess moisture may not develop the root system to reach that far. If roots have been growing to the side and there is no dominant taproot, then the taproot is unlikely to develop fully. Lateral roots may start to turn downward as the top layer dries, but they may not have the reach of a good taproot. In this case, a top dress of nitrogen may help the crop — as long as good growing conditions have returned, improving the potential return on that nitrogen investment.

The ideal timing for an in crop application is before crop uptake starts to peak. Nitrogen uptake in canola rises rapidly after the five-leaf stage, as shown in the graph, while sulphur uptake increases more gradually over the season. Therefore, a nitrogen top dress should ideally occur before the five-leaf stage of the crop. This allows time for rainfall to move fertilizer into the root zone, making it available before the peak uptake period begins. Sulphur can be top dressed any time before peak flowering, although the earlier the better.

Efficient products for in crop application are urea (dry) and UAN (liquid) for nitrogen, and ammonium sulphate for sulphur. ●

2.5 FERTILITY MANAGEMENT

Canola needs sulphur fertilizer

KEY PRACTICE: Apply at least 10 lb./ac. of sulphur to every canola acre, every year, no matter the soil test result. Increase if necessary to meet soil test recommendations.

KEY RESEARCH: C.A. Grant, S.S. Mahil and R.E. Karamanos. "Sulfur management for rapeseed," *Field Crops Research* 128 (2012) 119–128 reviews all key research.

Canola growers can experience substantial decreases in yield due to sulphur deficiency. The abstract to the Grant, Malhi and Karamanos review cited above begins with this: "(Canola) has a high concentration of sulphur in its tissue and seed and a particularly high demand for sulphur relative to its yield potential. Therefore, effective sulphur management is an important part of (canola) production. Sulphur deficiencies are becoming increasingly prevalent due to higher crop yields, decreasing aerial deposition of sulphur and decreasing mineralization of sulphur from soil organic matter."

The general recommendation for Western Canada is to apply at least 10 lb./ac. of sulphur to every canola acre, every year, no matter the soil test result. Apply higher rates when necessary to meet soil test recommendations, especially when soil test results are low in sulphur.

A minimum 10 lb./ac. blanket application is necessary because sulphur levels are highly variable within fields, and composite soil tests may show sufficient levels even though large parts of the field may be deficient.

Various field studies in Western Canada over the years have shown this, including S.S. Malhi's field trials in Luvisols in Saskatchewan from 2003-05. In this study, published in *Agronomy Journal* 99, 570-577, Malhi found seed yield was usually maximized at the rate of 30 kg/ha of sulphur, which is roughly 30 lb./ac. Rigas Karamanos in a 2004 study recognized the extremely high spatial variability in soil test S, which prompted him to recommend that a blanket application of 10 lb./ac. of sulphur may be necessary even on soils that test sufficient in sulphur.

Ammonium sulphate tends to be more efficient than elemental sulphur to address crop needs in the year of application. Numerous studies in Western Canada support this, including Malhi's 2000-02 study, as reported in the Canadian Journal of Plant Science in 2005. If using elemental sulphur, Malhi found that fall-applied elemental S usually had greater seed yield and S uptake than spring-applied elemental S.

New rapid release elemental S (RRES) fertilizers are an improvement over other elemental sulphur products, but still do not match yields from an equivalent amount of sulphate-S. From 2011 to 2013, Malhi ran a field experiment to determine the relative effectiveness of RRES fertilizer Vitasul (manufactured by Sulvaris) and sulphate-S fertilizer on canola seed yield on S-deficient Gray Luvisol loam soil at Star City, SK (see the table).

Compared to the zero-S control, seed yield increased significantly with all Vitasul treatments. In this study, spring broadcast pre-emergence and fall-applied Vitasul produced only slightly lower seed yield than the highest yielding spring applied sulphate-S treatments.

When using ammonium sulphate (AS), ideally place it outside the seed row.

An AAFC study led by Cindy Grant looked at seedling damage from combinations of seed-placed phosphate and sulphate products. The study found, as reported in the *Canola Digest Science Edition* 2013, that, "About half the site years showed seedling toxicity with excess rates of monoammonium phosphate and ammonium sulphate (MAP + AS) or ammonium polyphosphate and ammonium thiosulphate (APP + ATS) in combination. Seed-placed P and S significantly reduced stand density at several of the sites, with the effect of S being particularly damaging."

The recommendation is that growers save the seed row location for phosphorus fertilizer, as it provides a known early season benefit to stand establishment. Adding AS to the seed row in addition to ammonium phosphate may push seed-placed nitrogen levels too high for seedling safety in many cases, however good soil moisture and higher seedbed utilization will reduce the risks from seed-placed fertilizer.

An in-crop application of sulphate fertilizer can be effective — whether broadcast early to meet the crop demand or to rescue yield potential when canola shows signs of deficiency. Malhi found that canola's demand for sulphur is highest during flowering and seed set, and that early-season S deficiencies can be corrected with sulphate fertilizer applied as late as rosette to early bolting stages.

Malhi demonstrated this in the study, "Restoring canola yield by applying suphur fertilizer during the growing season," which was published in Lee, D.W. (Ed.), Agrium Symposium: Sulfur Fertility and Fertilizers. Agrium New Products R & D, Calgary, pp. 51–55. ●

Seed yield of canola with rapid release elemental S (RRES) and sulphate-S fertilizers applied at 20 kg S ha with various combinations of application time and placement method in 2011, 2012 and 2013 on a S-deficient soil at Star City, Saskatchewan.

Treatment		Seed yield (kg/ha)			
No	S source/time/method	2011	2012	2013	Mean
1	Control (no S fertilizer)	2021	1361	2759	2127
2	RRES Broadcast Autumn	2836	1860	3872	2856
3	RRES Broadcast Spring Pre-Till	2451	1666	4028	2715
4	RRES Broadcast Spring Pre-Emergence	2692	1929	4100	2907
5	RRES Spring Sideband	2521	1586	3854	2666
6	RRES Spring Seedrow-Placed	2472	1592	3846	2637
7	Potassium Sulphate Broadcast Autumn	2858	1829	3980	2889
8	Potassium Sulphate Broadcast Spring Pre-Till	2985	1952	4215	3051
9	Potassium Sulphate Broadcast Spring Pre-Emergence	2939	1907	3933	2926
10	Potassium Sulphate Spring Sideband	2830	1948	4097	2958
11	Potassium Sulphate Spring Seedrow-Placed	2993	1661	4013	2889
	$LSD_{0.05}$	425	228	337	207

Rapid release elemental sulphur is an improved way to deliver elemental sulphur, but sulphate fertilizer still provides the best crop response in the year of application.

Source: S.S. Malhi, AAFC

Potassium deficiency shows first in cereals

KEY PRACTICE: Most Prairie soils are not short of potassium, and canola rarely responds to applied potassium fertilizer. When checking for deficiencies, note that cereals will show symptoms long before canola.

KEY RESEARCH: R.J. Soper, University of Manitoba. "Soil tests as a means of predicting response of rape to added N, P, and K," 1971, *Agronomy Journal* 63: 564-566.

Most canola crops grown in Western Canada are not short of potassium because most Prairie soils have sufficient potassium levels. Sandy soils with low clay content are most likely to be short of potassium, especially if those fields have been in forages where a large percentage of the biomass is removed each year.

Cereals in the rotation will show signs of potassium deficiency long before canola does. Cereal symptoms may start to show when soil potassium levels drop below 300 lb./ac., which is well above the critical point for canola.

Wheat with a potassium deficiency will have chlorosis on older plant parts, and leaves may eventually become streaked with yellow. This will look similar to some plant diseases, and in fact some wheat diseases are more common when potassium is deficient, according to International Plant Nutrition Institute (IPNI) resources. Any nutrition management measures that address potassium deficiency in cereals will likely also address any potential deficiencies in canola.

Canola rarely responds to applied potassium fertilizer, even under conditions where cereals normally respond. This is based on R.J. Soper's research in Manitoba between 1961 and 1969. Soper's results were published in Agronomy Journal in

Potassium deficiency symptoms will show up in cereals well before it shows up in canola. As you can see in this photo, potassium deficiency in barley looks a lot like leaf diseases. Soil tests and tissue tests may help identify the problem.

Source: IPNI

1971, and they remain the definitive study for potassium fertilization of canola.

Soper concluded that canola would not consistently or economically respond to fertilizer potassium unless the soil test is very low — possibly as low as 70 lb./ac. (35 ppm).

Here is the entire section on potassium from Soper's Agronomy Journal article:

"Rape responded significantly to added K in only 2 of 12 experiments. Nevertheless, there was an obvious relationship between exchangeable K as measured by NH_4OAc and percent yield; a logarithmic equation gave the best fit for this relationship. From this equation, it would appear that rape would respond in yield to fertilizer K on soils which had exchangeable K contents of 200 ppm or less.

"However, the critical value seems to be lower since a significant yield response was not obtained on five soils which had exchangeable K values less than 200 ppm. Tentatively, it is suggested that a critical level of 100 ppm of exchangeable K be used to distinguish between sufficient and deficient soils with respect to their K supplying power for rapeseed production and a value of 35 ppm be used for predicting large yield responses."

Crop nutrition experts believe Soper's work is still relevant, given that soil test levels are unlikely to change much over time. Most potassium taken up by plants remains in the plant biomass, not the seed, and is returned quickly to the soil. Eroding clay particles restock available soil potassium levels.

When applying potassium fertilizer, note that the high salt index of potash limits the amount that can be safely applied near the seed. Most potassium-deficient soils are sandy, which increases canola sensitivity to seed-placed fertilizer. Put potassium fertilizer in a band away from the seed row. ●

Micronutrients: Take care of macros first

KEY PRACTICE: Economic response to micronutrient applications is rare for canola in Western Canada. However, if growers apply recommended rates of nitrogen, phosphorus and sulphur and yields are not increasing, growers may want to check the micronutrient situation.

KEY RESEARCH: Karamanos, R.E., Westco Fertilizers, et al. "Canola response to boron in Canadian prairie soils," 2003, *Canadian Journal of Plant Science* 83: 249–259

Of the six top micronutrients, boron is arguably the most important to canola on the Canadian Prairies. Whole plant tissue analysis of canola at flowering shows a sufficiency level of 29 parts per million for boron, compared to 19 ppm for iron, 14 for manganese, 14 for zinc, 2.6 for copper and 0.02 for molybdenum. What's more, boron is one micronutrient deficiency most likely to show up in canola before it shows up in other crops.

Molybdenum is also more likely to show up in canola before any other crop, but molybdenum is needed at very low levels and deficiencies have not been observed in canola on the Prairies. Iron deficiency is also rare for any field crop on the Prairies. A deficiency in copper is more likely to show up in cereals before canola, manganese in oats before canola, and zinc in alfalfa, flax and beans before canola. Correcting any evident shortages in these other crops should take care of any potential deficiencies in canola.

For these reasons, boron tends to get more attention than any other micronutrient when it comes to canola nutrition management. However, documented cases of boron deficiency are rare.

When boron deficiencies are identified, they typically occur (although still rarely) in marginal sandy soils under dry conditions. These can be corrected with sodium borate broadcast and incorporated in the spring at rates of 0.5 to 1.5 lb./ac. or applied in crop at 0.3 to 0.5 lb./ac. It is worth noting here that rate selection and placement are important. Boron can be toxic to plants and over-application can decrease crop yield. Rates of sodium borate that exceed 1.0 lb./ac. in the seed row can kill canola seedlings.

Rigas Karamanos led a study, published as "Canola response to boron in Canadian prairie soils" in the *Canadian Journal of Plant Science* in 2003, that found no response to boron fertilizer — even on soils with less than 0.15 ppm hot-water extractable boron and with control canola yields of up to 63 bu./ac.

This builds on an earlier study by S.S. Malhi et al, called "Feasibility of boron fertilization on canola in the Saskatchewan parkland," which they presented at the Soils and Crops Symposium in Saskatoon, SK, in 2000. Malhi's study made the following valuable agronomic recommendation: "Some producers apply boron fertilizer to canola without knowing if boron application increases seed yield of canola. In order to save money and optimize the use of boron fertilizer, the following are suggestions to the canola producers: (a) Apply boron fertilizer in test strips and determine if there is any increase of seed yield, and then consider boron fertilization of whole fields on a regular basis. (b) If it is already planned to use boron fertilizer on canola, then leave some canola strips without boron fertilizer in the field and compare the seed yields with and without boron fertilizer."

Boron deficiency is rare, but can happen in dry sandy soils and tends to be extremely variable within a field. This case of boron deficiency occurred on a sandy soil near Carrot River, SK.

Source: Lyle Cowell, CPS

Boron for heat stress

Boron used to prevent bud blast and flower abortion due to heat stress has shown inconsistent results in Ontario field studies led by Hugh Earl at the University of Guelph. Earl has also done greenhouse trials showing a yield response when boron is applied to heat-stressed canola, but limited studies on the Prairies have not shown any consistent positive response to this practice. ●

Rotate crops for blackleg and clubroot management

KEY PRACTICE: Increasing the number of years between canola crops in the rotation reduces incidence and severity of blackleg and clubroot in fields.

KEY RESEARCH: Kutcher, H.R., University of Saskatchewan, et al. "Blackleg Disease of Canola Mitigated by Resistant Cultivars and Four-Year Crop Rotations in Western Canada." *Canadian Journal of Plant Pathology* (2013).

Peng, G., Agriculture and Agri-Food Canada (AAFC), et al. "Crop Rotation, Cultivar Resistance, and Fungicide/Biofungicides for Managing Clubroot (*Plasmodiophora brassicae*) on Canola." *Canadian Journal of Plant Pathology* (2014).

Research in Western Canada has identified significant risk of yield loss from blackleg and clubroot when canola is grown in short rotations. Crop insurance data shows that a one-year break between canola crops provides a clear yield advantage over back-to-back canola. However, longer rotations can improve the management of both of these diseases.

A one-year break between canola crops significantly reduces the carryover of the blackleg fungus on canola stubble, which reduces blackleg severity and the risk of yield loss. A two-year break between canola crops provides a further reduction, and a three-year break can effectively eliminate the yield loss risk from blackleg.

A longer break is also better for clubroot. Note that rotation does not cause clubroot, but short rotations can increase the disease once clubroot is present in a field. Effective management also requires use of clubroot-resistant varieties, limited soil movement and control of clubroot host weeds. Crop rotation is an important long-term management step to maintain effectiveness of the clubroot resistance gene on those fields infested with clubroot spores.

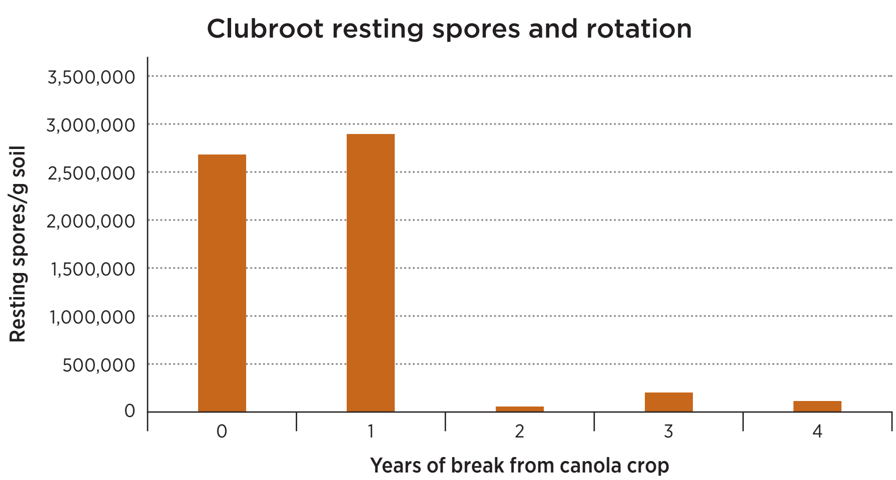
Randy Kutcher of the University of Saskatchewan et al published "Blackleg Disease of Canola Mitigated by Resistant Cultivars and Four-Year Crop Rotations in Western Canada." This 10-year study, funded by SaskCanola, was to determine the implications of shorter rotations while considering cultivar and pesticide improvements made since the four-year rotation recommendation was established.

Canola rotations consisted of continuous canola, wheat-canola, wheat-pea-canola, wheat-pea-wheat-canola and wheat-flax-wheat-canola. Both blackleg-resistant hybrid (HYB) and blackleg-susceptible open-pollinated (OP) cultivars were tested.

With the OP cultivar, blackleg incidence doubled (62 percent) with continuous canola cropping when compared to the four-year rotation (31 percent). Blackleg severity was also 2.6 times higher with continuous canola compared to the four-year rotation.

Similar incidence and severity results were seen with the resistant hybrid cultivar, but the extent of the disease was expectedly reduced. Incidence was 3.3 times greater in continuous canola production (24 percent) and more than double in the two-year rotation (15 percent) compared to the four-year rotation (seven percent).

Although fungicides were effective at reducing blackleg incidence for both cultivars, the magnitude of the reduction in incidence and severity was greater for the OP than the HYB.



*Concentration of **P. brassicae** (clubroot) resting spores drops significantly with a break between canola crops, as Gary Peng of Agriculture and Agri-Food Canada discovered in trials in Normandin, PQ from 2009 to 2013.*

Kutcher concluded, “Yield data would suggest that progress was made in genetic resistance to blackleg in the HYB cultivar, but this has not overcome the need for at least three-year, if not four-year, rotations to achieve optimum canola yield and to reduce the risk of resistance breakdown of current canola cultivars.”

Another paper, “Crop Rotation, Cultivar Resistance, and Fungicide/Biofungicides for Managing Clubroot (*Plasmodiophora brassicae*) on Canola,” published by Gary Peng of AAFC et al, is an analysis of recent canola research in Canada to examine the effect of crop rotation, cultivar resistance and biofungicide or fungicide treatments against clubroot.

Three field studies were also used to answer questions about potential synergy between cultivar resistance and biofungicides; biofungicide seed dressing and crop rotation; and the interaction of resistant cultivars and crop rotation.

Based on the results of this research, use of synthetic fungicides or biofungicides could not be deemed commercially feasible for managing clubroot on canola until greater efficacy is achieved through development of improved formulations.

“At this time, a resistant canola cultivar used in conjunction with a three-year crop rotation is likely to be the most effective and practical strategy for clubroot disease management,” Peng concluded. “This practice reduces the inoculum loads in the field and allows the resistant cultivar to reach maximum yield potential.” ●

3.2

INTEGRATED PEST MANAGEMENT

Thicker stands improve weed management

KEY PRACTICE: Higher seeding rates mean a more competitive crop, which can translate into higher yields and lower in-crop weed management costs.

KEY RESEARCH: Harker, K.N., Agriculture and Agri-Food Canada (AAFC), et al. “High-Yield No-Till Canola Production on the Canadian Prairies.” *Canadian Journal of Plant Science*. (2012).

Harker, K.N., AAFC, et al. “Seeding Rate, Herbicide Timing and Competitive Hybrids Contribute to Integrated Weed Management in Canola (*Brassica napus*).” *Canadian Journal of Plant Science*. (2002).

Seeding canola at relatively high rates results in a more competitive crop. Current research shows both higher yields and improved weed management in crops seeded at a higher rate compared with lower rates of seeding.

Neil Harker of AAFC Lacombe et al published a paper in the *Canadian Journal of Plant Science* (2012) titled: “High-Yield No-Till Canola Production on the Canadian Prairies,” discussing a three-year project on plots in Alberta, Saskatchewan and Manitoba. Harker’s study compared higher-than-average input level combinations with lower-level combinations to determine which would increase canola seed and oil yields in relation to current production practices. Direct-seeded experiments were conducted on eight plots in canola-wheat-canola or continuous canola rotations. Plots were seeded at the rates of 75 and 150 seeds per square metre (or about 7.5 and 15 per square foot). Overall, high seeding rates increased canola yields by the equivalent of 1.3 to 2.9 bu./ac. over low seeding rates.

The paper concluded that, “High-yielding canola on the Canadian Prairies is likely to be grown in rotation with other crops, with more nitrogen than is currently recommended from soil tests, and with more than 75 seeds per square metre.”

In an earlier paper, also published by Neil Harker et al, results of a three-year field experiment at Lacombe and Lethbridge, AB show a 41 percent yield increase through a combination of high seeding rate and early weed removal. This Alberta study analyzed various cultivars, seeding rates and weed management through timing of weed removal to determine the optimal combinations with respect to canola yield and quality.

Hybrid and open-pollinated canola cultivars were seeded at rates of 100, 150 and 200 seeds per square metre (approximately 10, 15 and 20 per square foot). By weight, these rates averaged approximately 5, 7.5 and 10 lb./ac. for the hybrid cultivar and 3.5, 5 and 6.3 lb./ac. for the open-pollinated.

Based on this study’s results, seeding at the lower rate reduced yields by an average of seven percent across all sites, compared with the two higher rates. Typical current canola seeding rates, equivalent to approximately 5 lb./ac., translate to approximately 10 seeds per square foot for hybrid cultivars and closer to 15 seeds per square foot for open-pollinated cultivars, similar to the ones tested. Harker concludes that the combination of higher seeding rates, early weed removal and the use of a competitive cultivar leads to high levels of canola production. ●

Control weeds early

KEY PRACTICE: Control weeds early through a combination of pre-seed weed control and one in-crop application before the four-leaf stage.

KEY RESEARCH: Harker, K. Neil, Agriculture and Agri-Food Canada (AAFC), et al. "Field-Scale Time of Weed Removal in Canola." *Weed Technology* (2008).

Harker, K. Neil, AAFC, et al. "Seeding Rate, Herbicide Timing and Competitive Hybrids Contribute to Integrated Weed Management in Canola (*Brassica napus*)." *Canadian Journal of Plant Science* (2002).

Sapsford, Ken S., University of Saskatchewan. "Timing of Spring Application for Winter Annual Weed Control."

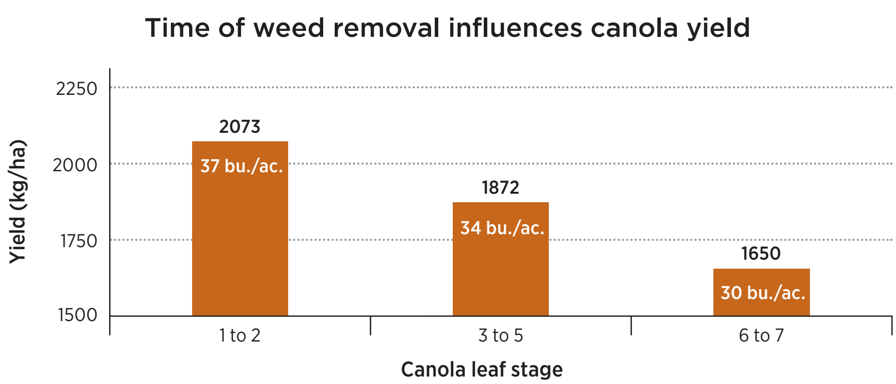
Canola in the seedling stage is a poor competitor against weeds. A combination of a pre-seed burn-off treatment and in-crop herbicide application prior to the four-leaf stage will have greater yield benefits than controlling weeds later in the season.

University of Saskatchewan research shows that, in terms of yield, early weed control is even more beneficial than early seeding. Although this particular study was conducted on wheat, lead researcher Ken Sapsford says results would be similar for canola.

When averaged across all site years in Sapsford's study, early herbicide application, regardless of seeding date, resulted in eight percent higher yields than the combination of late herbicide application with late seeding.

"Field-Scale Time of Weed Removal in Canola," published by Neil Harker et al, discusses the findings of small-plot experiments conducted in 10 Western Canadian canola fields over two years.

Each location was seeded with imidazolinone-resistant (IR) canola and treated with a commercial mixture of imazamox and imazethapyr in 10 gal./ac. of water at the 1- to 2-leaf stage, 3- to 5-leaf stage, and 6- to 7-leaf stage with a field sprayer. Average canola yields across all site years were 2,073 kg/ha (37 bu./ac.) when treated at the 1- to 2-leaf stage, 1,872 kg/ha (34 bu./ac.) when treated at the 3- to 5-leaf stage, and 1,650 kg/ha (30 bu./ac.) at the 6- to 7-leaf stage.



*Early weed control means higher canola yield. This graph is based on results in Neil Harker's paper, "Field-Scale Time of Weed Removal in Canola." **Weed Technology** (2008).*

Harker concluded that canola growers are well advised to ensure weed removal at relatively early growth stages. Delaying weed removal until the 6- to 7-leaf stage reduced canola yields in this study by 20 percent.

In "Seeding Rate, Herbicide Timing and Competitive Hybrids Contribute to Integrated Weed Management in Canola (*Brassica napus*)," Harker outlines the findings of a three-year study funded by the Alberta Canola Producers Commission. Field experiments conducted at Lacombe and Lethbridge analyzed various cultivars, seeding rates and timing of weed removal to determine the optimal combinations with respect to canola yield and quality.

Hybrid and open-pollinated canola cultivars were seeded at rates of 100, 150 and 200 seeds per square metre (or about 10, 15 and 20 per square foot). Both cultivars received the same seed treatments with weed removal timings at the 2-, 4- or 6-leaf stage of canola.

Over all sites, yield was reduced by four percent when weed removal was delayed until the 6-leaf stage of canola. This is consistent with previous studies that show higher yields after early weed removal. The combination of high seeding rate and early weed removal resulted in yield increases of up to 41 percent in this study.

"Managing these factors at optimal levels may help increase net returns, reduce herbicide dependence and favour the adoption of more integrated weed management systems," Harker concluded. ●

Follow insect thresholds

KEY PRACTICE: Follow insect thresholds to manage input costs against potential yield response. Conserve and protect natural enemies and beneficial insects by using economic thresholds to determine the need and timing for insecticidal controls.

KEY RESEARCH: Bracken, G.K. and Bucher, G.E. "An Estimate of the Relation Between Density of Bertha Armyworm and Yield Loss on Rapeseed, Based on Artificial Infestations." *Journal of Economic Entomology* (1977).

Carcamo, Hector, Agriculture and Agri-Food Canada (AAFC). "Refine and Validate Economic Threshold for Lygus Bugs in Canola Production in Alberta." project.

Wise, I.L. and Lamb, R.J. "Economic Threshold for Plant Bugs, Lygus spp. (*Heteroptera: Miridae*), in Canola." *The Canadian Entomologist* (1998).

Prevention of significant insect infestation is an essential long-term component of integrated pest management. Economic thresholds determine the need and timing for insecticidal controls based on potential yield reductions from insect damage while helping to conserve and protect natural enemies and beneficial insects.

If insect counts are at the threshold, yield benefit from an insecticide spray will be enough to cover the product and application cost of the spray on a breakeven basis. When insect numbers rise above the threshold, there will be a return on investment.

Lygus and bertha armyworm thresholds are based on research that measured how much yield loss can be attributed to each insect. The "nominal" thresholds used to manage all other insects in canola are based on experience but not research to quantify impact on the crop.

"An Estimate of the Relation Between Density of Bertha Armyworm and Yield Loss on Rapeseed, Based on Artificial Infestations," published by Bracken and Bucher, provides the basis for current bertha armyworm thresholds. They found that each bertha armyworm larvae per square metre could cause a 0.058 bu./ac. loss.

The thresholds table is based on how many bertha armyworms can be present per square metre before a spray becomes economical, adjusted for spray cost and canola price. Once bertha numbers are at or over the economic threshold, spray as soon as they start feeding on pods.

Lygus thresholds are based on "Economic Threshold for Plant Bugs, Lygus spp. (Heteroptera: Miridae), in Canola," published by Wise and Lamb. They found that one lygus could cause a 0.1235 bu./ac. loss at the late flowering to early pod stages and a 0.0882 bu./ac. loss at the late pod stage. At later stages of canola, insecticide applications would not be economical.

Threshold tables are based on lygus adults and late instar nymphs per 10 sweep-net sweeps and vary based on cost of application and the price of canola. For example, if canola is worth $12 per bushel and spray costs $8 per acre, the threshold at the early pod stage is five per 10 sweeps.

continued on page 26

Bertha armyworm thresholds in canola

Spraying cost – $/acre	Expected seed value – $/bushel										
	6	7	8	9	10	11	12	13	14	15	16
	Number of Larvae/metre²										
7	20	17	15	13	12	11	10	9	9	8	8
8	23	20	17	15	14	13	11	11	10	9	9
9	26	22	19	17	16	14	13	12	11	10	10
10	29	25	22	19	17	16	14	13	12	11	11
11	32	27	24	21	19	17	16	15	14	13	12
12	34	30	26	23	21	19	17	16	15	14	13
13	37	32	28	25	22	20	19	17	16	15	14
14	40	35	31	27	24	22	20	19	17	16	15
15	43	37	32	29	26	23	22	20	19	17	16

This bertha armyworm threshold table, from MAFRD, is based on Bracken and Bucher's research from 1977. For more on bertha armyworm thresholds and other insect thresholds, go to www.canolawatch.org and search for the article "Thresholds: insect management tools."

Courtesy of MAFRI

FOLLOW INSECT THRESHOLDS
continued from page 25

Current thinking is that five lygus per 10 sweeps is far too few to warrant a spray and that the threshold is likely higher, especially for canola growing strong with decent moisture.

Wise and Lamb acknowledged this in their research paper, stating, "When precipitation is greater than 100 mm (4″) from the onset of bud formation to the end of flowering, the crop may partially compensate for plant bug damage."

Canola Council of Canada agronomist Keith Gabert confirms this based on recent fieldwork in central Alberta. "In areas where moisture is generally adequate and we have frequent lygus infestation, it has become normal to double or triple the threshold charts we have for lygus," Gabert says. This is likely due to potential improvements in economic return and a lack of yield response in previous years when spraying lighter infestations.

Canola plants are bigger and hardier than in the mid-1990s when Wise's and Lamb's studies were conducted. Current hybrids may be able to compensate for more lygus feeding.

Hector Carcamo with Agriculture and Agri-Food Canada (AAFC) is leading new research to refine and validate economic thresholds for lygus bugs in canola production in Alberta. He writes: "It is anticipated that such improved decision making tools will help canola growers to reduce the business risk of canola production by improving management of lygus bugs, as well as increase its economic viability and environmental sustainability by reducing unnecessary pesticide sprays." ●

3.5 INTEGRATED PEST MANAGEMENT

Take care of beneficial insects

KEY PRACTICE: Use insecticides judiciously and employ strategies that may increase populations of some beneficial insects and reduce mortality of some parasitoids. These strategies include reducing tillage, leaving tall stubble to improve overwinter survival and intercropping.

KEY RESEARCH: Dosdall, Lloyd, University of Alberta. "Improved Integrated Crop Management with Beneficial Insects." *Canola Digest* Science Edition (2013).

Dosdall, Lloyd, University of Alberta. "Determining Athropod Biodiversity in Canola Cropping Systems as a Key to Enhancing Sustainability of Production." *Canola Digest Science Edition* (2013).

Beneficial insects provide valuable contributions to canola production, both in terms of pollination of crops and predation of insect pests. Monitoring populations of both pest insects and parasitoids can help canola producers make decisions about the need for insecticide applications.

Canola growers should also employ strategies that may increase populations of some beneficial insects and reduce mortality of some parasitoids. These include limited spraying during flowering to protect bees and other pollinators, and reducing tillage, leaving tall stubble to improve overwinter survival, intercropping and even leaving late-emerging weeds in canola to bolster dominant predator counts.

Lloyd Dosdall of the University of Alberta led two recent projects focused on beneficial insects (both were summarized in the *Canola Digest Science Edition*, 2013).

"Determining Arthropod Biodiversity in Canola Cropping Systems as a Key to Enhancing Sustainability of Production" provides a starting point towards filling the gaps that exist in our understanding of potentially beneficial insects at work

***Diadegma insulare**, shown here along with two diamonback moth larvae, are known to sometimes completely terminate diamondback moth outbreaks in Western Canada.*

in our fields. This includes development of a new database of insect biodiversity in canola fields in Alberta.

Dosdall found that weeds in a field increased insect biodiversity. For this reason, sequential herbicide applications to control late-emerging weeds should be avoided. The negative effect of these weeds on crop yield may be minimal, and the study indicates that small weedy backgrounds have the potential to enhance arthropod biodiversity, especially of predatory ground beetles.

"Improved Integrated Crop Management with Beneficial Insects" was a three-year study led by Dosdall and Owen Olfert, Julie Soroka and Neil Harker of Agriculture and Agri-Food Canada (AAFC). This study focused on the parasitoids that help keep diamondback moth populations regulated. *Diadegma insulare* is known to sometimes completely terminate diamondback moth outbreaks in Western Canada. *Microplitis plutellae* and *Diadromus subtilicornis* also attack diamondback moth, sometimes inflicting high levels of parasitism. The aim of this project was to develop forecasting strategies to predict abundance levels and distributions for these three parasitoids.

Field surveys identified three other parasitoids of diamondback moth, including the discovery of an unknown species of braconid believed to be *Costesia vestalis*. This species appears responsible for a substantial level of the total parasitism of diamondback moth.

The most efficient approach to monitoring canola for diamondback moth and its parasitoid fauna is to take sweep net samples from several locations in each production field.

This study shows parasitism of diamondback moth larvae and pupae can be relatively high early in the season. Producers are encouraged to carefully monitor pest and natural enemy populations to ensure insecticide applications are necessary. ●

Bees and other pollinators are most active when the crop is flowering. Avoid spraying insecticide on flowering canola. If this is unavoidable, apply products to flowering canola after 8:00 p.m. until dusk, or into night, when bees aren't actively foraging. Follow thresholds when making spray decisions. For more information, go to www.canolawatch.org and search for the article "Bee BMPs."

Photo: John Gavloski, MAFRD

***Banchus flavescens** attacks the early larval stages of bertha armyworm.*

Photo: John Gavloski, MAFRD

Ensure all crop inputs are working together

KEY PRACTICE: Recommended fertilizer rates and seeding rates that provide for a competitive stand will make canola more resilient against weeds, insect damage and disease.

KEY RESEARCH: Brandt, S.A., Agriculture and Agri-Food Canada (AAFC), et al. "Seeding Rate, Fertilizer Level and Disease Management Effects on Hybrid Versus Open Pollinated Canola (*Brassica napus* L.)."

Effective pest management uses all the tools available in a method that reduces the severity and economic impact of the pest problem. All inputs must work together to establish a plant stand and crop canopy that are resilient against weeds, insect damage and disease and to maintain this protection through to harvest.

"Seeding Rate, Fertilizer Level and Disease Management Effects on Hybrid Versus Open Pollinated Canola (*Brassica napus* L.)," published by Stu Brandt of AAFC et al discusses studies conducted to investigate the influence of seeding rates, fertilizer level and fungicide application on canola variables, including growth and seed yield.

The objective of Brandt's study was to determine if recent high-yielding canola cultivars require different seeding and fertilizer rates from past recommendations. The study also analyzed the benefit of fungicide across various soil-climatic zones.

The three-year study involved two high-yielding canola cultivars, one hybrid and one open pollinated, seeded at rates of approximately 2.5, 5 and 7.5 lb./ac. at three sites in the Canadian Parkland region. Fertilizer was applied to supply 67 percent, 100 percent and 133 percent of the commercially recommended level of nitrogen (N), with phosphorus, potassium and sulphur proportionally varied for each level.

Vinclozolin fungicide was applied at the 20 to 30 percent bloom stage to control sclerotinia stem rot, which was observed at very low levels at all but one site-year, where it was moderate. Both chosen cultivars were highly resistant to blackleg which was therefore observed at very low severity. At only one site-year, azoxystrobin fungicide was applied at the two- to four-leaf stage to further inhibit blackleg development.

In terms of overall growth, seeding rate had more of an impact on time to flowering or plant maturity than the cultivar or fertilizer rate. Fungicide had no notable impact.

Averaged over all site years, the incidence of sclerotinia was higher in the hybrid cultivar compared to the open-pollinated, and also higher when no fungicide was applied. Seeding rate and fertilizer level had no significant impact on sclerotinia.

Blackleg incidence was low and also not affected by any of the treatments in this study.

There was a significant interaction across all site-years between seeding rate and fertilizer level, indicating that seed yield response to one input was dependent upon the rate of the other. In general, the high fertilizer level increased yield by zero to six percent over low-level fertilizer when plant densities were less than 45 plants per square metre. When plant densities were 65 plants or more per square metre, the high fertilizer level resulted in 12 to 18 percent higher yield than the low level.

At the low fertilizer level, yield increased with an increase from the low to mid rate of seeding, but with no further yield increase at a high seeding rate. However, at the high fertilizer rate, there was a notable further increase in yield when the seeding rate was increased from mid to high. This would indicate that the full yield potential of a higher seeding rate is only realized with a higher rate of fertilizer application, and vice versa.

Brandt reports, "Overall, the hybrid performed better than the open-pollinated, and the full economic value of high-yielding canola cultivars was only realized when fertilizer and seeding rates were at or above the current recommended rates." ●

Genetics will reduce harvest losses

KEY PRACTICE: Canola varieties with pod shatter tolerance have arrived. Pod shatter tolerance adds more flexibility for harvest timing, allowing crops to stand longer with fewer losses.

KEY RESEARCH: Cavalieri, A., University of Manitoba, et al. "Pod Drop and Pod Shatter Are Not Closely Related in Canola." *Crop Science* (2014).

Gan, Y., Agriculture and Agri-Food Canada (AAFC), et al. "Assessment of Seed Shattering Resistance and Yield Loss in Five Oilseed Crops." *Canadian Journal of Plant Science* (2008).

Holzapfel, C., Indian Head Agricultural Research Federation. "Cultivar Considerations for Straight Combining." Canola Agronomic Research Program (CARP) project, 2014.

Shan, S., Alberta Innovates and Rahman, H., University of Alberta. "Developing *Brassica napus* Lines With Reduced Pod Shattering." CARP project (2013).

New pod shatter tolerance traits make the variety decision an even bigger part of harvest management.

Despite being considered together as harvest loss, pod shatter and pod drop are not closely related in canola. A recent study from Andrea Cavalieri found that pod shatter is primarily impacted by genotype, while environment is the dominant driver for pod drop. The fact that pod shatter tolerance is largely genetic makes variety selection even more critical, especially for those considering the straight combining method. This study also discovered that despite greater hybrid seed size, open-pollinated varieties actually had higher pod drop than the hybrid counterparts.

Yantai Gan's study into seed shattering resistance and yield loss in various oilseed crops also concluded that various species and cultivars expressed different degrees of pod shatter, especially under high shattering conditions. This adds more emphasis to the importance of variety selection, especially in areas more prone to high shattering conditions.

Encouraging results came out of Shan and Rahman's four-year project, "Developing *Brassica napus* lines with reduced pod shattering." Pod shattering genes were isolated and canola transformations were made. The first generation of transformed canola plants were assessed for pod shattering resistance and those with reduced pod shattering were grown into succeeding generations, which were then reassessed for shatter resistance. When straight combined in a field test, several lines reported a 30 percent reduction in pod shattering compared to the straight combined control. Therefore, this project has identified *B. napus* genes that can be used to develop non-GMO canola with reduced pod shattering.

Chris Holzapfel highlighted variety selection in his 12 cultivar, three herbicide system, four-year, Saskatchewan-based study, "Cultivar Considerations for Straight Combining." Preliminary results show significant differences in shatter losses between varieties, with new shatter resistant lines performing well. Final results are anticipated for future canola publications.

Still, the greatest limiting factor at this point may be finding a variety that suits all needs. For instance, if clubroot resistance is a necessity, reduced pod shattering may not be available in the same variety. Yield potential, lodging resistance and days to maturity may be other helpful factors in harvest management. Canola Performance Trials (CPT) provide valuable updates on how varieties are performing in a multitude of locations around the Prairies. These data can be viewed by year, type of herbicide tolerance as well as by percentage of checks or actual values. This year's results are posted on the CPT website at www.canolaperformancetrials.ca. ●

A recent study by Andrea Cavalieri with the University of Manitoba found that pod shatter is primarily impacted by genotype, while environment is the dominant driver for pod drop.

Harvest prep starts in the spring

KEY PRACTICE: Reducing harvest losses starts with strong crop establishment, adequate fertilization, early weed control and frequent scouting.

KEY RESEARCH: Liu, C., Agriculture and Agri-Food Canada (AAFC), et al. "Evaluation of On-Farm Crop Management Decisions on Canola Productivity." *Canadian Journal of Plant Science* (2014).

Watson, P.R., Alberta Research Council, et al. "Canola Harvest Management Study." Canola Agronomic Research Program project (2008).

A 2014 study by Chang Lui et al reported 24 percent greater seed yield when canola was straight combined instead of swathed. The sample size was small — only six growers in this study straight combined compared to 55 who swathed. But the study brought up an interesting point: a portion of the success growers who straight combined enjoyed may have been due to the other management strategies, such as the use of preseed weed control, which they all used.

Similarly, it has been estimated that a portion of the seed yield increase attributed to straight combining is due to the extended time the seeds are allowed to mature before the crop is cut. Deliberate management techniques, such as accurately assessing the stage of seed development, can be crucial to the success of straight combining experiences.

Paying special attention to seeding rate and speed, seed placement (which promotes uniform maturity later in the season) as well as variety selection (for improved pod shatter tolerance) can increase the potential for a successful experience with straight combining. A field that is well knit-together, yet not excessively branched, with uniform maturity, good pod integrity and good standability is also thought to deliver best results when straight cutting.

In addition, a study called: "Canola Harvest Management" by Paul Watson et al determined that growers who straight combined canola also generally seeded early, adhered to an adequate nitrogen fertility program, used high seeding rates and maintained early weed removal as part of their crop management. While some of these strategies may have had more impact on the final yield than others, this study found that increased fertility was the most important factor for improving potential yield, and thereby increasing the chance of success (as measured by yield) for straight combining. The importance of greater crop density and early weed removal were also reported, but they tended to be dependent on the location and year.

Straight cutting is also more successful when the crop has even maturity. This can be achieved by planting at a rate adequate to produce seven to 10 plants per square foot, which will keep branching to a minimum, allow a buffer against plant losses due to various pests and environmental stresses throughout the season, and provide plants with the vigour required to outcompete weeds.

Further support was provided by Rob Gulden's 2010-13 study: "Evaluation of Harvest Losses and Their Causes in Canola Across Western Canada," which found that lower harvest losses were associated with higher yielding crops. This could be attributed to the additional successful management strategies that high-yielding growers carry out earlier in the season, such as seeding early, early weed control and frequent field scouting.

Chris Holzapfel had similar conclusions after his 2011 harvest management study. To reduce harvest losses, he suggested using a relatively high seeding rate in order to produce a stand with even and early maturity, while controlling disease and weed pressure. ●

Studies have found that lower harvest losses in canola are associated with higher yield potential, especially when straight combining. This could be attributed to the additional strategies high-yielding growers carry out earlier in the season, such as seeding early, early weed control and frequent field scouting.

Wait for 60 percent seed colour change

KEY PRACTICE: Swathing at 60 percent seed colour change, or later, tends to increase harvested yield.

KEY RESEARCH: Canola Council of Canada. "Time of Swathing Trial." *Crop Production Centre summary report* (2001 and 2002).
Vera, C.L., Agriculture and Agri-Food Canada (AAFC), et al. "Yield and Quality of Canola Seed as Affected by Stage of Maturity at Swathing." *Canadian Journal of Plant Science* (2007).

Growing spring canola in the moderately short growing season of the Canadian Prairies always tests the tipping point between maximum maturity time (to produce maximum yield) and avoiding the first frost. With growers taking on more acres than ever, the time crunch at harvest can make it tempting to begin swathing early. But the yield gain and improved quality that rewards additional time for colour change can make it well worth the wait.

The study that first shared these findings was published in the Canola Council of Canada's (CCC) Crop Production Centre summary reports in 2001 and 2002 and has since been supported in subsequent literature. This 12-site year CCC study, carried out in locations across Manitoba, Saskatchewan, Alberta and one site in British Columbia, determined that the highest yielding swathed crops were cut at either 50 to 60 percent seed colour change (SCC) or 60 to 70 percent SCC on the main stem. Swathing progressively later (to a maximum of 60 to 70 percent SCC) also corresponded to increasingly better economics. By delaying swathing until 60 to 70 percent SCC, canola fields produced higher seed weights, greater oil content, lower green seed percentage and a higher grade.

A similar swath timing study by Brown et al (1999) determined that yield loss and swath timing were strongly related. The lowest losses were associated with swath timing as late as 60 to 80 percent "brown seed" and the highest losses were recorded for crops swathed at 10 to 20 "brown seed".

For growers producing seed canola, Elias and Copeland (2001) also found that harvesting canola when seeds were brown to black instead of greenish-brown to light brown resulted in higher seed quality, including increased germination and seed vigour. More recently, Daun (2006) confirmed that yield and oil content were positively correlated in an extensive study of canola samples from across Western Canada. The increased duration required for higher yielding crops to mature also provides the additional time needed for chlorophyll levels to decrease to an optimal level. This is supported by Watson et al (2008) who determined that percent green seed was significantly higher in early harvest and seedpod shatter losses were greater in the later harvested treatment.

Interestingly, the varieties used today may have even more dramatic results, since high-yielding hybrid varieties, which produce secondary branching, make harvesting canola at the optimal time even more crucial.

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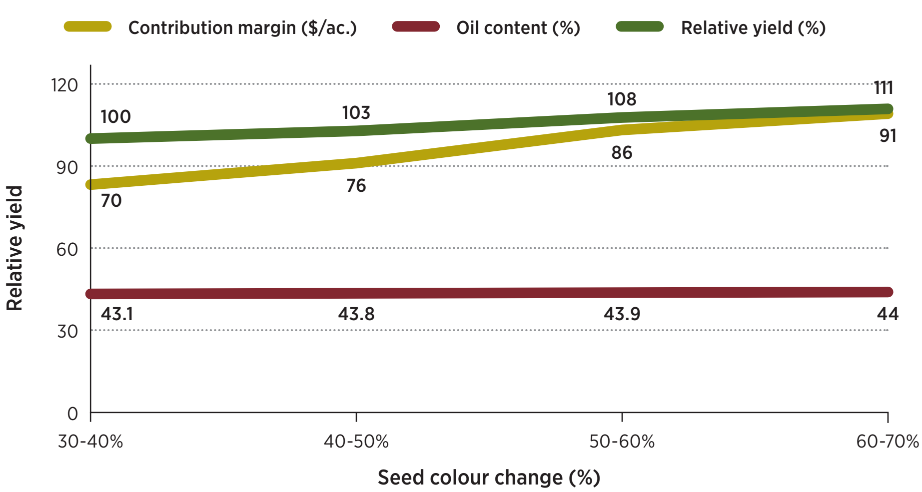
Time of swathing trials (12 site years)



CPC Summary Data (2001-2002)

WAIT FOR 60 PERCENT SEED COLOUR CHANGE

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By delaying swathing until 60 to 70 percent seed colour change on the main stem, canola fields have been shown to produce higher seed weights, greater oil content, lower green seed percentage and a higher grade.

Just as the shift in acres from lower yielding (determinate flowering) *Brassica rapa* to higher yielding (indeterminate flowering) *B. napus* was associated with a greater time to maturity, so is the shift from older to more current varieties with high yield potential.

Since the seed yield increases as the crop matures and seed moisture decreases, it is imperative to postpone harvest until the maximum yield is reached. Vera et al (2007) reported the sigmoid curve that seed yield follows as seed moisture content decreases over time, with some sites only reaching their maximum yield near 20 percent moisture. Premature swathing (in this study) led to significantly lower seed yield, seed weight reductions and compromised seed quality. Meanwhile, swathing at physiological maturity resulted in higher yields.

To get a better idea of how long to wait to swath, note that SCC can increase at a rate of approximately three to five percentage points every day. Therefore, a field at 20 percent SCC will be at ideal swath timing in approximately eight to 13 days.

On the Prairies, canola that is physiologically mature will typically see one to three percentage points of moisture loss per day. This means that a crop swathed at 25 percent moisture could drop down to 10 percent moisture in five to 15 days. Hot, dry conditions will accelerate both increase in SCC and dry down rate.

Of course, every year won't necessarily allow for ideal conditions and 60 percent SCC. If growers can't wait for this threshold for all crops, waiting even a few extra days to swath on a few fields will reduce average quality losses and increase yields for the farm. For more informa-tion check out the CCC swathing guide at: www.canolacouncil.org/media/530966/canola_swathing_guide.pdf ●

Improved genetics, larger farms and the yield benefits realized in fields harvested at (at least) 60 percent seed colour change (SCC) have made straight combining an attractive — and realistic — alternative to swathing. There is good reason for this consideration, too: reduced time, cost and equipment wear, along with the potential increases in seed size, yield and oil content associated with this harvest method. However, the increased risk can be a deterrent.

Determining which method is most appropriate requires the consideration of several factors, which may vary in importance according to the growing conditions in an area. A two-year study: "Canola Genotypes and Harvest Methods Affect Seedbank Addition," by Teketel Haile et al (2014), determined that swathing resulted in significantly higher seed shatter, and consequently greater seed loss than straight combining. In addition to this yield loss, the seeds contribute to volunteers that will have to be managed the following year, requiring more time, machinery use and cost.

Major pre-harvest losses come from pod drop and pod shattering. Commercial pod sealant products may seem to provide a quick way to prevent these losses, but Haile tested two of these products and found that neither had a significant impact on seed loss in canola. In fact, in this study, the pod sealant (straight combined) treatments added a significantly greater number of seeds

Reduce losses while combining

KEY PRACTICE: Ground speed and mechanical adjustments to the combine can reduce harvest losses and increase yields. For growers who want to try straight combining, start with one field with uniform maturity and high yield potential.

KEY RESEARCH: Gulden, R.H., University of Manitoba, et al. “Evaluation of Harvest Losses and Their Causes in Canola Across Western Canada.” *Canola Digest Science Edition* (2013).

Haile, T.A., University of Saskatchewan, et al. “Canola Genotypes and Harvest Methods Affect Seedbank Addition.” *Agronomy Journal* (2014).

Holzapfel, C., Indian Head Agriculture Research Foundation. “Evaluating the Effects of Glyphosate and Pod Sealants on the Yield of Straight-Combined Canola on a Large Field-Scale.” Canola Agronomic Research Program (CARP) project (2011).

Holzapfel, C., Indian Head Agriculture Research Foundation. “Evaluating the Effectiveness of Pod Sealants for Reducing Shattering Losses in Several Cultivars of Direct-Combined Canola.” CARP project (2010).

to the seedbank than the swathed treatment. The straight combined sites in another Haile et al study (2014) produced seeds with significantly higher 1,000-seed weight, which, along with the reduced cost of running over the field twice, suggests that straight combining can be attractive for reasons other than just reduced harvest losses.

Reducing harvest losses, whether picking up a swath or straight combining, can be achieved with slower combine speeds and through variety selection, as Gulden found in his Growing Forward study: “Evaluation of Harvest Losses and Their Causes in Canola Across Western Canada.” Combine method, time of day of swathing, and combine type and manufacturer were not shown to have significant impacts on harvest losses.

Alternatively, Chris Holzapfel’s 2011 study of combine headers found the draper header to be better than a rigid type or an extended header with the knife out front of the reel. The Ontario Canola Growers Association also ran a study in 2012 to compare shatter loss and yield differences between three straight cut headers. It found that a modified 30-foot John Deere 930 header with the flex pan removed and replaced with a solid pan with an 18″ table extension had the lowest seed loss.

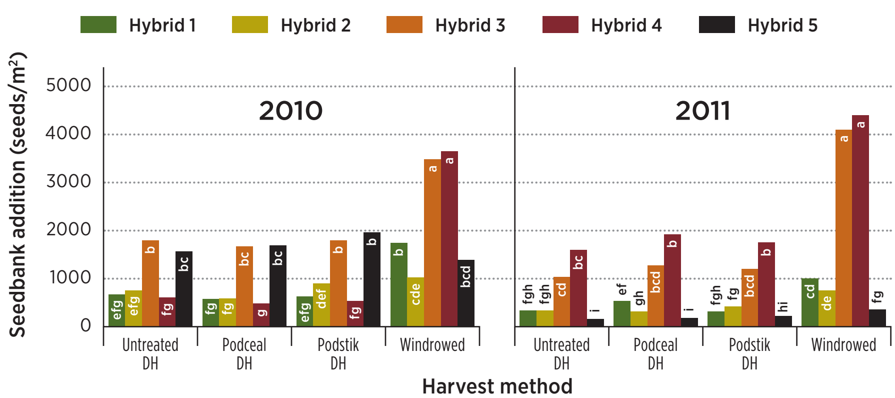
Wheatland Conservation Area at Swift Current, SK found some evidence that specialty headers with the knife out front of the reel will reduce shatter losses, but concluded that more work is necessary in a wider range of Prairie conditions. Prairie Agricultural Machinery Institute (PAMI) has just begun another comparison.

Testing combine loss and making several minor adjustments can save big losses. For tips on how to check harvest losses, go to www.canolawatch.org and search for the article “Reduce costly harvest losses — tips.”

Aside from all the aspects growers can control, Holzapfel highlighted some additional aspects of straight combining. Timing of desiccant applications are critical to the resulting green seed counts in straight combining operations, and if desiccants aren’t applied aerially, driving over a crop can lead to wheel tracks reducing yield by two to five percent. Therefore, Holzapfel suggested selecting a variety suitable for this harvest method. One that is high-yielding and relatively resistant to shattering is ideal. Paying extra attention to the maturity level of the crop in order to avoid harvest delays on these fields is also beneficial.

For more on the risks and benefits of straight combining versus swathing, see the article “Straight combining: Risk or reward?” in the September 2013 edition of *Canola Digest*. Go to www.canolacouncil.org and search for this title. ●

Canola seedbank additions by harvest method and hybrid



Seedbank additions from seed shatter for the interactions of canola genotype × harvest method in 2010 and 2011. Means were separated within each year. Within each year, treatment means with the same letter are not significantly different according to the LSD at the 5% level. DH = direct-harvested.

Teketel Haile’s 2010 and 2011 trials show minimal benefit to pod sealants. But they also show that losses can be higher with swathing, and that losses vary by variety.

Store it, but don't forget it

KEY PRACTICE: Eight percent moisture and cool grain temperatures are best for long-term storage. Ideally, put canola on aeration after harvest to cool it and remove moisture that "sweats" out of the grain. Check stored canola often, and especially when the outside temperature shifts in fall and spring.

KEY RESEARCH: Agnew, J., Prairie Agricultural Machinery Institute (PAMI). "Canola Storage Research." PAMI/CCC project (2014).

Jayas, D.S., University of Manitoba, and White, N.D.G., Agriculture and Agri-Food Canada (AAFC). "Storage and Handling Characteristics of New Varieties of High Oil Content Canola." *Canola Digest Science Edition* (2013).

Jian, F., University of Manitoba, et al. "Heat Production of Stored Canola Seeds Under Airtight and Non-Airtight Conditions." Transactions of the ASABE (2014).

After escaping all the yield loss traps in the field, there is one more obstacle to overcome before delivering canola to the elevator: storage. Grain mismanaged in a bin can result in disappointing losses. Paying attention to the moisture and temperature of the grain as well as outdoors is critical to management.

Canola storage was the focus of Joy Agnew's group at the Prairie Agricultural Machinery Institute (PAMI) this past summer. In collaboration with the Canola Council of Canada (CCC) and the provincial canola grower organizations, she monitored temperatures and relative humidity of three canola bins throughout the summer to determine best management strategies for summer storage. Agnew's project began in the winter, turning on aeration fans in temperatures below -30°C to freeze the canola. Nine temperature and humidity sensors were inserted into the bins in early June, using long probes for minimal grain disturbance, and monitored until removed.

The three bins used in this study each had their own treatments. One was left alone, one was turned in early June and one had the fans turned on at night beginning in mid-June. Preliminary results indicate that if frozen (due to the conditions experienced in early 2014), canola is best left alone to safely store throughout the summer.

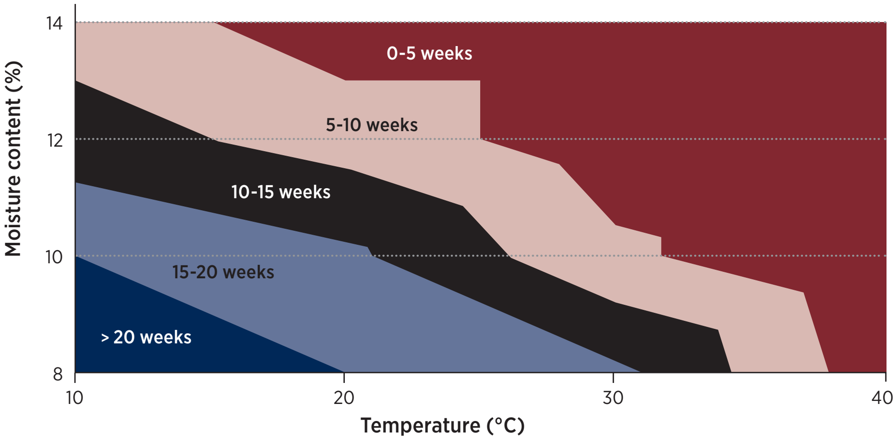
The most critical thing to remember about storage management is to check your grain often. Heating, high moisture or pest problems can develop quickly if the grain is not under regular surveillance. Watching the temperatures change with the PAMI project supports this. To read a blog of Agnew's results, go to www.canolawatch.org and search for "Blog: Canola bin watch."

Heat isn't the only concern with stored canola. Microflora infestations can be a problem too. Fuji Jian et al's 2014 study determined that canola seed at 14 percent moisture was able to support a variety of microorganisms at each of three storage conditions (20°C non-airtight, 30°C non-airtight, and 30°C airtight), with greater infestations in the non-airtight conditions. These organisms can contribute to heat production and reduce grain quality. The spoilage risk is lower for cool and dry canola, with eight percent moisture and temperatures below 15°C considered safer for long-term storage.

Aside from traditional bin storage, research on short-term storage bags suggests they are a viable option. Digvir Jayas, a researcher at the University of Manitoba, continues to test the limits for storing canola in these large grain bags. He has found that canola can be safely stored for over 10 months at moisture levels of eight and 10 percent.

For further storage details, read the storage chapter at www.canolacouncil.org/canola-encyclopedia." ●

Safe storage guidelines for high oil (45 percent) canola.



Source: D.S. Jayas, University of Manitoba

The federal government's $15 million investment in canola research through Growing Forward 2 combined with the canola industry's contribution of $5 million is funding 23 research projects for five years. Here are short descriptions and early progress reports for agronomy projects on that list, organized into the four strategic plan categories. Final results are still a few years away.

Growing Forward 2
A federal-provincial-territorial initiative

Research briefs: 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: To compare canola emergence, yield and quality when several canola seed sizes are seeded at two seeding rates using new hybrid cultivars.

PROGRESS: Field experiments were successfully conducted at nine locations in 2013. Seed size effects on canola emergence, yield or seed quality were not significant. Increasing seed size had a positive linear association with early canola biomass and 1,000-seed weights, whereas days to flowering and days to the end of flowering had a negative linear association with seed size.

Canola yield and quality optimization – investigating tolerance of canola genotypes to heat and drought stresses, and root traits estimation by electrical capacitance

LEAD RESEARCHER: Bao-Luo Ma, AAFC Ottawa, ON

PURPOSE: To select for canola genotypes with better tolerance to heat and drought stresses, focusing on root traits, the critical period of sensitivity to heat stress and the critical temperatures causing flower abortion.

PROGRESS: Early-seeded canola outperformed late-seeded canola in yield, number of branches, pods per plant, number of seeds per pod, 1,000-seed weight and had the lowest amount of damaged seed in an Ottawa field experiment. Seeding rate significantly affected stand establishment, final yields, number of branches, pods per plant and number of seeds per pod.

Does seed size matter? Neil Harker with AAFC Lacombe, AB has just started a new experiment to see whether seed size influences germination, stand establishment, days to flowering and yield.

Canola rotation studies

LEAD RESEARCHER: Claude Caldwell, Dalhousie University

PURPOSE: The overall goal of this project is to gain a better understanding of how canola will fit into existing cropping systems in Eastern Canada or areas of Western Canada that include soybean and corn in their rotations.

PROGRESS: Three years into a four-year study, results suggest continuous crop rotations yield lower than non-continuous rotations. In other rotations (excluding continuous canola), canola didn't show any significant effect on the yields for following crops, and preceding crops didn't show any significant effect on canola yields.

Fertility management

Variable N fertility management of canola at the field scale

LEAD RESEARCHER: Alan Moulin, AAFC Brandon, MB

PURPOSE: To assess management zones for variable application of nitrogen (N) fertilizer based on analyzed soil test data, yield maps, and landform and soil properties. Remote sensing data will be combined with analysis of elevation and landform attributes to assess yield response in these zones.

PROGRESS: Three sites in Alberta, one in Saskatchewan and three in Manitoba were carried out according to protocol.

Economic profitability and sustainability of canola production systems in Western Canada

LEAD RESEARCHER: Scott Jeffrey, University of Alberta

PURPOSE: To assess the level of technical efficiency of a sample of Western Canadian canola producers and examine whether adoption of environmental stewardship practices has any effect on these efficiency levels.

PROGRESS: Model results (which were significantly influenced by moisture problems in 2011) indicate that best management practice (BMP) variables for soil tests, nutrient management planning and precision farming are positively related to technical efficiency.

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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: This project builds on prior identification of diverse clubroot resistance (CR) sources and focuses on characterizing CR genes in the resistance genotypes identified in order to provide the industry with new sources of resistance.
PROGRESS: AAFC Saskatoon, University of Alberta and University of Manitoba laboratories have identified three CR genes, evaluated a three-way cross involving a clubroot resistant rutabaga line and two spring canola lines in field plots, and mapped eight loci from different *B. rapa* materials.

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

LEAD RESEARCHERS: Sheau-Fang Hwang, Alberta Agriculture and Rural Development (AARD), and Stephen Strelkov, University of Alberta
PURPOSE: To further understand this host-pathogen interaction for knowledge-based management of clubroot in canola.
PROGRESS: A method for the genetic transformation of the clubroot pathogen (*P. brassicae*) has been developed, which is substantial because it enables scientists to apply many modern molecular techniques to the study of this pathogen. This will speed up research and help researchers to better understand the biology of the clubroot pathosystem, by providing insights into the ways in which *P. brassicae* can infect its host and cause disease.

Early results from research by Sheau-Fang Hwang with Alberta Agriculture and Rural Development demonstrate that soil fumigation with Vapam at 1,000 L/ha (left) does show a benefit in clubroot-infested soil.

Management of clubroot in a dynamic environment

LEAD RESEARCHERS: Sheau-Fang Hwang, AARD, and Stephen Strelkov, University of Alberta
PURPOSE: This study will assess the impact of cropping resistant canola on pathogen population dynamics and of rotations on clubroot incidence and severity. It will also evaluate the effectiveness of soil fumigants on localized clubroot infestations, improve clubroot sanitation protocols, and maintain a consortium field nursery to assess host resistance and conduct experimental trials.
PROGRESS: Clubroot fumigation techniques were explored and, based on preliminary results, will likely contribute to new or improved processes and practices over the course of this project.

Clubroot surveillance and epidemiology: staying ahead of an important canola issue

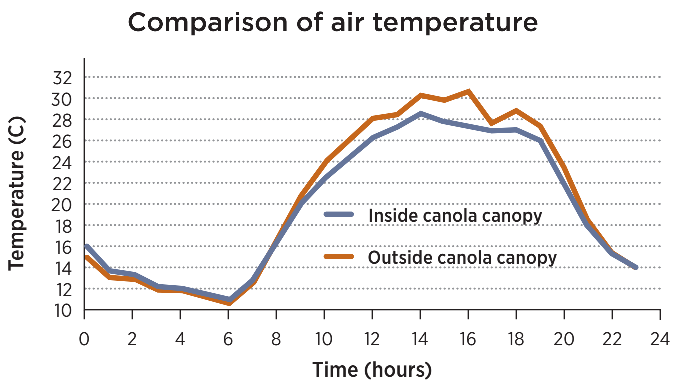
LEAD RESEARCHER: Stephen Strelkov, University of Alberta
PURPOSE: To provide critical information on the nature and extent of the clubroot outbreak in Canadian canola as part of a sustainable clubroot management strategy.
PROGRESS: In 2013, clubroot surveillance activities revealed 118 new cases of the disease in central and southern Alberta. That same year, additional surveys by county and municipal personnel identified another 300 new records of the disease for a total of 418 clubroot-infested fields. Clubroot survey results are posted to the Canola Council of Canada (CCC) website clubroot.ca directly after they are generated.

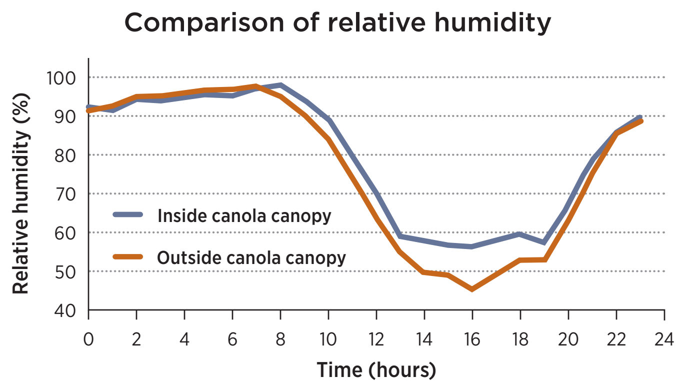
Development of pest management decision-making protocols for the swede midge in canola

LEAD RESEARCHER: Rebecca H. Hallett, University of Guelph
PURPOSE: Develop pheromone-based action thresholds for swede midge in canola and investigate the optimal plant growth stage for insecticide applications.
PROGRESS: Results from 2013 indicate that the presence of swede midge during the early vegetative stage (2 to 4 true leaves) has a significant impact on damage severity and yield. This suggests earlier insecticide application timings are likely needed to protect canola from economic damage of swede midge, which will be considered in the design of a preliminary pheromone-based action threshold in 2014.

Improved integrated crop management with beneficial insects

LEAD RESEARCHER: Julie Soroka, AAFC Saskatoon, SK
PURPOSE: To determine the extent of the newly discovered host-parasitoid associations of the diamondback moth and *D. insulare* on the Prairies. This will include surveying, conducting genetic analysis and investigating sources of annual diamondback moth re-establishment in Western Canada. It will also involve clarifying cues used by *D. insulare* and diamondback moth in host-seeking and host acceptance, and developing models to predict the responses of both insects to irregular patterns of global climatic change.
PROGRESS: This project just began in 2014, instead of 2013 as planned.





These graphs from Rishi Burlakoti show how temperature and relative humidity vary inside the canopy and outside the canopy through a 24-hour period. This is from a canola field south of Winnipeg on July 31, 2014. The research is to develop models for forecasting canola growth staging, sclerotinia stem rot risk and yield.

Canola sustainability-risk mitigation

LEAD RESEARCHER: Neil Harker, AAFC Lacombe, AB
PURPOSE: To determine if the risks of growing canola more frequently in rotations can be mitigated by growing different canola cultivars in alternating years or growing mixtures of canola cultivars within a given year selected (Phase 1); or by utilising agronomic inputs such as specialized seed treatment, higher macro- and micro-nutrient applications, higher seeding rates and chaff removal, alone and in combination (in Phase 2).
PROGRESS TO DATE: Phase 1 found that yield was lower, and that root maggot damage and blackleg incidence and severity were higher in continuous canola rotation than rotations including wheat and field peas.

Operational models to forecast canola growth stage, sclerotinia risk, and yield in Western Canada (2013 to 2018)

LEAD RESEARCHER: Rishi Burlakoti, Weather Innovations
PURPOSE: To develop models for forecasting (on a near real-time basis) canola growth staging, sclerotinia stem rot risk and canola yield for growers and industry.
PROGRESS: Due to the late project approval, a comprehensive literature review and a canola web platform were developed instead of fieldwork. This year, 12 evaluation sites were established throughout Manitoba and intensive observations of growth stages, sclerotinia stem rot, yield, and weather data were collected for use in model development.

Canola sustainability – the environmental footprint of canola and canola-based products

LEAD RESEARCHER: Vern Baron, AAFC Lacombe, AB
PURPOSE: This study has two objectives. (1) To determine how much farm-gate canola carbon footprint has decreased from 1990 to 2010 and why. (2) To determine the greenhouse gas intensity for canola production using best management practices in a high yield, high input region.
PROGRESS: Objective 1: A life cycle assessment of Western Canadian canola crop production for 1990 versus 2010 was completed (MacWilliam et al 2014), showing that the environmental profile of canola production per tonne has improved due to increased yield and plant biomass from enhanced genetics, adoption of herbicide tolerant and hybrid canola, and improved crop production practices. Objective 2: The field scale experiment at Lacombe, AB requires two more years to complete field work and an additional year to summarize and write up the report.

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

LEAD RESEARCHERS: Chrystel Olivier and Julie Soroka, AAFC Saskatoon, SK
PURPOSE: To generate knowledge of factors influencing biology of the two new pests in canola.
PROGRESS: A laboratory colony of swede midge has been established for future use. A survey of swede midge damage was carried out in eastern Saskatchewan and pheromone traps were monitored populations at 20 locations in three provinces. An aster yellows disease survey was also carried out in Saskatchewan, in addition to conducting assessments of aster yellows incidence in the *B. napus* germplasm nursery, and work on economic thresholds.

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 assess the feasibility of bag storage systems under Canadian Prairie conditions by quantifying the changes in canola seed quality during bag storage.
PROGRESS: Preliminary results show that canola seeds with eight percent moisture content or less can be stored in silo bags for 10 months, canola at 10 percent moisture can be stored for seven months without any quality deterioration and seed at 12 percent moisture only maintained its grade if unloaded before the ground thaws. ●

Canola growers across the Prairies fund many research projects with their levy payments to Saskatchewan Canola Development Commission, Alberta Canola Producers Commission and Manitoba Canola Growers Association. Many of those projects are funded through the joint Canola Agronomic Research Program (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 of and updates on all ongoing projects directly funded by provincial canola grower organizations.

Grower-funded research projects

Plant establishment

Response of canola to low plant populations and evaluation of reseeding options

LEAD RESEARCHER:
Anne Kirk, University of Manitoba
FUNDING: SCDC
PURPOSE AND PROGRESS: The purpose is to determine the plant population at which reseeding would be recommended based on the influence of plant population on yield, maturity, seed size and green seed count. Results indicate that hybrid canola compensates for reduced plant stands by increasing branching and podding, however days to maturity and percent green seed increase as plant density decreases. Final results show the minimum plant stand required to achieve 90 percent of the maximum yield was 18 plants per square metre.

Investigating wider row spacing in no-till canola: Implications for weed competition, response to nitrogen fertilizer and seeding rate recommendations

LEAD RESEARCHER:
Chris Holzapfel, Indian Head Agricultural Research Foundation
FUNDING: SCDC
PURPOSE AND PROGRESS: Year 3 of 4. Objectives are to evaluate the performance of canola at row spacing levels ranging from 25 to 60 cm (10″ to 24″) and to investigate the potential implications of wider row spacing on side-banded nitrogen, seeding rate recommendations and weed competition. So far, under good growing conditions, canola can perform well at row spacing as wide as 60 cm. Preliminary results indicate that nitrogen fertilizer and seeding rate recommendations will be similar regardless of row spacing.

Seeding between the lines: Evaluating the potential of inter-row seeding for canola in Southern Alberta

LEAD RESEARCHER:
Ken Coles, Farming Smarter
FUNDING: ACPC
PURPOSE AND PROGRESS: Year 3 of 3. The purpose is to study the influence of seed row placement in relation to the previous stubble, using enhanced GPS guidance. So far, seeding directly on top of the previous stubble reduces canola plant stand establishment but does not impact yield. Inter-row and check treatments resulted in best seedling survival while disc/hoe openers with independent depth control out-yielded rigid frame shank openers.

Seeding rates for precision seeded canola

LEAD RESEARCHER: Laryssa Grenkow, Western Applied Research Centre
FUNDING: SCDC
PURPOSE AND PROGRESS: The purpose is to compare seedling uniformity and subsequent yield response of canola seeded with air-seeders equipped with an UltraPro roller versus a traditional Valmar roller across a range of target

Chris Holzapfel with Indian Head Agricultural Research Foundation is evaluating canola performance at row spacing ranging from 10″ to 24″.

seeding rates. Differences in seedling uniformity and seed yield between the two rollers are inconsistent among site-years. Conversely, increases in seeding rate to target plant populations above 40 plants per metre squared appear to provide consistent yield increases regardless of roller type.

Verifying seed primer benefits on canola and wheat establishment, vigour and yield under direct seeding in Alberta

LEAD RESEARCHER: Kabal S. Gill, Smoky Applied Research & Demonstration Association (SARDA)
FUNDING: ACPC, SARDA
PURPOSE AND PROGRESS: During 2013 and 2014, the responses of canola to nine seed primers and of wheat to 10 seed primers were determined in seven site-years. Stand establishment, vigour and yield responses to the tested seed primers were inconsistent.

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

LEAD RESEARCHER: Kabal S. Gill, SARDA
FUNDING: ACPC, ABC, SARDA
PURPOSE AND PROGRESS: Year 6 of 7. Compared the canola and wheat monocultures with 2 to 3 year crop rotations that also included peas, barley and flax. Results have indicated crop rotation benefits of 10.3 bu./ac. for canola and 7.4 bu./ac. for wheat during the years 2010 to 2013.

Evaluation of winter *Brassica rapa* for cultivation in Alberta

LEAD RESEARCHER: Habibur Rahman, University of Alberta
FUNDING: ACPC, ACIDF
PURPOSE AND PROGRESS: Winter *B. rapa* survived the Canadian winter often (three of four study years) in Lethbridge where winter is generally milder compared to the other locations in Alberta. Crops seeded and grown under retained stubble condition showed better survival compared to bare soils under the tillage condition.

Fertility management

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

LEAD RESEARCHER: Ken Coles, Farming Smarter
FUNDING: ACPC, Farming Smarter
PURPOSE AND PROGRESS: Year 3 of 4. This study looks at the usefulness of electro-conductivity sensors for zone delineation in variable rate applications. Both Veris and EM38 sensors are practical tools that can be used to characterize soil variability. However more work and analysis are needed to understand yield response curves associated with this variation. On-farm research trials are proving useful in verifying opportunities with variable rate technologies.

Long-term effects of different soil test based fertilizer rates on crop production, contribution margin, and soil quality in the Peace region

LEAD RESEARCHER: Kabal S. Gill, SARDA
FUNDING: ACPC, ABC, APG, SARDA
PURPOSE AND PROGRESS: From 2009 to 2012, a canola-barley-field pea-wheat rotation was used to assess the response of crops and fertilizer recommendations to repeated applications of 0, 60, 80, 100, 120, and 140 percent of the soil test N, P, K and S rates. Responses depended on the crop type and growing conditions (mainly rain and temperature) in the season. The N and P fertilizer recommendations for crops changed with the growing conditions (mainly rain and temperature) in the previous season.

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, SARDA
PURPOSE AND PROGRESS: Year 5 of 6. Starting from 2010, cereal (wheat or barley) and canola responses to fertilizer rates (0, 60, 100 and 140 percent of soil test recommendations) were assessed under conventional and direct seeding systems. Crop yields were significantly increased with 60 percent rates while differences between the 60 to 140 percent were not always significant. No consistent interactions were observed between the seeding systems and fertilizer recommendations.

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GLOSSARY OF ABBREVIATIONS

AAFC ...... Agriculture and Agri-Food Canada
AARD ...... Alberta Agriculture and Rural Development
ABC .... Alberta Barley Commission
ACIDF ..... Alberta Crop Industry Development Fund
ACPC ...... Alberta Canola Producers Commission
ADF .... Agriculture Development Fund (a Saskatchewan program)
AIBIO ...... Alberta Innovates Bio Solutions
APG .... Alberta Pulse Growers
ASCA ...... Alfalfa Seed Commission — Alberta
AWC .... Alberta Wheat Commission
CARP ...... Canola Agronomic Research Program
MAFRD ... Manitoba Agriculture, Food and Rural Development
MCGA ..... Manitoba Canola Growers Association
PAMI .... Prairie Agricultural Machinery Institute
PGA .... Potato Growers of Alberta
SARDA .... Smoky Applied Research & Demonstration Association
SCDC ...... Saskatchewan Canola Development Commission
WGRF ..... Western Grains Research Foundation ●

GROWER-FUNDED RESEARCH PROJECTS

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Quantifying the economic and soil quality benefits of long-term no-till using a canola-spring wheat rotation

LEAD RESEARCHER: Chris Holzapfel, Indian Head Agricultural Research Foundation
FUNDING: SCDC, ACPC
PURPOSE AND PROGRESS: Year 3 of 3. Objectives are to examine the changes occurring in the soil as length of time under no-till increases. The study compares the impact of past and present nitrogen (N) rates on crop N uptake and grain yield at two adjacent sites differing in the length of time under no-till. By comparing yields between the short- and long-term no-till sites over the past 10 years, it was determined that a canola-spring wheat rotation under long-term no-till management provided a substantial economic advantage over short-term no-till, indicating that the soil is continually improving under no-till management.

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

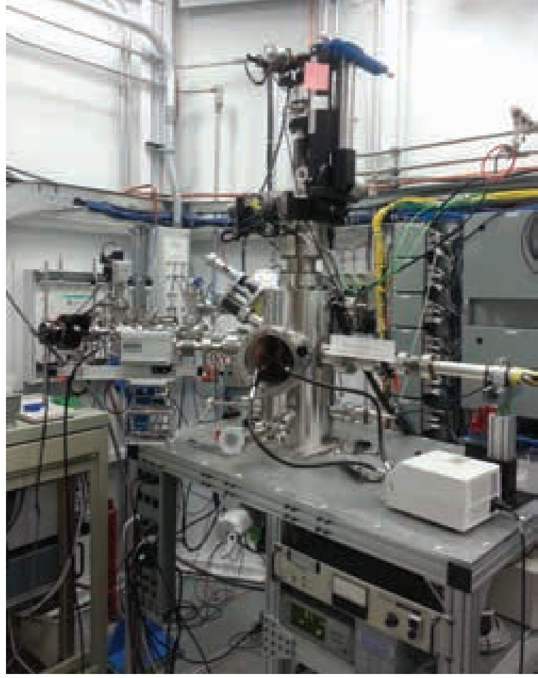
LEAD RESEARCHER: Ramona Mohr, AAFC Brandon
FUNDING: SCDC
PURPOSE AND PROGRESS: Year 1 of 2. The purpose is to determine whether using different nitrogen (N) management practices over the course of a four-year canola-wheat rotation will affect N availability in subsequent growing seasons. Nitrogen availability following a crop failure versus a "bumper crop" is also being assessed. So far, researchers have observed some differences in crop growth among treatments, suggesting differences in N availability in the first year after the rotation. However, analysis is underway to confirm these observations and to quantify plant-available N supply.

Canola yield, grain quality and nitrate movement in soils of Northern Alberta as affected by use of different nitrogen sources

LEAD RESEARCHER: Mackenzie Applied Research Association
FUNDING: ACPC
PURPOSE AND PROGRESS: Year 1 of 5. The purpose is to examine the effects of urea, ESN, Agrotain urea and SuperU on canola yield and oil content. Analysis of yield, chlorophyll concentration index and oil content data had not been completed for year 1 when this magazine when to print. However, germination data did not show any difference.

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

LEAD RESEARCHER: Jeff Schoenau, University of Saskatchewan
FUNDING: SCDC, ADF
PURPOSE AND PROGRESS: The purpose is to determine the fate of different forms of sulphur fertilizers applied in the seed-row of canola, peas and wheat. So far, researchers have observed that sulphate sources are effective in supplying large amounts of available sulphate in the seed-row after seeding. Gypsum, a slightly soluble sulphate form, is highly effective in supplying available sulphate early in the growth period. Elemental S was least effective. These findings were supported by plant uptake data and synchrotron spectroscopy results on soil samples analyzed at the Canadian Light Source.



Jeff Schoenau with University of Saskatchewan used the synchrotron at the Canadian Light Source in Saskatoon to test soils for his study into transformations and fate of seed-placed sulphur fertilizers. With the synchrotron, Schoenau can measure absorption of x-ray wavelength light to identify sulphur fertilizer reaction products in the soil.

Can slow-release monoammonium phosphate (MAP) and struvite improve phosphorus use efficiency and reduce seedling toxicity in canola?

LEAD RESEARCHER: Francis Zvomuya, University of Manitoba
FUNDING: ACPC, SCDC, MCGA
PURPOSE AND PROGRESS: Year 2 of 2. The purpose was to compare phosphorus uptake and seedling toxicity from hog manure-recovered struvite and coated MAP versus regular MAP application. Results show that recovered struvite and coated MAP produce similar canola yields to MAP and cause less seedling toxicity than MAP.

Francis Zvomuya at the University of Manitoba has found that phosphorus-rich struvite (shown in the photo) from hog manure produces similar canola yields to monoammonium phosphate (MAP) and causes less seedling toxicity.

PHOTO: Franciz Zvomuya (Bottom)

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

LEAD RESEARCHER: Jocelyn Ozga, University of Alberta
FUNDING: ACPC, APG, Agricultural and Food Council, University of Alberta, Syngenta
PURPOSE AND PROGRESS: Researchers tested to see if the application of specific auxin-type plant growth regulators (PGRs) to plants could increase seed yield under normal and heat stress conditions during reproductive development. In greenhouse and field studies, certain cultivars responded to an auxin-type PGR application by increasing seed yield under normal and heat stress conditions during reproductive development. Yield component data suggested that the auxin application could increase the seed 1,000-kernel weight.

Improving growth and yield of canola with a novel fungal endophyte Piroformospora indica

LEAD RESEARCHER: Janusz Zwiazek, University of Alberta
FUNDING: ACPC, AIBIO, WGRF
PURPOSE AND PROGRESS: Objectives are to determine the effects of the novel growth-promoting fungus *Piriformospora indica* on nutrient uptake, stress resistance, growth and yield of canola. So far, canola plants inoculated with the fungus had higher root and shoot fresh weights when exposed to low growth temperature and when subjected to water deficit stress and reduced nitrogen and phosphorus nutrition. Fungal inoculation had no effect when canola plants were subjected to high salinity treatment.

Optimizing variable rate nitrogen fertilizer application in fields with spatial variability

LEAD RESEARCHER: Doon Pauly, AARD
FUNDING: ACPC, ACIDF
PURPOSE AND PROGRESS: Canola was included in this study as it was part of the co-operators' rotation. In 2013 there was 1 of 5 sites with canola, but it had extensive hail damage and minimal treatment effects. As a result, limited canola data is available on this project at this time.

Integrated pest management

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

LEAD RESEARCHER: Tim Dumonceaux, AAFC Saskatoon
FUNDING: SCDC, ADF
PURPOSE AND PROGRESS: Year 1 of 2. The purpose is to develop molecular diagnostics for plant pathogens that are applicable to field-based studies. Target pathogens for initial development are clubroot (*Plasmodiophora brassicae*), blackleg (*Leptosphaeria maculans*) and aster yellows (*Candidatus Phytoplasma* spp). Researchers have developed and partially validated both lab-based (quantitative PCR) and field-based (loop-mediated isothermal DNA amplification) methods for all of these pathogens. The researchers have also developed rapid methods for DNA extraction from insects that may carry *Candidatus Phytoplasma* spp., and have successfully tested our methods by assaying insects. These preliminary studies have helped determine the needs for more extensive field-based studies planned for 2015.

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: ACPC, Alberta Innovates
PURPOSE AND PROGRESS: The long-term goal is to develop an in-field sensor for the detection of plant disease pathogen levels for disease prevention. Results indicate a positive correlation, a linear relationship, between the numbers of *S. sclerotiorum* ascospores and the conductivity of their antibody-spore-gold nanoparticle complex. The study also proved that conductivity measure-ment can detect as few as five ascospores of *S. sclerotiorum* in the sample. A negative correlation, a linear relationship, was also obtained when *Leptosphaeria maculans* was used as a pathogen, indicating that the future device could be species-specific and applied to more plant disease pathogens.

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Tim Dumonceaux and his colleagues at AAFC Saskatoon use rapid in-the-field DNA tests to check insects for aster yellows-causing phytoplasma. DNA is extracted from insects and a one-hour molecular test called LAMP (loop-mediated isothermal DNA amplification) is performed on the extracted insect DNA. Samples displaying fluorescence ("glowing" tubes) are positive.

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Development of canola cultivar blackleg resistance groups: feasibility evaluation

LEAD RESEARCHER: Ralph Lange, Alberta Innovates
FUNDING: ACPC, WGRF, ACIDF
PURPOSE AND PROGRESS: 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. 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. Cultivar testing is proceeding.

Evaluation of the toxicity of the secondary metabolites produced by *Leptosphaeria maculans*

LEAD RESEARCHER: Xiujie Li, Alberta Innovates
FUNDING: ACPC
PURPOSE AND PROGRESS: This study found that sirodesmin PL has comparable toxicity to gliotoxin, however no sirodesmin PL was found in canola products. This includes canola seeds collected from blackleg-infected fields and seeds with very high levels of *L. maculans* contamination in Alberta. No sirodesmin PL was detected in canola oil or canola meal obtained from processors or retailers in Alberta.

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: SCDC, ACPC, ACIDF, WGRF
PURPOSE AND PROGRESS: This project intends to provide an up-to-date *L. maculans Avr*-gene profile in key canola production regions, monitor fluctuation of *Avr*-gene frequency in the pathogen population, and identify new virulent races of *L. maculans* capable of overcoming cultivar resistance promptly when it happens. Profiling *L. maculans* isolates from Westar trap plots showed that *AvrLm1*, *AvrLm9*, and *AvrLep2* were completely absent in the pathogen population, while *AvrLm3* and *AvrLep1* were present at very low levels. This indicates that the resistance genes corresponding to these Avr genes will not be effective against blackleg in Western Canada. In contrast, *AvrLm2*, *AvrLm4*, *AvrLm6* and *AvrLm7* genes were common in the pathogen population. Commercial fields of R- or MR-rate cultivars with severe blackleg often showed a unique pattern of *Avr*-gene composition, and the relevance of this pattern to the "resistance breakdown" is being analyzed.

Identifying virulence factors in *Leptosphaeria maculans*, the causative agent of blackleg disease of canola

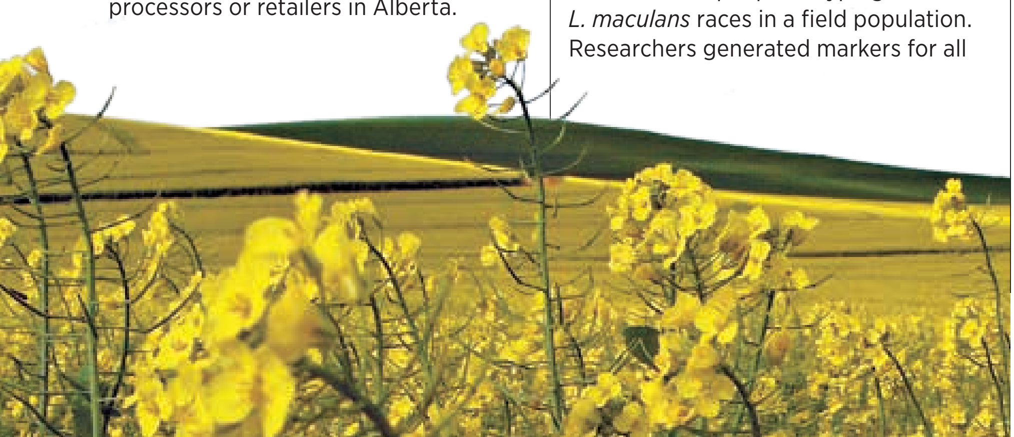
LEAD RESEARCHER: Hossein Borhan, AAFC Saskatoon
FUNDING: SCDC
PURPOSE AND PROGRESS: Year 3 of 3. The main objective is to develop molecular markers for rapid pathotyping of *L. maculans* races in a field population. Researchers generated markers for all currently known virulence genes as well as virulence genes recently identified by their lab. These markers have been tested in a subset of *L. maculans* field populations and proved to be highly reliable for rapid race determination.

Mitigating blackleg disease of canola using fungicide strategies

LEAD RESEARCHERS: Dilantha Fernando, University of Manitoba; Gary Peng, AAFC Saskatoon; Ralph Lange, Alberta Innovates
FUNDING: ACPC, SCDC, MCGA
PURPOSE AND PROGRESS: Year 3 of 3. Objectives are to better understand whether fungicides are useful against the blackleg pathogen, and to understand whether isolates of blackleg would become resistant to the chemicals. The research found an early fungicide application (2 to 4 leaf) may provide a benefit against blackleg when cultivar resistance is lost or unavailable. QOI fungicides generally reduced disease incidence and severity more effectively than a DMI fungicide. However, the yield improvement was negligible. Although isolates showed variation in sensitivity to the QOI fungicides, more study is required to understand the true resistance of blackleg strains to fungicides.

Blackleg resistance stewardship: Improving our management of host resistance

LEAD RESEARCHER: Dilantha Fernando, University of Manitoba
FUNDING: ACPC, SCDC, MCGA
PURPOSE AND PROGRESS: Update: Year 3 of 3. The purpose is to better understand the resistance genes available to the blackleg pathogen populations on the Prairies and also the avirulence genes of the pathogen in growers' fields. The goal is to formulate better blackleg resistance stewardship through the understanding of the R-genes and the avirulence (*Avr*) genes. The study found that most canola/rapeseed accessions/cultivars carried Rlm3 (65 percent), while the corresponding *AvrLm3* was extremely low (3 percent) on the Prairies. This explains the reason for the recent breakdown of resistance in canola fields throughout the Prairies.



Biocontrol of clubroot and blackleg by the endophytic microorganisms of canola

LEAD RESEARCHER: Paul Holloway, University of Winnipeg
FUNDING: ACPC, SCDC, MCGA
PURPOSE AND PROGRESS: Endophytes are bacteria and fungi that inhabit the tissue of plants without causing any harm and, in fact, they may benefit the plant. Researchers are isolating and identifying plant endophytes that have protective activity against canola pathogens and may in the future be used to suppress canola diseases.

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

LEAD RESEARCHER: Bruce Gossen, AAFC Saskatoon
FUNDING: SCDC, ADF, WGRF
PURPOSE AND PROGRESS: 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. 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.

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

LEAD RESEARCHER: Sheau-Fang Hwang, AARD
FUNDING: ACPC, ACIDF, WGRF
PURPOSE AND PROGRESS: Year 1 of 4. 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. 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 108 spores/gram of soil while resistant cultivars contributed 1.2 x 107 spores/g of soil. Use of Vapam on clubroot-infested land improved crop establishment, plant height and seed production of plants and reduced clubroot severity.

Clubroot soil testing in Manitoba

LEAD RESEARCHER: Lee Anne Murphy, Pest Surveillance Initiative
FUNDING: MCGA, MAFRD and AAFC
PURPOSE AND PROGRESS: The specialized molecular detection laboratory called the Pest Surveillance Initiative will collect, process and analyze soil samples for the presence of clubroot at very low levels and before plant symptoms are present. A grid sampling program has begun that will sample fields in every township-range in agro-Manitoba to establish a benchmark for clubroot presence.

Effects of clubroot resistant canola lines

LEAD RESEARCHERS: Stephen Strelkov, University of Alberta, and Sheau-Fang Hwang, AARD
FUNDING ORGANIZATIONS: ACPC
PURPOSE AND PROGRESS: In a study to determine the effects of resistant cruciferous plants on spore populations, repeated introduction of both susceptible and resistant plants progressively increased spore populations in the soil. Introduction of a susceptible cultivar resulted in greater spore populations, higher disease levels and more root hair infection compared with the resistant cultivar. Project Completed.

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

LEAD RESEARCHER: Michael Harding, AARD
FUNDING: ACPC, WGRF, ACIDF
PURPOSE AND PROGRESS: Year 2 of 4. Objectives are: (1) to maintain a clubroot nursery in a naturally-infested, irrigated commercial field in Southern Alberta where canola lines and varieties can be evaluated for clubroot resistance; and (2) enhance clubroot surveillance in southern Alberta to allow early detection of new infestations south of Highway 1. At this stage, numerous canola lines, varieties and cultivars display complete resistance to *Plasmodiophora brassicae* pathotype 5. Additionally, surveillance in commercial canola fields has revealed no new infestations south of Highway 1.

Improving sclerotinia disease control in edible beans and canola

LEAD RESEARCHER: Michael Harding, AARD
FUNDING: ACPC, WGRF, APG
PURPOSE AND PROGRESS: Year 2 of 4. Objectives are: to screen for synergistic interactions between fungicides and micronutrient ions that improve sclerotinia disease control; and to do field evaluations of plant resistance activators that improve sclerotinia disease control. At this stage, researchers have observed additive and perhaps synergistic antimicrobial activity when silver nitrate, manganese sulfate, zinc sulfate or copper sulfate were combined with one or more of three commercially available fungicides.

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: SCDC, ACPC, MCGA
PURPOSE AND PROGRESS: Final Year. The purpose is to develop and refine a rapid quantitative method for pathogen detection on canola and flower petals. The molecular method has been developed with large numbers of samples collected and tested for sclerotinia in numerous commercial canola fields in the Edmonton region. Various parameters such as seeding date were also monitored and recorded. The large dataset is now being analyzed in order to validate the robustness of the test.

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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, Indian Head Agricultural Research Foundation
FUNDING: SCDC
PURPOSE AND PROGRESS: Year 2 of 3. Objectives are: to evaluate genetic tolerance to sclerotinia stem rot combined with foliar fungicide applications for reducing sclerotinia stem rot infection in canola; and to determine if fungicides may be recommended when growing a resistant cultivar under heavy disease pressure. So far, although sclerotinia levels have been relatively low, researchers have observed lower incidence with a tolerant hybrid and also when foliar fungicides were applied. There have been no cases where yields of a tolerant hybrid were increased with fungicide application or where dual fungicide applications were advantageous over a single application, but these results may differ under more severe disease pressure.

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

LEAD RESEARCHER: Dilantha Fernando, University of Manitoba
FUNDING: ACPC, SCDC, MCGA
PURPOSE AND PROGRESS: Year 1 of 3. The purpose is to better understand the biological processes associated with the protection of canola against sclerotinia. So far, researchers have observed that large sets of genes are turned on directly at the site of infection in canola leaves in response to sclerotinia infection. Putative targets of the plant defense response pathway have been identified and will be functionally characterized.

Seed treatment as an alternative method to control aster yellows

LEAD RESEARCHERS: Chrystel Olivier and Bob Elliott, AAFC Saskatoon
FUNDING: AAFC, SCDC, and industry partners
PURPOSE AND PROGRESS: Second year. The primary objective is to evaluate the potential of seed treatments as an alternative method to control leafhoppers and suppress aster yellows (AY), using laboratory and field assays. During the first year, an AY rating scale based on specific AY symptoms was developed to measure the frequency and severity of AY disease in canola plants. Other results indicate that, in treated plants, leafhopper mortality and frequency and severity of AY symptoms depend on soil moisture, canola growth stage and the number of leafhoppers per plant. Leafhopper mortality is higher in dry soil as compared to wet soil and consequently, frequency and severity of AY symptoms is higher in wet soil as compared to dry soil.

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

LEAD RESEARCHERS: Chrystel Olivier and Julie Soroka, AAFC Saskatoon
FUNDING: ACPC, WGRF, ACIDF
PURPOSE AND PROGRESS: Second year. The purpose is 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. In 2013, no significant difference in AY severity and incidence was observed between commercially available canola cultivars. Depending on the location, AY infections in leafhoppers were between 10 and 30 percent in 2013 and less than 1 percent in 2014. Swede midge continues to expand its range on the Prairies, with adults, larvae or damage seen west of North Battleford, SK and close to the American border in Manitoba in 2014. Swede midge adults emerged relatively late in 2014, and damage to canola was light. Little variation in swede midge damage was seen among 18 different lines in six different crucifer species. Specimens of a pteromalid wasp were observed parasitizing swede midge larvae in the field, and investigations on the species as a potential biological control were initiated.

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

LEAD RESEARCHER: Julie Soroka, AAFC Saskatoon
FUNDING: SCDC
PURPOSE AND PROGRESS: Year 1 of 3. The purpose is to investigate the correlation of 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. Swede midge damage in field plots was light in 2014. Earlier-seeded plots did not suffer less damage than plots seeded two weeks later. Further, none of the seed treatments applied for flea beetle control decreased swede midge damage.

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

LEAD RESEARCHER: Owen Olfert, AAFC Saskatoon
FUNDING: ACPC, SCDC, MCGA, WGRF
PURPOSE AND PROGRESS: Year 1 of 5. The purpose 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. So far, sampling protocols have been developed/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.

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

LEAD RESEARCHER: Christoph Neeser, AARD
FUNDING: ACPC, AARD, ACIDF, WGRF, APG, AWC, ASCA, PGA
PURPOSE AND PROGRESS: Development of small and relatively inexpensive unmanned aerial vehicles (UAVs) has generated much interest in their use as a field-scouting tool. Over the 2014

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CanoLAB is a one-day concentrated learning experience, with real canola plants and top experts to help you identify symptoms from disease, insect feeding, herbicide carryover, nutrient deficiency, to give just a few examples.

Saskatoon, SK
February 10-11, TCU Place

Olds, AB
February 18-20, Olds College

Brandon, MB
March 11-12, ACC

Photographs from this unmanned aerial vehicle (UAV) are being tested for their value in field scouting for weeds and disease. Chris Neeser with AARD leads the project, with JZAerial of Calgary providing the technology.

cropping season images of alfalfa, barley, canola, peas, potatoes and wheat were captured in June, July and August. For ground verification, selected areas were photographed from the ground following the capture of the UAV images. These images have been processed and will be analyzed to determine to what extent they can be used to locate weeds, crop diseases or other problem areas. The final step will consist of a cost benefit analysis of this technology.

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

LEAD RESEARCHER: Daniel Itenfisu, AARD
FUNDING: ACPC, AARD
PURPOSE AND PROGRESS: The purpose is to develop and implement a provincial weather-based monitoring/prediction model for three economically significant insect pests in Alberta: bertha armyworm, wheat midge and alfalfa weevil. The model will use near real time (NRT) weather data from around 350 stations and provincial pest survey data. In year one, researchers: (1) collected field data relevant to the project and data organization; (2) are reviewing suitable weather-based models and current AARD pest surveillance branch insect pest field survey programs; (3) are designing a portable weather station; (4) produced provincial biweekly preliminary prediction maps for bertha armyworm, wheat midge and alfalfa weevil through the growing season; and (5) are finalizing the hiring of a full time researcher.

Detection, identification and control strategies for management of cutworms (*Noctuidae*) on the Prairies

LEAD RESEARCHER: Kevin Floate, AAFC Lethbridge
FUNDING: ACPC, SCDC
PURPOSE AND PROGRESS: Year 3 of 4. The purpose is to facilitate the control of cutworms that are pests of canola. Among the results achieved so far, are: (1) development of a molecular-based method to provide quick and accurate identification of key pest species; (2) surveys of cutworms in Alberta, Saskatchewan and Manitoba; (3) identification of wasps and flies parasitic on these cutworms; (4) studies to assess the ability of these parasitoids to attack different species of pest cutworms; and (5) studies to assess the effect of seed cultivar, seed treatment and fertilizer regime on cutworm development.

Biocontrol of canola cutworms: Identification and attraction of parasitoids

LEAD RESEARCHER: Barbara Sharanowski, University of Manitoba
FUNDING: ACPC
PURPOSE AND PROGRESS: Year 3 of 3. The purpose is to examine the parasitoid community associated with cutworms in canola and investigate cover crops that may improve their efficiency as natural enemies. In addition to identifying several new species of parasitoids previously unknown to attack cutworms, researchers have also shown that the polyembryonic parasitoid *Copidosoma cuproviridis* is attracted to yellow flowers and odours from plants in the family Brassicaceae. Several cover crops improve longevity in this species, but parasitoid rates remain low in the field. Researchers will examine alternative natural enemies for control, such as entomopathogenic fungi.

*Barb Sharanowski at the University of Manitoba is looking for parasitoids of cutworms. This cutworm has been parasitized by a **Copidosoma** wasp. **Copidosoma** are attracted to yellow flowers and odours from plants in the family Brassicaceae.*

Management of lygus bugs and seedpod weevils in canola

LEAD RESEARCHER: Hector Carcamo, AAFC Lethbridge
FUNDING: ACPC
PURPOSE AND PROGRESS: This four-year study examined the effect of spraying canola at early flower for seedpod weevils on lygus bugs. In most cases, fields sprayed at early flower had fewer lygus bugs at the pod stage. Planting date also had a major effect on insect abundance: early seeded fields had more weevils and fewer lygus at pod than those planted late; late seeded fields had fewer weevils at early flower but more lygus at the pod stage than those planted early. To maximize canola yield potential growers should plant early and manage weevils if they exceed the economic thresholds, but should NOT spray fields where weevils are below threshold to attempt to reduce lygus at the pod stage because other factors such as rain and predators may reduce lygus numbers. Tank-mixing insecticide with fungicide spray in full flower is not recommended for weevils or lygus, and can be harmful to pollinators and natural enemies.

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PHOTO: Udari Wanigasekara (Right)

GROWER-FUNDED RESEARCH PROJECTS
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Ken Coles with Farming Smarter is working on three canola studies, including one on how time of day influences herbicide efficacy. He found that mid-day timing resulted in the best overall weed control for in-crop applications in Liberty- and glyphosate-tolerant canola.

Improving lygus management for current canola and faba bean cultivars

LEAD RESEARCHER: Hector Carcamo, AAFC Lethbridge
FUNDING: ACPC, ACIDF, APG
PURPOSE AND PROGRESS: Year 3 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. Yield and insect data are being processed and preliminary analysis of the first three years will be shared at extension meetings in the winter.

Improving crop risk assessment tools for bertha armyworm

LEAD RESEARCHER: Scott Meers, AARD
FUNDING: ACPC
PURPOSE AND PROGRESS: This project has reconfirmed the validity of the current bertha armyworm monitoring and forecasting system. Although occasionally populations crash due to disease outbreaks, if the traps are in sufficient density, the pheromone trapping system is very good at identifying areas that are at risk of bertha armyworms at damaging levels.

Reliable and effective use of managed bees for canola pollination

LEAD RESEARCHERS: Shelley Hoover, AARD; Steve Pernal, AAFC Beaverlodge; Ralph Cartar, University of Calgary
FUNDING: ACPC, SCDC, ACIDF, ASCA, Beekeepers Commission of Alberta
PURPOSE AND PROGRESS: Year 1 of 3. The purpose is to quantify the contribution of managed pollinators to canola yield, and to provide management guidelines to maximize both pollination and bee health. Preliminary results indicate that insect visitation of commodity canola flowers tends to decrease with depth into a field, whereas the volume of nectar available to pollinators tends to increase with distance from the field edge.

Night spraying: Pesticide efficacy with nighttime applications

LEAD RESEARCHER: Ken Coles, Farming Smarter
FUNDING: ACPC, Farming Smarter
PURPOSE AND PROGRESS: Year 3 of 3. The purpose is to study time of day influences on weed control in pre-seed burndown applications as well as in-crop applications in Liberty and glyphosate tolerant canola, and in peas and wheat. Differing environmental conditions within a 24-hour period can significantly influence weed control. Mid-day application timing resulted in the best overall control in pre-seed applications and with Liberty and glyphosate tolerant canola. Nighttime applications were best for peas and worst for Liberty canola. Wheat herbicides performed the best in all conditions.

Emergence timing and management of cleavers in Saskatchewan canola crops

LEAD RESEARCHER: Christian Willenborg, University of Saskatchewan
FUNDING: SCDC, ADF
PURPOSE AND PROGRESS: 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 populations. Preliminary data also suggests that two unregistered herbicides, in combination with in-crop recommended herbicides for each herbicide tolerant system, provide good control of cleavers. Registration of these herbicides could come within a couple of years.

Glyphosate-resistant kochia survey in Saskatchewan

LEAD RESEARCHER: Hugh Beckie, AAFC Saskatoon
FUNDING: SCDC
PURPOSE AND PROGRESS: A stratified-randomized survey of 342 sites in southern and central regions of Saskatchewan and 283 sites in southern Manitoba was conducted in the fall of 2013. Screening confirmed 17 glyphosate-resistant (GR) kochia populations in nine municipalities in west-central or central Saskatchewan, and two GR populations from different municipalities in the Red River Valley of Manitoba.

Can harvest weed seed management be used to control kochia, cleavers and wild buckwheat?

LEAD RESEARCHER: Steve Shirtliffe, University of Saskatchewan
FUNDING: ACPC, SCDC, MCGA
PURPOSE AND PROGRESS: The purpose is to determine when weed seeds are shed relative to the maturity of canola. This will determine which weeds are candidates for pre-harvest herbicides or harvest weed seed management.

Biology and management of glyphosate-resistant kochia

LEAD RESEARCHER: Bob Blackshaw, AAFC
FUNDING: ACPC, AWC, ABC, ACIDF, WGRF
PURPOSE AND PROGRESS: Year 2 of 3. The purpose is to identify cost-effective alternative herbicides to control glyphosate-resistant kochia in pre-seed, chemfallow, in-crop, and post-harvest applications. Additionally, studies examining timing of seed maturity and seed dormancy will allow more optimal herbicide timing and aid in developing integrated management strategies. So far, several unregistered herbicides show potential to control glyphosate-resistant kochia and this information have been conveyed to the respective crop protection companies.

PAMI has just started a three-year header comparison study looking at yield, seed quality, header shatter loss, and environmental shatter loss for draper, rigid and extendable cutterbar headers as well as a swath-based system.

Harvest management

Quantifying potential canola yield loss due to shattering and pod drop amongst high-yielding *Brassica napus* cultivars

LEAD RESEARCHER: Chris Holzapfel, Indian Head Agriculture Research Foundation
FUNDING: SCDC
PURPOSE AND PROGRESS: Year 4 of 4. Objectives are to quantify environmental yield losses due to pod shatter and pod drop amongst a variety of modern canola hybrids and a wide range of environments. So far, while differences in seed losses are frequently observed, they are not always consistent from one site to the next and environmental conditions (i.e. weather, disease) are typically the most important determining factors affecting the magnitude of seed losses in standing, mature canola. While losses due to pod drop tend to be relatively minor when canola is straight-combined at an optimal stage, they become increasingly significant as straight-combining is delayed and can sometimes exceed shattering losses.

Developing a rapid method to evaluate pod-drop in canola

LEAD RESEARCHER: Rob Gulden, University of Manitoba
FUNDING: ACPC, SCDC
PURPOSE AND PROGRESS: Year 2 of 3. The purpose is to refine and validate pod retention resistance measurements as a new and rapid method of estimating pod-drop in canola. So far, the method performs consistently across a number of genotypes and environments. Researchers are refining the number of measurements and the position on the plant from which these measurements should be obtained to best estimate pod-drop among these genotypes.

Summer storage of canola

LEAD RESEARCHER: Joy Agnew, Prairie Agricultural Machinery Institute (PAMI)
FUNDING: SCDC, ACPC, MCGA, CCC
PURPOSE AND PROGRESS: Year 1 of 1. The purpose is to evaluate best management practices for summer storage of canola. So far, all three treatments (no management, turning the bin, aerating the bin) resulted in safe storage of dry canola throughout the summer months.

Canola direct-cut harvest system development

LEAD RESEARCHER: Nathan Gregg, PAMI
FUNDING: SCDC, ADF, WGRF, PAMI
PURPOSE AND PROGRESS: Year 1 of 3. The purpose is to compare header types for straight combining canola, looking for the optimal system. Yield, seed quality, header shatter loss, and environmental shatter loss are compared for draper, rigid and extendable cutterbar headers as well as a swath-based system. The study will also compare results for standard hybrids and hybrids with pod shatter resistance. Data is being processed from year one.

Genetics

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

LEAD RESEARCHER: Isobel Parkin, AAFC Saskatoon/University of Saskatchewan
FUNDING: SCDC, ADF, ACPC and industry partners
PURPOSE AND PROGRESS: Year 2 of 4. The purpose is 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. Excellent progress has been made. Highly diverse founder lines were selected and the first three generations are completed with the final lines scheduled to be ready in the spring of 2015. Extensive phenotyping of the founder lines is ongoing in both the field and lab, which has identified interesting variations for multiple traits including stress resistance and seed quality.

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Margaret Gruber with AAFC Saskatoon is working on trichome-rich germplasm with resistance to the crucifer flea beetle and seedling drought. This photo compares the trichomes (hairs) on leaves of a seedling of GMO hairy canola (left) with leaves of non-hairy canola (right). The cotyledons (lower fleshy storage leaves from the seed) are hairless in both seedlings, but the hairless cotyledons of the hairy canola line are still resistant to flea beetles in field trials. Gruber is working to understand the basis of the cotyledon resistance in the new line.

PHOTOS: Nathan Gregg (Top); Margaret Gruber (Right)

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resistance gene in spring canola. It has also shown that while most plants are resistant to most pathogens, *P. brassicae* uses primary infection to overcome this general type of resistance, which allows the disease to progress when secondary zoospores attack.

Final phase research to improve 'hairy canola' trait in *Brassica napus*

LEAD RESEARCHER: Margaret Gruber, AAFC Saskatoon
FUNDING: SCDC, ADF
PURPOSE AND PROGRESS: Year 3 of 4. The purpose is to develop new canola tester lines with modified expression of individual trichome (hair) genes in an effort to develop trichome-rich germplasm with resistance to the crucifer flea beetle and seedling drought. Researchers have a number of new GMO lines, and are now testing several genes for potential to develop a non-GMO hairy canola line.

Molecular cytogenics 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: ACPC, ACIDF
PURPOSE AND PROGRESS: The project has identified the chromosomal location of one of the B-genome resistance genes. Identification of the other B-genome resistance genes and introgression in canola is in progress.

Studies on the genetic and molecular basis for clubroot resistance in canola

LEAD RESEARCHER: Stephen Strelkov, University of Alberta
FUNDING: SCDC, ACPC
PURPOSE AND PROGRESS: Final Year. The aim is to help build durable clubroot resistance by increasing understanding of major resistance genes, developing molecular markers, and investigating the biological function of host and pathogen genes differentially expressed during the infection process. The research has shown that resistance to pathotype 3 in selected host populations is under monogenic control, and has identified molecular markers linked to a clubroot

Characterization and utilization of newly identified resistance sources for sustainable clubroot control on canola

LEAD RESEARCHER: Gary Peng, AAFC Saskatoon
FUNDING: SCDC
PURPOSE AND PROGRESS: This project builds on prior identification of diverse clubroot resistance (CR) sources, and focuses on characterizing CR genes in the resistance genotypes identified in order to provide the industry with new sources of resistance. Between labs at AAFC Saskatoon, University of Alberta and University of Manitoba, progress during the first year includes identifying three CR genes, evaluating a three-way cross involving a clubroot resistant rutabaga line and two spring canola lines in field plots, and mapping eight loci from different *B. rapa* materials.

Genomics of clubroot disease development in canola and development of in-plant RNAi to impart novel resistance

LEAD RESEARCHER: Peta Bonham-Smith, University of Saskatchewan
FUNDING: SCDC, ADF
PURPOSE AND PROGRESS: Ten thousand full-length cDNAs have been isolated and sequenced from a library of canola root gall tissues. Of these, 7,000 sequences have been analyzed and annotated against the NCBI database; 2,730 cDNAs are from the *Plasmodiophora brassicae* pathogen and 2,590 cDNAs are from the infected canola. Researchers are currently identifying the *P. brassicae* secretome and possible pathogen effectors associated with the infectious stage(s) of the pathogen. They are also reviewing plant sequence data to identify changes in the expression of plant genes/pathways responsible for, or as a result of, infection and disease. First generation (T1) transgenic Arabidopsis plants (model system for canola) carrying single and double RNAi constructs (with *P. brassicae* sequences) have been produced and are currently being screened for successful T2 lines. Once homozygous T3 lines are isolated they will be challenged with the pathogen.

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

LEAD RESEARCHER: Peta Bonham-Smith, University of Saskatchewan
FUNDING: SCDC, ADF
PURPOSE AND PROGRESS: The purpose is to explore 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. So far, 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.

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

LEAD RESEARCHER: Fengqun Yu, AAFC Saskatoon
FUNDING: SCDC, ADF, WGRF
PURPOSE AND PROGRESS: Year 1 of 4. The purpose is 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. So far, researchers have obtained all donor resistant lines and initiated introgression of clubroot resistance genes into a *B. napus* cultivar.

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

LEAD RESEARCHER: Fengqun Yu, AAFC Saskatoon
FUNDING: ACPC, WGRF
PURPOSE AND PROGRESS: Year 2 of 3. The purpose is to identify clubroot resistance genes in *Brassica rapa* and

develop molecular markers for rapid introgression of the clubroot resistance into canola. So far, researchers have identified two clubroot resistance genes and developed more than ten SNP markers tightly linked to one of the genes. These markers are available to the Canadian canola industry for rapid incorporation into their canola variety development programs.

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: SCDC
PURPOSE AND PROGRESS: This collaborative effort with Rahman's group at the University of Alberta has identified a resistance locus in *Brassica napus* and has further determined genome-wide transcriptional dynamics in cohorts of susceptible and resistant lines of *B. napus* arising from genetic segregation.

Improving the Ogura CMS hybrid system and establishing heterotic gene pools for hybrid breeding in canola *Brassica juncea*

LEAD RESEARCHER: Bifang Cheng, AAFC Saskatoon
FUNDING: SCDC
PURPOSE AND PROGRESS: Objectives are: (1) to develop a fully functional Ogura hybrid system in canola B. juncea; and (2) to establish heterotic gene pools for use in development of high-yielding hybrids. Researchers successfully developed the improved *B. juncea* homozygous R line VR441 (*RfoRfo*) via molecular marker-assisted selection in combination with the increased recombination frequencies involving the *Rfo* gene in resynthesized *B. juncea*. Development of VR441 has made the Ogura CMS hybrid system fully functional in this species.

The Canola Council of Canada's Keep It Coming strategic plan targets an average yield of 52 bu./ac. across the Prairies by 2025. This is an 18 bu./ac. increase over the average yield at the time the plan launched. Of that, 10 bu./ac. will come as a result of agronomic improvement through the four categories outlined in this magazine. The other 8 bu./ac. will come from genetics. This article summarizes the seed industry's perspective on their target and how it could be achieved.

Toward genetic gain of eight bushels per acre

Seed company representatives are in general agreement that significant genetic yield gains will continue. Achieving the target 8 bu./ac. gains by 2025 will be the challenge.

"I'm confident the plant breeding community can deliver an additional 8 bu./ac. — or more," says one rep. But another says, "Genetics alone will not support an 8 bu./ac. yield increase."

One takes the mathematical approach: "We assume that genetic gain in canola is about one percent per year. With a gain of 0.5 bu./ac. per year, over the next 10 years we can assume genetic gain of about 5 bu./ac."

One provides the bigger picture view: "Canola genetics will need to hit the extra 8 bu./ac. targets set out by the Canola Council of Canada (CCC) just to remain competitive as one of the crops in Western Canadian producers' rotation."

Key traits that will drive yield gains

Disease tolerance was the most common theme. With improved disease tolerance, more of the inherent yield potential can come through. Sclerotinia tolerance has the most potential to actually boost yields. One seed company

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TOWARD GENETIC GAIN OF EIGHT BUSHELS PER ACRE

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representative said that while yield loss from sclerotinia stem rot is well documented, to date only 25 to 35 percent of canola receives a fungicide application to protect against it. Increased adoption of sclerotinia trait canola and genetic improvements in sclerotinia tolerance will help growers maximize the yield potential on their farm.

Enhanced blackleg and clubroot protection traits will be more about maintaining the current level of resistance, given the pressures of pathotype shift in some fields. Stacking strategies for blackleg, clubroot and sclerotinia will lead to better overall resistance.

Herbicide tolerance: Next generation weed control traits will play a large part in helping growers achieve canola's full yield potential, and will provide more tools to manage weed resistance. One example is glyphosate-tolerant traits that allow for higher rates and a wider window of application.

Pod shatter tolerance: This is top of mind for many breeding organizations and more varieties with this pod shatter reduction trait will come to market. Pod drop reduction traits will also reduce losses. Average yields could be much higher if so much canola wasn't lost during harvest. These traits could also facilitate more efficient harvest practices such as straight cutting.

Nutrient and water use efficiency: These are longer-term objectives. With breeding tools becoming more precise, these complex multiple-gene traits are more likely to be identified.

Reps also noted that while genetics will bring gains, other seed technology advancements — seed treatments, specifically — will play critical a role in continuing to advance canola yields.

Capturing current yield potential

Seed company representatives agree that overall production could increase by more consistently tapping the genetic potential of current varieties. Temperature and moisture situations cause most of this yield variability year to year. Research into how canola interacts with varying yield environments would help growers manage that variation and help seed companies make better hybrid recommendations.

Even with today's level of knowledge, careful variety selection can help growers get more out of current genetics. For example, by choosing a variety with good standability, a grower has the option to push more inputs and get a higher yield response. Trying varieties with different features side by side under local conditions is a good way to check how some of these other features may more suitably match a grower's management system.

Choosing varieties with harvest logistics in mind is another example. Many growers are forced to begin swathing as early as 30 percent seed colour change so that they can swath all their canola acres before the last of it gets to maturity and shells out. However, cutting canola at 30 percent seed colour change could mean at least a 10 percent loss in yield potential. Choosing a combination of maturities as well as some hybrids with pod shatter reduction traits for later swathing or straight combining could improve harvest timing, and therefore yield potential.

Seed company reps outline a few other agronomy steps to extract more of the yield potential from current varieties. Set the stage with an appropriate seeding rate and seed placement to achieve a uniform stand. Seeding technology can also positively impact yields. New precision planting drills that improve emergence and stand establishment will lead to improved fungicide effectiveness and harvest timing, because the crop will be at a uniform stage through the growing season.

Nutrient management technology is another ally in improving yield potential. Some reps specified that it will become mainstream to analyze fields with high-resolution satellite imagery to determine each crop's yield potential and to develop customized fertilizer plans. With sufficient nutrition, canola can also best withstand the stresses that may occur through the season.

Investing the time to scout fields throughout the season will generate the real time information needed to make profitable crop protection and fertilizer top dress decisions. When growers don't have the time or expertise for accurate scouting across the farm, paying for field agronomy can bring current, specific knowledge that, when applied, will drive

QUESTIONS AND RESPONDERS

This article was put together based on seed company responses to four questions:

1. Do you think genetics alone can contribute an 8 bu./ac. realized yield increase for Western Canadian canola by 2025?
2. What genetic traits will drive yield gains over the next 11 years?
3. Is there untapped genetic yield potential that growers are not realizing now?
4. If yes, what would your company like to see growers do to realize that potential, recognizing that growers will also want those measures to increase profits as well?

Thank you to Shaun Vey from Syngenta; Dave Harwood from Pioneer Hi-Bred; Dave Kelner, Monsanto; Mark Woloshyn, Dow AgroSciences; Kevin McCallum, DL Seeds; Bruce Harrison, CPS Proven Seed; Rick Wiebe, Cargill; Dave Hansen, Canterra Seeds; Rene Mabon, BrettYoung; and James Humphris, Bayer CropScience for their input. •

yield and profitability. Some seed companies also conduct farm agronomy trials that explore concepts like fertility, seeding rates and harvest management. Participating in these projects allows growers to network with these seed company agronomists and other progressive growers.

Harvest management comes up often in talking with seed company representatives. Significant yield loss is taking place in August and September every year as growers make difficult decisions to manage time, equipment and labour resources. Cutting canola prematurely can easily result in a five to 10 bu./ac. yield penalty. A higher percentage of canola swathing at 60 percent seed colour change and growers adopting straight canola harvest practices "will drive a step change in canola yields," one rep says.

The final consideration is residue management. Better management of residue from high yielding cereal crops will help improve canola seed placement the following spring.

One rep provided this perfect closing statement: "There is so much we don't yet understand about growing canola. The high variation in seed survival and optimal stand establishment are just two examples. We would encourage growers to continue to support and push for research that strengthens our understanding of this relatively new crop to Western Canada." •

QUOTABLE

Here is a selection of quotes from seed company representatives.

JAMES HUMPHRIS, BAYER CROPSCIENCE: "We would like to see growers look at choosing multiple hybrids to spread out harvest management. This may include choosing hybrids with different maturity. And with the pod shatter reduction trait, delayed swathing (90 percent colour change) or straight cutting are now viable options to be part of the overall canola mix allowing all canola on the farm to reach its genetic potential."

RENE MABON, BRETTYOUNG: "Many growers may not be consistently realizing the genetic yield potential of a variety, but they are likely consistently achieving its yield potential based on the multitude of risk/reward decisions they must make each year, given the vagaries of weather."

DAVE HANSEN, CANTERRA SEEDS: "Pod shatter tolerance is now on the minds of many breeding organizations and we'll continue to see more and more of these types of varieties hit the market. The yield average of the existing canola crop could arguably be much higher if so much of it wasn't lost during harvest time."

RICK WIEBE, CARGILL: "The canola industry today has the technology and tools required to make continued advancements in canola's yield potential and to stabilize yield performance for growers under varying conditions. To deliver on this we will need continued market access by ensuring that consumers are educated and are accepting of the benefits of modern agriculture including biotechnology."

BRUCE HARRISON, CPS PROVEN SEED: "Modern breeding tools are being employed to better understand germplasm. These modern tools will facilitate our study of genetic diversity and traits, which will be important for germplasm management and enhancement. Tackling complex disease resistance traits, abiotic stress traits or possibly utilization of "yield enhancing genes" could be possible outcomes."

KEVIN MCCALLUM, DL SEEDS: "Canola breeders will need to compete over the next 10 years against other crop types with big research investment into them like corn, soybeans and wheat. Canola genetics will need to hit the extra 8 bu./ac. targets set out by the CCC just to remain competitive as one of the crops in Western Canadian producers' rotations."

MARK WOLOSHYN, DOW AGROSCIENCES: "The development of an effective strip trial program by almost every seed organization has allowed new hybrids to be tested under a number of field conditions that more closely mimic growers' conditions. This practice should help to select for genetics that perform well under tighter rotations, cooler soil temperatures and more challenging sites than manicured small plot locations."

DAVE KELNER, MONSANTO: "Canola is a relatively young crop from a breeding perspective, with a lot of potential to improve yields through breeding assisted by new technology such as markers, genomic selection, precision phenotyping, and climate modeling."

DAVE HARWOOD, PIONEER HI-BRED: "There is most likely potential to drive increased productivity with modern genetics through increased and more timely fertility application. More work needs to be done to evaluate late nitrogen applications to high yield potential canola crops to determine if doing so allows the expression of genetic potential."

SHAUN VEY, SYNGENTA: "Growers continue to do an excellent job of understanding this crop and pushing canola yields to new levels, but there is still room for improvement to further maximize the return on seed investments. For growers, maximizing their seed investment starts the previous fall with good pre- and post-harvest weed control and trash management. Proper seeding rates and related practices (i.e. speed and placement) are also very important." •

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