2021 Oilseed Disease Situation Report

for the

Western Committee on Plant Diseases

of the

Western Forum on Pest Management

CHAPTERS:

Compiled by Alireza Akhavan, SK Ministry of Agriculture and Justine Cornelsen, Canola Council of Canada

25-October, 2021

Flax Disease Situation Report: Manitoba and Saskatchewan in 2021

Submitted by K. Nabetani, T. Islam, H. R. Kutcher, C. Peru, M. Beaith, A. Akhavan, C. Jacob, S. Roberts, M. Brown, A. Noble, K. Stonehouse, A. Fransoo

In 2021, we surveyed 84 flax crops, of which 59 were in Saskatchewan and 25 were in Manitoba. Out of the flax crops surveyed in Saskatchewan, nine locations were at Linseed Coop trial plots situated within multiple research farms throughout Saskatchewan. All surveys were conducted between August 3rd and September 16th. Maturity and stand establishment were measured on a scale of 1 to 5, where 1 is very poor/early and 5 is excellent/mature. Disease prevalence was measured as the percentage of fields affected by each disease out of all fields surveyed. A hundred flax plants in each field were examined to measure disease incidence as the percentage of flax plants affected by each disease, and pasmo severity as the percentage of stem area covered by pasmo symptoms averaged over 100 plants.

Of all flax crops surveyed, 69% (76% in Manitoba, 66% in Saskatchewan) were at the yellow to brown or brown boll stages at the time of survey. Twenty-eight percent of flax crops were at the green to yellow or yellow boll stages (20% in Manitoba, 31% in Saskatchewan) and only 4% of all flax crops; 4% in Manitoba and 3% in Saskatchewan; was at the green boll stage. The majority of flax crops, 54% (56% in Manitoba, 53% in Saskatchewan), had excellent stand; however, the rate was lower than 2019 or 2020 (Islam et al. 2020, Nabetani et al. unpublished). This could be attributed to the unusually hot and dry conditions during the growing season in 2021. Lodging was reported in only one flax crop. The low incidence of lodging could be due to the shorter plant heights observed in many flax crops under the drought conditions. Drought or dry conditions were reported from 20% of surveyed flax crops. Grasshopper infestation with the infestation level ranging from the population less than threshold to visible crop damage was reported in 30% of flax crops.

Despite the hot, dry conditions in summer 2021, the prevalence of pasmo symptoms was 54% over the flax crops surveyed (32% in Manitoba, 63% in Saskatchewan); pasmo was the most prevalent disease on flax in both provinces. Of all flax crops, trace to 10% incidence was seen in 25% of crops. Eight percent of flax crops showed 11 – 30% pasmo incidence and 11% had 31 – 60% incidence. Only 10% of flax crops had pasmo incidence higher than 60%. Pasmo severity in most infected crops ranged from trace to low. Of the flax crops surveyed, trace to 5% pasmo severity was found in 14% of crops and 6 – 25% severity in 25% of crops. Pasmo severity between 25% and 75% was observed in 13% of flax crops, which were all located in Saskatchewan. One crop with very high severity (>76% severity) occurred in Saskatchewan. High pasmo incidence and severity was mainly observed in flax crops grown in south central regions of Saskatchewan where there were higher moisture levels during the growing season than the rest of the province in 2021.

Alternaria blight was the second most prevalent disease on flax and was observed in 24% of all surveyed flax crops (4% in Manitoba, 32% in Saskatchewan). It was less prevalent than Alternaria blight found in 2018, 2019 or 2020 (Rashid et al. 2019; Islam et al. 2020; Nabetani et al. unpublished). The third most prevalent disease was Fusarium wilt, which was found in 19% of flax crops with 24% in Manitoba and 17% in Saskatchewan. The prevalence of Fusarium wilt in 2021 was higher than reported in the surveys

of 2018, 2019 or 2020 (Rashid et al. 2019; Islam et al. 2020; Nabetani et al. unpublished). This higher prevalence of Fusarium wilt in 2021 could be attributed to the drier conditions that many regions in Manitoba and Saskatchewan experienced. It is also possible that flax plants could have been more prone to show wilt symptoms due to lack of moisture on top of Fusarium wilt infection. Aster yellows was found in 14% of flax crops. No powdery mildew or flax rust was observed during the survey.

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Survey of Canola Diseases in Manitoba, 2021

Submitted by Yong Min Kim, Jennifer Graham, David Kaminski, and Dane Froese

METHODS

A total of 135 canola crops were surveyed between July 22 and September 8 in the major canola production regions of Manitoba. Regions included Southwest (62), Central (35), Northwest (23), Eastern/ Interlake (15). The majority of the crops were surveyed before swathing while plants were between growth stages 5.1 and 5.5 (Harper and Berkenkamp 1975). Disease assessments were made in each field by collecting 20 plants from each of five sites at least 20 m from the edge of the field and separated from each other by at least 20 m. Fields were assessed for the prevalence (percent fields infested) and incidence (percent plants infected per field) of sclerotinia stem rot (*Sclerotinia sclerotiorum*), blackleg (*Leptosphaeria maculans*), aster yellows (AY phytoplasm), foot rot (*Rhizoctonia* spp., *Fusarium* spp.), verticillium stripe (*Verticillium longisporum*) and clubroot (*Plasmodiophora brassicae*). For sclerotinia stem rot, each plant was rated for severity according to a rating scale of 0 to 5 (Kutcher and Wolf, 2006). For blackleg, plants were scored for either basal stem cankers or lesions that occurred on the upper portions of the stem. Blackleg basal stem cankers were rated for severity based on a rating scale of 0 to 5 that estimates the amount of disease in the basal stem cross-section. If present, clubroot symptoms were rated using a scale of 0 to 3 (Kuginuki et al. 1999). The prevalence and percent severity (Conn et al. 1990) of alternaria black spot (*Alternaria brassicae*, *A. raphani*) were also determined. When diseases were observed in the crop, but not in the sample of 100 plants, they were recorded as "trace" and counted as 0.1%. Results are presented in two formats: 1) based on values from diseased crops only and 2) based on values from all crops surveyed (provincial basis).

RESULTS AND COMMENTS.

Sclerotinia stem rot was observed in 1.5% of the crops surveyed. The average incidence in crops with the disease was 1.5% with an average severity of 1.5. The average incidence was highest in the Eastern/Interlake region (2%) and lowest in the Central and Southwest regions (0%). The severity of sclerotinia was highest in the Eastern/Interlake region (2.0) and lowest in the Central and Southwest regions (0.0). The mean incidence of sclerotinia stem rot based on all crops surveyed (provincial basis) was 0.02% with a mean severity of 0.02.

Canola samples were confirmed positive for blackleg through basal stem cross-section analysis. This disease was present in 84% of Manitoba canola crops surveyed with an average disease incidence of 12% in diseased fields. The average incidence was highest in the Eastern/Interlake region (24%) and lowest in the Northwest and Southwest regions (9%). The average severity of blackleg basal cankers in diseased fields was 1.4 with the highest severity in the Eastern/Interlake and Northwest regions (1.6) and the lowest in the Southwest region (1.3). The mean incidence of blackleg basal canker for the province (all crops surveyed) was 10% with a mean severity of 1.2.

Blackleg stem lesions were present in 50% of canola crops in Manitoba with an average incidence of 7% in diseased fields. Stem lesions were most prevalent in the Southwest region and observed in 68% of fields surveyed. The average disease incidence was highest in the Eastern/Interlake region (14%) and lowest in the Northwest region (3%). Stem lesions were rated as present or absent, so there are no severity ratings. On a provincial basis (all crops surveyed), the mean incidence of blackleg stem lesions was 4%.

Aster yellows was observed in 10% of canola crops surveyed in Manitoba, and in all regions but Eastern/Interlake, with an average incidence of 3.4% in diseased fields. Verticillium stripe was found in 30% of canola crops with an average incidence of 15% in diseased fields. On a provincial basis, the mean incidence of verticillium stripe was 4.4%. Foot rot was recorded only in the Southwest region (1.6%) with an average incidence of 1% in fields with the disease. The mean incidence of foot rot for the province (all crops surveyed) was 0.01%.

Alternaria pod spot was observed in 6.7% of canola crops surveyed in the province in 2021, with an average incidence of 7.3% in infected crops. The prevalence of pod spot was highest in the Eastern/Interlake region (20%) and lowest in the Central region (0%). The average severity of alternaria pod spot across the province (all crops surveyed) was 1.1.

In 2021, there were no new symptomatic cases of clubroot in the 135 canola fields surveyed. Soil samples from 45 fields have been collected and are currently being processed for clubroot DNA.

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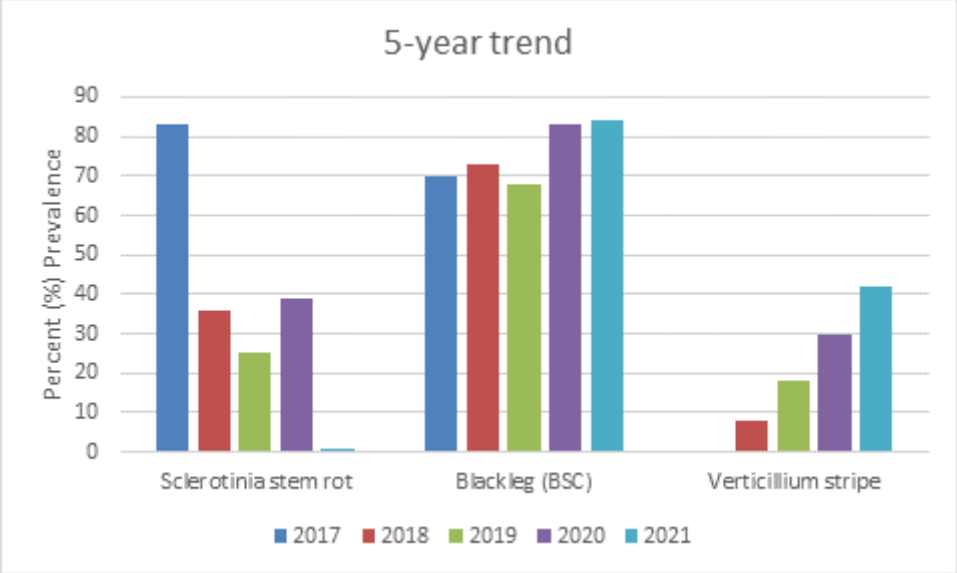
Figure 1. Five year trend of some of the key diseases on canola in Manitoba

Submitted by David Kaminski



Saskatchewan canola disease situation report 2021

Submitted by Alireza Akhavan, Carter Peru, Cory Jacob, Raul Avila, Scott Hartley, Crops Extension Specialists (Saskatchewan Ministry of Agriculture), SARM Plant Health Officers (Saskatchewan Association of Rural Municipalities) and surveyors from Meadow Lake Co-op, Bayer Crop Science Inc., and Nutrien.

General comments:
According to the Saskatchewan Agriculture's weekly crop report (ending on October 4, 2021), 99% of the crop in Saskatchewan has been harvested. This is well ahead of the five-year (2016-2020) average of 79% for this time. As of October 4th, 98% of canola has been combined.

Canola Disease Survey – *conducted by the Saskatchewan Ministry of Agriculture, Saskatchewan Association of Rural Municipalities and industry agronomists*

This report includes the preliminary results of the 2021 Saskatchewan canola disease survey and includes the survey results from 213 surveyed fields located across the major canola growing regions of Saskatchewan. This is a progressing work and all the information presented here may evolve and ultimately, the final results will be published in the Canadian Phytopathological Society Canadian Plant Disease Survey: Disease Highlights 2021. The largest number of surveyed fields were located in the East-Central with 24.4% (52 fields) (Table 1). Crops were surveyed before swathing while plants were between growth stages 5.2 and 5.5 (Harper and Berkenkamp, 1975). Survey dates ranged between July 28 and September 16. Disease assessments were made in each field by collecting 20 plants from each of five sites (100 plants per field) located at least 20 metres from the field edge and separated from each other by at least 20 metres. Fields were assessed for both prevalence (per cent of fields with symptoms of the disease) and incidence (per cent of plants surveyed with symptoms of the disease per field). The diseases assessed include: sclerotinia stem rot (*Sclerotinia sclerotiorum*), blackleg (*Leptosphaeria maculans*), aster yellows (AY phytoplasma), foot rot (*Rhizoctonia* spp., *Fusarium* spp.), alternaria black spot (*Alternaria brassicae*, *A. raphani*), fusarium wilt (*F. oxysporum* f.sp. *conglutinans*), Verticillium Stripe (*Verticillium longisporum*), powdery mildew (*Erysiphe cruciferarum*), downy mildew (*Peronospora parasitica*), white rust (*Albugo candida*), grey stem (*Pseudocercosporella capsellae*), bacterial pod spot (*Pseudomonas syringae* pv. *maculicola*) and clubroot (*Plasmodiophora brassicae*). Severity ratings were also conducted for both sclerotinia stem rot and blackleg. For sclerotinia stem rot, each plant (100 per field) was rated for severity according to a rating scale of 0 to 5 described by Kutcher and Wolf (2006). For blackleg, plant stems were cut and then scored for basal stem cankers severity using a rating scale ranging from 0 to 5. Average severity values for blackleg and sclerotinia stem rot in each field were calculated as the sum of the severity ratings divided by the total number of plants examined. Stem lesions were recorded when observed on the upper stem or when associated with a basal canker. The prevalence of alternaria black spot (*Alternaria brassicae, A. raphani*) in the field was recorded. For all of the diseases assessed, prevalence and average disease incidence or severity values were calculated across the entire province and separately for each of six regions within Saskatchewan.

Sclerotinia stem rot was reported in 35.21% of canola crops surveyed with low incidence and very low severity. The average incidence in the province was 2.20%. Incidence was highest in the West-central region (4.88%) and lowest in the Southeast region (0.47%). The provincial average sclerotinia stem rot severity was 0.03. Severity was very low across the province ranging from 0.01 to 0.07 in different regions.

Blackleg basal symptoms were present in 66.20% of canola crops surveyed in Saskatchewan (Table 1). The average incidence in the province was 6.90%. The average blackleg basal canker incidence was highest in the East-central region (10.83 %) and lowest in the Northeast region (3.11%). The average severity of basal cankers across the province was 0.09. The highest severity was in the East-central region (0.15); while the severity was lowest (0.04) in the Southwest region. Blackleg stem lesions were present in 28.64% of canola crops surveyed with an average incidence of 1.95%. The highest average incidence was in the East-central region (3.83 %) and the lowest incidence was in the Northeast region (0.26 %). The prevalence of basal cankers and stem lesions together (combined blackleg) was 18.78 % with an average incidence of 1.39 %. The highest incidence of combined blackleg was in the Southeast region (3.17 %) and the lowest incidence was in the Northeast region (0.05 %) (data not presented).

Aster yellows was found present in 19.25 % of canola crops surveyed. This prevalence estimate includes fields where aster yellows symptoms were observed within the 100 plant sample or at trace levels in the field outside of the sample sites. It is possible to have a region with a relatively high prevalence but a low or even 0% average incidence. This occurred where aster yellows symptoms were observed in the surveyed field but symptoms were not present in the 100 plant sample assessed in any of the fields. The average incidence in the province was 0.35 %. The highest incidence of aster yellows occurred in the Northwest region (2.21 %). Foot rot was present in 1.88 % of canola crops surveyed. The highest prevalence was in the Northwest region (3.45 %). Foot rot was not detected in the Northeast, and Southeast regions.

Alternaria black spot prevalence is calculated as the per cent of fields surveyed where the disease was observed within the field. Alternaria black spot was observed in 41.78 % of fields in 2021. The highest prevalence was in the Southwest (65.63%) and the lowest prevalence was in the West-central (28.13%). Alternaria severity was generally low throughout the province.

Symptoms suggesting verticillium stripe were found in a total of two fields. Symptoms of grey stem, powdery mildew, downy mildew, white rust, fusarium wilt and bacterial pod spot were not found during the formal survey in any of the surveyed fields assessed.

In 2021, the Saskatchewan Ministry of Agriculture, with support from SaskCanola, Saskatchewan Crop Insurance Corporation (SCIC) and the Saskatchewan Association of Rural Municipalities (SARM) Plant Health Officers, worked to better understand the distribution of clubroot in Saskatchewan through the 2021 clubroot monitoring program. This involved in-field surveillance in high clubroot risk areas and throughout the province, efforts to increase external reports of clubroot infested fields by producers and agrologists, encouraging the on-farm monitoring for the clubroot pathogen through the clubroot soil testing program and following-up on fields identified as positives through previous years. The purpose of this program was to increase our understanding of the distribution and severity of clubroot in regions where the disease and/or pathogen are known to occur and in areas not surveyed in previous surveys, also to contribute in managing the spread of clubroot by re-testing positive fields to determine pathogen persistence, ensuring compliance under *The Pest Control Act*, and reinforcing management practices to reduce the risk of clubroot spread. The in-field surveillance has been completed, and data entry and soil sample testing are currently underway. This information will be used to raise awareness of the clubroot situation in Saskatchewan to promote proactive clubroot management prevention and update the clubroot distribution map to be released in early 2022.

Table 1. Prevalence, mean incidence and severity of sclerotinia stem rot and blackleg of canola in Saskatchewan in 2021.

Region (No. of Crops)	Sclerotinia			Blackleg Basal Canker			Blackleg Stem Lesions	
	Prev[1]	Inc[2](Inc[3])	Sev[4] (Sev[5])	Prev[1]	Inc[2](Inc[3])	Sev[4] (Sev[5])	Prev[1]	Inc[2](Inc[3])
Northeast (38)	23.68	0.95 (4.00)	0.01 (0.05)	31.58	3.11 (9.83)	0.05 (0.15)	10.53	0.26 (2.50)
Northwest (29)	34.48	0.79 (2.30)	0.01 (0.03)	93.10	7.41 (7.96)	0.08 (0.09)	20.69	1.45 (7.00)
East-Central (52)	32.69	1.62 (4.94)	0.02 (0.05)	78.85	10.83 (13.73)	0.15 (0.19)	32.69	3.83 (11.71)
West-Central (32)	46.88	4.88 (10.40)	0.07 (0.16)	56.25	4.69 (8.33)	0.06 (0.10)	31.25	1.31 (4.20)
Southeast (30)	23.33	0.47 (2.00)	0.01 (0.02)	76.67	10.47 (13.65)	0.12 (0.16)	66.67	3.70 (5.55)
Southwest (32)	53.13	4.84 (9.12)	0.07 (0.14)	62.50	3.44 (5.50)	0.04 (0.06)	12.50	0.34 (2.75)
Overall mean Crops (213)	35.21	2.20 (6.24)	0.03 (0.09)	66.20	6.90 (10.43)	0.09 (0.13)	28.64	1.95 (6.80)

[1]Average per cent prevalence of disease in all canola crops in 2021 Saskatchewan Canola Disease Survey

[2]Average per cent incidence of disease in all canola crops in 2021 Saskatchewan Canola Disease Survey both with and without the given disease

[3] Average per cent incidence of disease in canola crops in 2021 Saskatchewan Canola Disease Survey infected with given disease

[4] Average severity of disease in all canola crops in 2021 Saskatchewan Canola Disease Survey

[5]Average severity of disease in canola crops in 2021 Saskatchewan Canola Disease Survey infected with given disease

Table 2. Total prevalence and mean incidence of aster yellows and prevalence of foot rot and alternaria black spot in canola crops surveyed in Saskatchewan in 2021.

Region (No. of Crops)	**Aster Yellows**		**Foot Rot**	**Alternaria black spot**
	Total Prev[1]	Inc[1,2](Inc[1, 3])	Prev[4]	Prev[5]
Northeast (38)	21.05	0.05 (1.00)	0.00	34.21
Northwest (29)	41.38-	2.21 (9.14)	3.45	44.83
East-Central (52)	15.38	0.02 (1.00)	1.92	36.54
West-Central (32)	9.38	0.03 (1.00)	3.13	28.13
Southeast (30)	30.00	0.17 (2.50)	0.00	46.67
Southwest (32)	3.13	0.03(1.00)	0.03	65.63
Overall mean Crops (213)	19.25	0.35 (5.29)	1.88	41.78

[1]For aster yellows, total prevalence includes fields where symptoms were present in the 100 plant sample or at trace levels in the field outside of the sample sites but the incidence is calculated on the 100 plant sample only.

[2]Average per cent incidence of disease in all canola crops in 2021 Saskatchewan Canola Disease Survey both with and without the given disease.

[3]Average per cent incidence of disease in canola crops in 2021 Saskatchewan Canola Disease Survey infected with the disease

[4]Average per cent prevalence of disease in all canola crops in 2021 Saskatchewan Canola Disease Survey.

[5]Average per cent prevalence of disease in canola fields

Canola disease survey results, Alberta 2021

M.W. Harding, G.C. Daniels, T.B. Hill, M.A. Kennedy, and J. Feng

Three hundred seventy-one (371) canola fields in Alberta were surveyed between August 4 and October 8, 2020 (Figure 2). Clubroot and blackleg, were rated for prevalence, incidence, and severity. The presence/absence of Sclerotinia main stem infections, as well as symptoms of Verticillium stripe, were noted. Canola plants were rated at ten sample points in each field along a W-shaped transect with each location >20 m apart and from the field margin. Ten plants were rated, or collected, at each sample point for a total of 100 plants/field. Roots were rated in the field for clubroot using 0-3 scale for clubroot as described by Horiuchi and Hori (1980) and modified by Strelkov et al. (2006). The lower six to twelve inches of ten stems were collected at each of the ten sample points (100 stems/field) and rated for blackleg, Sclerotinia stem rot and Verticillium stripe. Blackleg was rated using a 0-5 blackleg (WCC/RCC 2009). The presence or absence of Sclerotina stem rot, and symptoms Verticillium stripe on the main stem, were noted, but severity was not estimated.

Survey results are shown in Table 3. Blackleg was by far the most prevalent disease, reported in 89.4% of fields, followed by Sclerotinia stem rot (25.4%), clubroot (9.0%), and Verticillium stripe (2.9%). The presence of *Verticillium* spp. in the suspicious samples will undergo testing to confirm the presence of the pathogen.

Despite their prevalence, the incidence and severity for all diseases was low (Table 3). This is a preliminary report and may not be complete. A complete report of the Alberta canola survey will be published in v101 of the Canadian Plant Disease Survey.

ACKNOWLEDGEMENTS
Field visits for clubroot rating and canola stem collections performed by the municipal Agricultural Fieldmen, or their designates, is very gratefully acknowledged.

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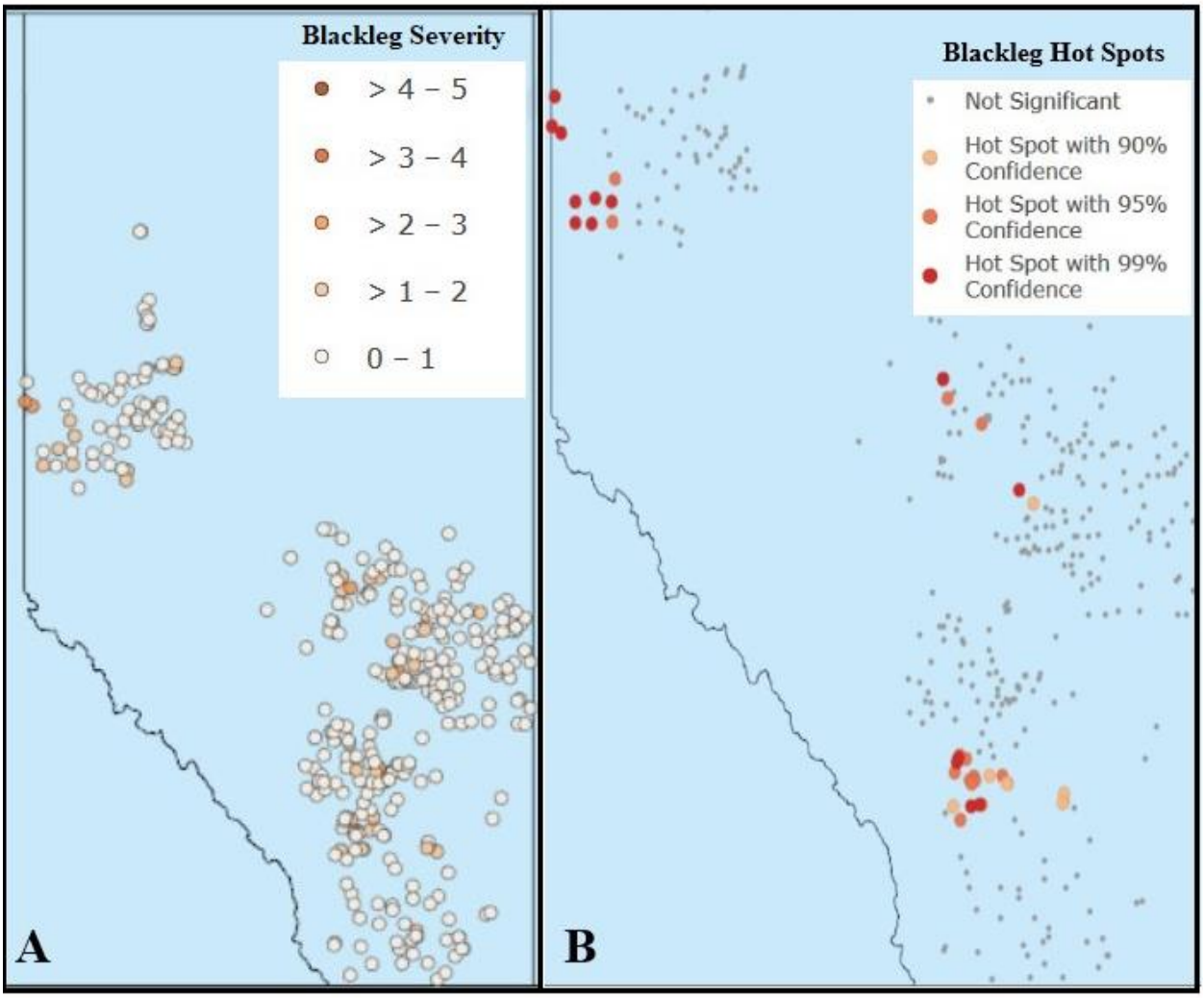
Western Canada Canola/Rapeseed Recommending Committee (WCC/RRC) Incorporated. 2009. Procedures of the Western Canada Canola/Rapeseed Recommending Committee for the evaluation and recommendation for registration of canola/rapeseed candidate cultivars in western Canada.

Table 3. Canola disease survey results for Alberta in 2021.

	Number of fields	Prevalence (%)	Incidence (%)	Severity	
				Range	Average
Clubroot	277	9.0	0.82	0 – 1.84	0.016
Blackleg	348	89.4	18.3	0 – 2.5	0.38
Sclerotinia	343	25.4	0.8	n.d.	n.d.
Verticillium	343	2.9	0.17	n.d.	n.d.

Figure 2. Canola survey locations, and blackleg severity (A) and hot spots (B), in Alberta in 2021.



Canola Disease Survey in Central-Northern Alberta in 2021

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Thirty-five canola fields were sampled near Edmonton, St. Albert, Namao, Morinville, Gibbons, Josephsburg, Villeneuve, Redwater, Opal and Bruderheim, Alberta, using W-shaped transects of each field. All plants within a 1-m^2 quadrat were examined at each of five points along the transects. The incidence of clubroot, blackleg, root rot, and white mold were noted at each sampling point. A total of 914 canola root samples were collected at random from low-lying areas in the fields. Samples showing symptoms of root rot were taken to the laboratory, where they are being analysed for causal organisms. The roots are sectioned and surface-sterilized, and then incubated on potato dextrose agar for 10-12 days under ambient light at room temperature. The fungal isolates obtained are sub-cultured for purification and identified visually. The percent pathogen-free samples and the mean percent incidence of each pathogen will be calculated for the root samples from each location.

RESULTS AND DISCUSSION:
The incidence of root rot was highest at Edmonton, with a mean incidence of 4.1% and 50% of roots infected at one sampling point (Table 4). At Morinville and Redwater, the overall incidence of root rot was also >4%. Blackleg incidence was greatest at Morinville, Opal, and Bruderheim. Some canola crops near Edmonton were heavily infected with clubroot, with a mean incidence of 7.2% and one sampling point where 95% of roots were infected. Most of the other areas showed little to no clubroot infection. A small amount of sclerotinia was observed at Edmonton, St. Albert, Morinville and Gibbons. A complete report including the incidence of pathogens recovered from canola in central and northern Alberta will be published in the *Canadian Plant Disease Survey*.

ACKNOWLEDGEMENTS: This survey was supported financially by the Alberta Canola Producers Commission and the Results Driving Agriculture Research Program.

Table 4. Incidence (%) of disease in canola plants collected in central Alberta, 2021.

Location	No. of fields	Root Rot		Blackleg		Clubroot		Sclerotinia	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
Edmonton	7	4.1	0-50	2.9	0-16	7.2	0-95	0.2	0-4
St. Albert	5	1.4	0-7	1.7	0-9	0	0	1.1	0-8
Namao	1	1.2	0-5	0	0	0	0	0	0
Morinville	6	4.1	0-30	4.3	0-20	0.2	0-6	0.04	0-1
Gibbons	3	0.4	0-2	1.3	0-5	0	0	0.07	0-1
Josephburg	2	0.2	0-2	0.6	0-3	0	0	0	0
Villeneuve	3	0.9	0-8	2.3	0-5	0	0	0	0
Redwater	4	4.4	0-25	0.9	0-5	0	0	0	0
Opal	1	0.2	0-1	4.2	0-11	0.2	0-1	0	0
Bruderheim	3	0.4	0-5	4.0	0-9	0.07	0-1	0	0
Total/Average	35	1.7	0-50	2.2	0-20	0.8	0-95	0.1	0-8

Crop Diagnostic Centre, Manitoba Agriculture and Resource Development. Summary of diseases diagnosed on oilseed crop samples submitted in 2021.

Submitted by Manika Pradhan, Manitoba Agriculture & Resource Development

Table 5. Diseases diagnosed on oilseed samples submitted to the MB AG Crop Diagnostic Centre (2021)

CROP	SYMPTOM/ DISEASE	CAUSAL AGENT	NUMBER OF SAMPLES
Canola	Alternaria black spot	*Alternaria* sp.	10
	Anthracnose	*Colletotrichum* sp.	10
	Aster yellows	*Phytoplasma*	3
	Blackleg	*Leptosphaeria maculans*	8
	Cladosporium leaf spot	*Cladosporium sp.*	1
	Grey stem	*Pseudocercosporella capsellae*	2
	Root rot	*Fusarium* sp., *Pythium* sp.; *Rhizoctonia solani*	15
	Verticillium stripe	*Verticillium* sp.	4
	Stress	Environmental injury	48
		Herbicide injury	12
	Nutrient deficiency	Possible Nitrogen/sulphur/Phosphorus deficiency	10
Flax	Leaf spot	*Alternaria linicola; Botrytis*	2
	Leaf and stem spot (Pasmo)	*Septoria linicola*	1
	Root rot	*Fusarium sp.; Pythium* sp. and *Rhizoctonia*	2
	Stress	Environmental injury	9
		Herbicide injury	2
Sunflower	Stress	Environmental/moisture	1

Saskatchewan Ministry of Agriculture Crop Protection Laboratory, 2021

Submitted by Scott Hartley, Tracey Sliva, Cerese Bawolin and Alireza Akhavan, Saskatchewan Ministry of Agriculture

Table 6. Diseases diagnosed on oilseed samples submitted to the Saskatchewan Ministry of Agriculture Crop Protection Laboratory (2021)

Oilseed Sample Diagnoses	Details / Scientific Name	Number
Canola		**16**
Environmental damage	Seeding depth, temperature fluctuations, high temperatures and lack of moisture	12
Blackleg (and clubroot)	*Leptosphaeria maculans (and Plasmodiophora brassicae)*	1
Powdery mildew	*Erysiphe cruciferarum*	1
Verticillium stripe	*Verticillium longisporum*	2
Albinism (and environmental damage)	Genetic albinism	1
Mustard		**1**
Fusarium wilt	*Fusarium oxysporum*	1
Flax		**1**
Root rot complex	*Fusarium* sp. *and Rhizoctonia* sp.	1

Summary of diseases diagnosed on canola submitted to the Alberta Plant Health Lab in 2021

Submitted by Jie Feng, Alberta Agriculture and Forestry

Table 7. Summary of diseases diagnosed on canola submitted to the Alberta Plant Health Lab in 2021

CROP	DISEASE/SYMPTOM	CAUSAL/ASSOCIATED AGENT(S)	NO. OF SAMPLES
Canola	Wilting, submitted for Verticillium testing	Negative for *Verticillium albo-atrum*, *V. dahlia*, and *V. longisporum*	2
	Root galling	*Plasmodiophora brassicae*	24
	Root rot	*Fusarium tricinctum, F. culmorum, F. avenaceum, Podospora/Phoma sp.*	1
Total			27

Current Plant Disease Research

Drs. Stephen Strelkov & Sheau-Fang Hwang (University of Alberta) – Ongoing research projects

1. **Study**: New Clubroot Pathotypes and Second Generation Resistance
   Principal investigators: Stephen E. Strelkov, Sheau-Fang Hwang & Rudolph Fredua-Agyeman, University of Alberta
   Funding: Canola Agronomic Research Program (CARP), Western Grains Research Foundation (WGRF)
   Purpose: Three main objectives are to (1) evaluate the infectivity of the most important P. brassicae pathotypes on a suite of canola cultivars with 2nd generation resistance, (2) determine the pathotype composition on 2nd generation CR canola recovered from commercial fields; and (3) assess the cross-infectivity of these pathotypes across 2nd generation CR canola cultivars.
2. **Study**: Study of the effects of Brassica root architecture and fertilizer application on clubroot disease severity and yield
   Principal investigators: Stephen E. Strelkov, Rudolph Fredua-Agyeman & Sheau-Fang Hwang, University of Alberta
   Funding: RDAR, ACPC, WGRF
   Purpose: Four main objectives are to: (1) provide knowledge on whether selecting for root-type is an important trait to consider in the breeding of Brassica crops for tolerance or resistance to clubroot and yield, (2) understand the effects of nitrogen levels on clubroot resistance, (3) provide a foundation for future studies to understand the genetic control of root morphology in Brassica species, and (4) provide a baseline for future studies to determine the association between chromosomal regions that determine root morphology and clubroot resistance in Brassica species.
3. **Study**: Understanding Fusarium wilt and root rot of hybrid canola: occurrence, host range, disease development, resistance and yield losses
   Principal investigators: Sheau-Fang Hwang & Stephen E. Strelkov, University of Alberta
   Funding: Results Driving Agriculture Research (RDAR) Program, Alberta Canola Producers Commission (ACPC)
   Purpose: The overall aim of this project is to improve seedling establishment, reduce root rot and wilt severity and maximize seed yield of canola by optimizing cultural methods to control the Fusarium pathogens causing seedling blight and root rot and wilt of canola.
4. **Study**: Fine-tuning of the blackleg yield loss model in canola
   Principal investigators: Sheau-Fang Hwang & Stephen E. Strelkov, University of Alberta
   Funding: Canola Agri-Science Cluster, SaskCanola, CCC
   Purpose: The overall aim of this project is to enhance understanding of the relationship between blackleg severity and yield losses in canola. The work involves one specific objective: to refine and improve an earlier yield loss model that was originally developed on 'Westar' using modern, hybrid cultivars.
5. **Study:** Verticillium Stripe Management
   Principal investigators: Sheau-Fang Hwang & Stephen E. Strelkov, University of Alberta
   Funding: SaskCanola, CCC

Purpose: Three main objectives are to: (1) Determine if there is yield loss and extent of yield losses from Verticillium stripe, (2) Determine the effects of growth stage and inoculation techniques on infection, and (3) Evaluate canola cultivars for resistance to Verticillium stripe.

6. **Study:** Pillar 1: Integrated disease management
   Principal investigators: Sheau-Fang Hwang & Stephen E. Strelkov, University of Alberta
   Funding: Canadian Canola Clubroot Cluster (C1)
   Purpose: The goal of this project is to develop management practices to reduce clubroot spore populations and prevent their buildup in at-risk areas. These practices are necessary to protect genetic resistance in canola varieties. Project objectives are to (1) characterize soil properties and pathotypes in clusters where resistance has been defeated, (2) test field pre-treatment and amendment techniques, including liming under varying spore concentrations and liming field entrances prior to clubroot introduction, (3) quantify yield loss in relation to disease severity, (4) assess the effect of cultivar rotation on clubroot pathotype structure, and (5) screen clubroot-resistance canola varieties against novel clubroot pathotypes.
7. **Study:** Clubroot inoculum management for sustainable canola production
   Principal investigators: Stephen E. Strelkov & Sheau-Fang Hwang, University of Alberta
   Funding: Alberta Agriculture Funding Consortium (AAFC)
   Purpose: The goal of this project is to develop techniques to reduce and suppress clubroot inoculum in fields in order to mitigate the impact of clubroot infection against novel clubroot pathotypes
8. **Study:** Alberta/Canada Canola Clubroot Cluster (C4) Pillar 4: Clubroot Pathotype Surveillance and Research
   Principal investigators: Stephen E. Strelkov & Sheau-Fang Hwang, University of Alberta
   Funding: Strategic Research Development Program (SRDP), AAFC
   Purpose: The aim of the project is to track and respond to changes in the clubroot pathogen via a team approach that includes three main objectives: (1) clubroot monitoring and sample collection with an emphasis on fields with pathotype change, (2) isolation and characterization of field and single-spore isolates, including pathotype identification on host differential sets, and (3) research into the genetic and virulence relationships between pathotypes.

Publication

- Askarian H., A. Akhavan, V.P. Manolii, T. Cao, S.F. Hwang, and S.E. Strelkov. 2021. Virulence spectrum of single-spore and field isolates of *Plasmodiophora brassicae* able to overcome resistance in canola (*Brassica napus*). Plant Dis. 105: 43-52 https://doi.org/10.1094/PDIS-03-20-0471-RE
- Botero-Ramirez, A., S.F. Hwang, and S.E. Strelkov. 2021. *Plasmodiophora brassicae* inoculum density and spatial pattern at the field level and relationship with soil-related characteristics. Pathogens 10(5):499. https://doi.org/10.3390/pathogens10050499
- Holtz, M.D., S.F. Hwang, V.P. Manolii, I.S. Silva-Strelkov, and S.E. Strelkov. 2021. Development of molecular markers to identify distinct populations of *Plasmodiophora brassicae*. Eur. J. Plant Pathol. 159:637-654. https://doi.org/10.1007/s10658-020-02194-4
- Jiang, J., R. Fredua-Agyeman, S.F. Hwang, and S.E. Strelkov. 2021. Differentially expressed genes in canola (Brassica napus) during infection by virulent and avirulent Plasmodiophora brassicae Pathotypes. Plant Pathology 70: 50-60. https://doi.org/10.1111/ppa.13267
- Strelkov, S.E., S.F. Hwang*, V.P. Manolii, G.D. Turnbull, R. Fredua-Agyeman, K. Hollman, and S. Kaus. 2021. Characterization of clubroot (*Plasmodiophora brassicae*) from canola (Brassica

napus) in the Peace Country of Alberta, Canada. Can. J. Plant Pathol. 43: 155-161. https://doi.org/10.1080/07060661.2020.1776931

- Yu, Z.Y., R. Fredua-Agyeman, S.F. Hwang, and S.E. Strelkov. 2021. Molecular genetic diversity and population structure analyses of rutabaga accessions from Nordic countries as revealed by single nucleotide polymorphism markers. BMC Genomics 22: 442; https://doi.org/10.1186/s12864-021-07762-4.
- Zhou, Q., L. Galindo-Gonzalez, V.P. Manolii, S.F. Hwang and S.E. Strelkov. 2021. Comparative transcriptome analysis of rutabaga (*Brassica napus*) cultivars indicates activation of salicylic acid and ethylene-mediated defenses in response to *Plasmodiophora brassicae*. Int. J. Mol. Sci. 21, 8381. https://doi.org/10.3390/ijms.20218381.
- Zhou, Q., L. Galindo-Gonzalez, S.F. Hwang and S.E. Strelkov. 2021. Application of genomics and transcriptomics to accelerate the development of clubroot resistant canola. Can. J. Plant Pathol. 43: 189-208. https://doi.org/10.1080/07060661.2020.1794541
- Fredua-Agyeman, R., J. Jiang, S.E. Strelkov and S.F. Hwang. 2020. QTL mapping and inheritance of clubroot resistance genes derived from *Brassica rapa* subsp. *rapifera* (ECD02) reveals resistance loci and distorted segregation ratios in three F2 populations of different crosses. Front. Plant Sci. 11:899. https://doi.org/10.3389/fpls.2020.00899
- Galindo-Gonzalez, L., V.P. Manolii, S.F. Hwang, and S.E. Strelkov. 2020. Response of *Brassica napus* to *Plasmodiophora brassicae* involves salicylic acid-mediated immunity: an RNA-seq-based study. Front. Plant Sci. 11:1025. https://doi.org/10.3389/fpls.2020.01025.

Research highlights from Gary Peng at AAFC Saskatoon

1. Understanding the critical window of infection
    - Funding: CAP Canola Cluster
    - Purpose: The study investigates the relative importance of cotyledons vs. lower true leaves for blackleg infection. It is also be of interest to understand how quantitative resistance (QR) affects the success of stem infection via cotyledons/lower true leaves. The information may help guide the timing of fungicide application, including seed treatment.
    - Progress: Experiments in greenhouse and field conditions have been completed. On a susceptible cultivar, cotyledon infection led to the highest level of stem infection (up to >80% of blackleg), whereas true-leaf (1st, 2^{nd} or 3^{rd}) infection caused lower (up to 15%) stem infection. However, blackleg rarely originates from the infection of 6^{th} leaf (>5%). On resistant cultivars based primarily on QR, the disease incidence resulting from leaf infection was much lower than that on the susceptible cultivar, especially via the true-leaf infection. A manuscript is being prepared.
2. Explore seed treatment options to mitigate the impact of blackleg on canola
    - Funding: CARP
    - Collaborators: Ralph Lange, InnoTech Alberta; Dilantha Fernando, U of M)
    - Purpose: To assesses the importance of infection from soil that also causes blackleg, an infection pathway reported in Australia. It also investigates the conditions that affect the success of infection, especially under the influence of pathogen inoculum level in the soil, root injury, cultivar resistance (QR) and fungicide seed treatment. The information will help assess how relevant this infection route is to blackleg impact and whether a fungicide seed treatment can mitigate it.
    - Progress: Experiments in greenhouse and field plots showed that soil inoculum at > 10^5 spores/g soil caused moderate levels of blackleg via root infection. The infection can be exacerbated when the roots were wounded mechanically, and this shows the potential of increased soil infection when roots are injured by diseases/insects in soil. A higher level of soil inoculum (10^6/g) substantially increased blackleg incidence and severity. Seed treatment with Fluopyram reduced blackleg through soil infection in greenhouse, but in field trials the treatment didn't show the efficacy when inoculation was delayed due to slow emergence caused by dry soil conditions. A droplet-digital PCR-based protocol has been developed to quantify the pathogen inoculum level in soil, which could have broad applications in disease management.
3. Improving management of blackleg on canola via better flea beetle control and effective fungicide seed treatment in western Canada
    - Funding: CAP Canola Cluster
    - Collaborators: Dilantha Fernando, U of M; Debra McLaren, AAFC Brandon
    - Purpose: The study assesses potential connection of flea-beetle feeding to blackleg infection. Spring conditions on the prairies are rarely conducive for the blackleg pathogen to infect intact canola seedlings due to generally low night temperature and a lack of moisture. But the pathogen may infect through wounds without the presence of

surface moisture. The study also investigates whether controlling flea beetles with foliar insecticide, using a resistant cultivar and protecting seedlings with a fungicide seed treatment can reduce blackleg infection under different flea beetle feeding pressure.

- Progress: Under controlled conditions, mechanical wounds on cotyledons of 0, 2, 4, 8, 12 and 24 h post wounding showed variable infection success when no additional leaf moisture was provided; wounds on cotyledons older than 4-8 h showed much reduced infection success relative to younger wounds, and the pattern was similar on both susceptible and resistant cultivars. This shows that *Leptosphaeria maculans* (blackleg pathogen) infects through fresh wounds more readily than does on older wounds or intact cotyledons when leaf-surface wetness is absent. Multi-year field trials at Carman, Brandon, MB and Vegreville, AB, however, could not establish the connection between reduced flea beetle feeding damage and lower blackleg levels. Additional work is being planned to better understand the results.

4. Developing a robust system based on the kinetics of fungal growth for identification and quantification of QR to blackleg

    - Funding: CAP Canola Cluster
    - Purpose: This study explores ddPCR for quantification of QR in canola germplasm and varieties that affects the kinetics of fungal growth in canola tissues. Once developed and validated, the method can be used to screen and quantify QR traits in in commercial canola germplasm, breeding lines and varieties.
    - Progress: More than 50 commercial hybrids/inbred lines with varied blackleg resistance shown in multi-year field trials were measured for effect on the kinetics of *L. maculans* based on ddPCR quantification of fungal DNA without the involvement of major R genes. The relationship between ddPCR readings and QR efficacy has also been validated using petiole and cotyledon inoculations under field conditions, with significant correlations. More commercial varieties/breeding lines will be screened for QR to blackleg in the coming year.

5. Monitoring the race dynamics of *L. maculans* for effective use of R genes to manage blackleg of canola in western Canada

    - Funding: CARP, Seed companies
    - Collaborators: Fengqun Yu, AAFC Saskatoon
    - Purpose: This study is part of the continued efforts to provide industry and producers with up-to-date pictures of *L. maculans* race profile, which can be used to guide the deployment/rotation of canola cultivars carrying different R genes. It also helps gain important insights into pathogen race changes in response to new resistant cultivars introduced.
    - Progress: This monitoring started in 2010 and has been continued over the past 10 years. The information provides a basis for the development of new canola cultivars with effective R gene. Data from each of the years have been analyzed up until 2019, and samples from 2020 and 2021 are being tested/collected. The pathogen population has not changed substantially on the prairies since 2014, with the avirulence genes *AvrLm4*, *AvrLm5*, *AvrLm6* and *AvrLm7* being present in high frequencies. This indicates the potential effectiveness of corresponding R genes. The annual information on the

avirulence-gene profile in *L. maculans* is of value to breeders in picking effective R genes for blackleg resistance breeding, and helps agronomists/growers to select cultivars that carry effective R gene(s).

6. Developing novel resistance resources and strategies to address the new threat of clubroot canola production on the prairies

    - Funding: CAP Canola Cluster
    - Participants: Fengqun Yu, AAFC Saskatoon; Habibur Rahman, Stephan Strelkov/Rudolph Fredua-Agyema, U of A.
    - Purpose: To screen and develop novel clubroot resistance resources for control of new pathotype variants of Plasmodiophora brassica capable of overcoming first generation of CR cultivars in Canada. The research include mapping of novel genes/QTLs linked to unique CR source and developing molecular markers for marker-assisted selections. CR modes of action, especially those related to multi-genic CR varieties for newly identified pathotypes, will also be studied to facilitate CR deployment strategies.
    - Progress: The resistance mechanisms associated with two CR genes residing on chromosomes A03 and A08, singly and in stacking, was studied using transcriptome analysis, fluorescent/electronic microscopy assisted with synchrotron-based spectroscopy. The study was carried out initially against pathotype 3H, the most predominant strain of P. brassicae in western Canada. The variety that carries stacked CR genes showed fewer ($P < 0.001$) root-hair infection (< 15%), relative to those with only a single CR gene (70%). The effect was similar on the reduction restricted to the exodermis. This shows that pyramiding CR genes may increase the sophistication of CR responses. There was clear strengthening of cell wall associated with the resistance (for both single and stacked CR genes), relative to the susceptibility; the cell-wall modification appeared to be related to the casparian band consisting of lignin.

    - Publications:

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

Hubbard M, Zhai C, Peng G. 2020. Exploring mechanisms of quantitative resistance to *Leptosphaeria maculans* (blackleg) in the cotyledons of canola (*Brassica napus*) based on transcriptomic and microscopic analyses. *Plants 9, 864* (48531).

Fu F, Zhang X, Liu F, Peng G, Yu F, Fernando WGD. 2020. Identification of resistance loci in Chinese and Canadian canola/rapeseed varieties against *Leptosphaeria maculans* based on genome-wide association studies. *BMC Genomics* 21: 501 (48721).

Karim MM, Dakouri A, Zhang Y, Chen Q, Peng G, Strelkov SE, Gossen BD, Yu F. 2020. Two clubroot-resistance genes, *Rcr3* and $Rcr9^{WA}$ mapped in *Brassica rapa* using bulk segregant RNA sequencing. *Int J Mol Sci*. 21, 5033 (49248).

Peng G, Liu C, Fernando WGD, Lange R, McLaren D, Kutcher HR, Singh G, Turkington TK, Johnson EN, Yu F. 2021. Early application of fungicide reduces the yield impact of blackleg only on susceptible canola under moderate to high disease pressure. *Can J Plant Pathol* 43: 384-393.

Soomro W, Kutcher HR, Yu F, Hwang SF, Strelkov SE, Fernando WGD, McLaren D, Peng G. 2020.

Race structure of *Leptosphaeria maculans* in western Canada between 2012 and 2014 and its influence on blackleg of canola. *Can J Plant Path*. 43: 480-493.

Liu F, Zou Z, Peng G, Fernando WGD. 2020. An extensive survey reveals the avirulence gene diversity of *Leptosphaeria maculans* population in western Canada. *Plant Disease* 105: 1440–1447

Zhai C, Liu XJ, Song T, Yu F, Peng G 2021. Genome-wide transcriptome reveals the mechanisms underlying *Rlm1*-mediated blackleg resistance on canola. *Scientific Reports* 11, 4407.

Yu C, Deng Y, Wu M, Peng G, Li G. 2021. First report of *Leptosphaeria biglobosa* '*brassicae*' causing blackleg on *Brassica rapa* subsp. *pekinensis* in China. Plant Dis. https://doi.org/10.1094/PDIS-09-20-1938-PDN

Cornelsen J, Zou Z, Huang H, Parks P, Lange R, Peng G, Fernando WGD. 2021.Validating the strategic deployment of blackleg resistance gene groups in commercial canola fields on the Canadian Prairies. *Front. Plant Sci*. 12: 669997.

Chen Q, Peng G, Kutcher HR, Yu F. 2021. Identification of genome-wide DNA variants reveals genetic diversity and population structure of Leptosphaeria maculans isolates collected in western Canada. Journal of Genetics and Genomics https://doi.org/10.1016/j.jgg.2021.06.019

Current canola disease projects co-funded by SaskCanola

Submitted by Doug Heath, Saskatchewan Canola Development Commission

Table 8. List of current canola disease projects co-funded by SaskCanola

SCDC File Name	*Principal Investigator Collaborators*	*Institution*	*Research Project Title*	*Length of Project*
AGRONOMY PROJECTS				
CARP CCC 2017.5	Rahman	AAFC	***Introgression of clubroot resistance from B.rapa into B.napus canola and identification of molecular markers for resistance, and pyramiding of this resistance with other resistance gene***	4
CARP CCC 2017-27	Peng	AAFC	***Monitoring the race dynamics of Leptosphaeria maculans (causative agent of blackleg) for effective deployment and rotation of resistance genes for sustainable management of blackleg of canola in western Canada***	5
CARP CCC 2018-1	Boyetchko	AAFC	***Biopesticides as a Novel Management Strategy for Sclerotinia in Canola***	5
CARP CCC 2019.6	Gossen	AAFC	***Managing small patches of clubroot infestation in canola fields***	4
CARP CCC 2019.9	Strelkov	U of A	***Influence of pH on the clubroot pathogen: are there pH-insensitive strains?***	3
CARP CCC 2019.10	Peng	AAFC	***Exploring novel seed-treatment options to mitigate the impact of blackleg on canola***	3
CARP CCC 2019.34	Hwang/Strelkov	U of A	***Verticillium Stripe - The Disease Management***	5
CAP CCC Canola Science Cluster		AAFC, U of M, U of S, GIFS, SK Ag, U of A, Innotech	***Canola Agri-Science Cluster***	5
CAP WGRF Agronomy Cluster	Yantai Gan, Kelly Turkington, Meghan Vankosky	AAFC, U of A,	***Integrated crop agronomy cluster (Activity 2,3,7) (PPMN, PCDMN)***	5

SCDC File Name	*Principal Investigator Collaborators*	*Institution*	*Research Project Title*	*Length of Project*
CARP ADF 2020.155 Gossen	Gossen/McDonald	AAFC	***Developing single-spore isolates of pathotypes of Plasmodiophora brassicae***	1
CARP ADF 2020.315 Halstead	Halstead	SK Polytech&AAFC	***Application of hyperspectral imaging for detection and mapping of small patch clubroot infestations in commercial canola fields***	3
CARP CCC 2021.10 Strelkov	Strelkov	U of A	***New Clubroot Pathotypes and Second Generation Resistance***	3
CARP CCC 2021.44 Fernando	Fernando	U of M	***Investigating interactions of ascospores and pycnidiospores with blackleg resistance in canola and efficacy of new seed applied fungicides in these specific interactions in western Canada***	3
CARP CCC 2021.18 F.Yu	F.Yu	AAFC	***Purifying genotypes of Plasmodiophora brassicae and developing SNP markers linked to races of P. brassicae populations collected in western Canada***	5
GERMPLASM PROJECTS				
CGDP CARP CCC 2020.07	Todd	U of S	***A proteomics-based approach towards identifying host and pathogen proteins critical to clubroot establishment in canola***	4
CGDP CARP CCC 2020.40	Vail	AAFC	***Pre-breeding lines combining canola quality with sclerotinia resistance, good agronomy and genomic diversity from PAK93***	
CGDP SCDC/ADF 2016-138	Bonham-Smith	U of S	***Genome wide functional analysis of Plasmodiophora Brassicae effectors and the management of clubroot disease***	5
CGDP SCDC 2017-7	Fernando	U of M	***Identification and genetic mapping of novel genes for resistance to blackleg in***	4

SCDC File Name	*Principal Investigator Collaborators*	*Institution*	*Research Project Title*	*Length of Project*
			Chinese and Canadian Brassica napus varieties	
CGDP ADF 2017-055	Yu	AAFC	***Defining populations of Plasmodiophora brassicae with near isogenic Brassica napus lines***	3
CGDP ADF 2017-072	Borhan	AAFC	***Overcoming blackleg disease in canola through establishment of quantitative resistance***	3
CGDP ADF 2018.021	Buchwaldt	AAFC	***Contribution of individual defense genes to sclerotinia resistance in canola***	4
CGDP ADF 2018.243	Xiao	U of S	***Establishing transgene-free CRISPR/Cas9 based genome editing platform to improve canola resistance against clubroot disease***	3
CGDP CCC 2019.27	Borhan	AAFC	***Towards better understanding of Leptosphaeria-Brassica interactions via international collaborations to standardize the nomanclature of blackleg resistance genes***	3