PROJECT DETAILS

- **Title**: Improving the management of sclerotinia stem rot of canola using fungicides and better risk assessment tool
- **Funders:** Agriculture and Agri-Food Canada, Canola Council of Canada, Alberta Canola, SaskCanola and Manitoba Canola Growers
- **Research program:** Canadian Agricultural Partnership
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- **Year completed:** 2023

Final report

Introduction

Sclerotinia stem rot of canola (*Brassica napus* L.) is an economically devastating disease caused by *Sclerotinia sclerotiorum* (Lib) de Bary. Epidemics of this disease can be devastating because of its wide host range, long lived resting structures (sclerotia) and potential for windborne ascospores to be spread from neighbouring fields. These factors coupled with conducive environmental conditions cause disease outbreaks to be unpredictable, with disease levels varying from field to field and year to year. Conditions that favour disease development are cool and wet, with the optimum temperature ranging between 7˚C – 30˚C. Previous methods for control have offered some reprieve from Sclerotinia symptoms, but the most reliable method continues to be routine fungicide applications. Traditionally, growers manage Sclerotinia stem rot by applying fungicides to coincide with early canola flowering, with the goal of covering as many flower petals as possible to prevent the disease from penetrating the host plant once the petals fall into the canopy.

Existing risk assessment systems have attempted to provide producers with more insight as to the risk of disease development, as Sclerotinia only displays symptoms after the disease has penetrated the plant and thus fungicide application needs to be done prior to symptom development. Current systems in use include risk checklists, which base their assessments on previous Sclerotinia infections, cropping history and recent weather events, as well as other factors. However, even with these check systems in place, producers make spray decisions with a large degree of uncertainty.

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Recent research investigating pathogen levels via qPCR analysis on petals coupled with assessment of factors known to influence disease pressure, like relative humidity and temperature, shows promise in terms of stem rot risk predictions. Development of qPCR for stem rot has allowed for a timelier and more accurate DNA based risk assessment versus older approaches such as agar plate petal testing, thus giving producers a more informed spray decision. Some companies are offering petal-based DNA tests, while others offer a result based on airborne ascospore levels determined with spore traps positioned above the canola canopy. The research evaluated and refined the use of qPCR and evaluated the utility of existing commercial PCR tools and spore trapping methods, while improving our ability to manage stem rot using fungicides.

The activity involved research sites where there can be an elevated risk of stem rot based on past stem rot development over the last 5-10 years, favourable weather conditions and/or the use of irrigation, The research trial was set up at each site as a factorial arrangement of treatments (two seeding rates x nine fungicide treatments) using a randomized complete block trial with four replications. The trial sites were at Beaverlodge, Lacombe, Brooks (irrigated), and Lethbridge AB; Scott, Melfort, Indian Head and Outlook (irrigated) SK; Brandon, MB; and Normandin, QC.

Specific objectives:

1. refining the use of qPCR analysis and investigating the potential of utilizing spore traps instead of canola petals;

2. understanding the role and impact of RH, rainfall, and temperature on inoculum production and disease development;

3. evaluating the efficacy of very early applications alone or in conjunction with later applications of fungicide for management of stem rot;

4. develop a better understanding of factors (e.g. seeding rate) that influence crop development and variability in flowering and how this influences fungicide response at various crop growth stages; and

5. develop a better understanding of how inoculum availability and environmental conditions prior to and during the flowering period influence stem rot risk and the efficacy of fungicide application.

Materials and Methods

A. Fungicide trial – 2022

Research Sites: AAFC Lacombe, AB.; AAF Brooks, AB.; AAFC Beaverlodge, AB.; AAFC Lethbridge, AB.; AAFC Scott, SK.; AAFC Melfort, SK.; AAFC Indian Head, SK.; AAFC Outlook, SK.; AAFC Brandon, MB.; and AAFC Normandin, QC. At each site data related to crop development, yield, kernel characteristics and stem rot incidence/severity were collected. In addition, In-crop and ambient RH and temperature data

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were collected in a check plot using Hobo Weather equipment. Pathogen inoculum load data were also collected weekly (or more frequent) based on qPCR analysis of spore trap and petals samples. Petal samples were assessed by J. Feng and H. Fu AAF Edmonton and by commercial testing labs (CPT1 and CPT2).

Treatment list (Factorial arrangement of treatments set up as an RCBD with 4 replicates):

A. Low and high canola stand densities: created using seeding rates of approximately 60 and 120 seeds/m_2.

B. Fungicide: Check; Yellow bud stage (YB), 1 week after YB; 2 weeks after YB; 3 weeks after YB; 4 weeks after YB; YB + 2 weeks after YB; YB and 3 weeks after YB; and YB and 4 weeks after YB.

The fungicide used was Proline 480 SC (480 g per L prothioconazole formulated as a suspension concentrate) at a rate of 140 mL/acre, with a water volume of 40 L/ac. Proline was used for all fungicide treatments; however, it is recognized that this approach does not facilitate fungicide resistance management. For the trial, the same product was used to allow for more effective comparisons of application timings and to avoid any confounding effects of different products and active ingredients. Technology transfer related to this project will emphasize the importance of rotating fungicide active ingredients if multiple applications are made within the same growing season.

The canola variety used will be the latest generation InVigor variety (or comparable) that is susceptible to stem rot. Fertilizer will be applied according to soil test recommendations. Weed management will reflect the weed spectrum at each site and the variety used and will follow recommendations in the provincial pesticide guides.

Data analyses:

1. Mixed model analysis of data for all sites and years to assess the effect of the various treatment combinations on diseases levels, crop yield, and growth stage, canopy and grain characteristics.

2. Graphing and visual interpretation of spore trapping and petal testing data in relation to date, crop growth stage, and environmental parameters to assess the relationship between inoculum availability, crop growth stage, and environmental conditions, and potential relationships to observed treatment responses.

Results and Discussion

A. General environmental conditions

General Weather Conditions:

In May 2022, temperatures for most of the prairie region and in the Normandin, QC region were -2$_o$C from normal to normal for most of the Prairie region (Fig. 1). For June 2022, most of the prairie region and the Normandin, QC area were normal to -2$_o$C below normal or +2$_o$C above normal for most of the Prairie region (Fig. 2). July temperatures in 2022 were generally normal to +2$_o$C from normal form most of the Prairie and Normandin regions (Fig. 3). In August 2022, the central to eastern Prairie region was from -2$_o$C to normal, while

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the central to western Prairie region was mostly +2$_o$C to +3$_o$C from normal, although there were regions including the Peace region and areas of central and southern Alberta where temperatures were +3$_o$C to +4$_o$C above normal, (Fig. 4). The Normandin, QC region was normal to about 2$_o$C above normal in August (Fig. 4).

In May 2022, central, northern and southern Alberta and west central and southern Saskatchewan had <40 to <85% of normal precipitation, while areas in east central Alberta, the south Peace, and central to north central and western Saskatchewan had 85% to <115% of normal precipitation (Fig. 5). In contrast, most of Manitoba, eastern Saskatchewan and the north Peace and BC Peace regions had 150 to >200% of normal precipitation (Fig. 5). Excessive spring moisture in these regions resulted in delayed seeding in many areas. The Normandin, QC region had > 115 to over 200 mm of rainfall in May (Fig. 5). For June 2022, most of northern, central and southern Alberta, northwestern and southwestern Saskatchewan 150 to >200% of normal precipitation (Fig. 6). The Peace region, some regions in Saskatchewan and most of Manitoba had 85 to 150% of normal precipitation, while the Normandin region was mainly in 150-200% of normal precipitation (Fig. 6). In contrast, central and south central Saskatchewan were drier with <40 to <85% of normal precipitation. In July 2022, most of the central to southern Prairie region and Manitoba had 85% to >200% of average precipitation (Fig. 7). Northern regions of Saskatchewan and Alberta and the Peace region were much drier with <40 to <60% of average precipitation. The Normandin region had from 60 to 115% of normal precipitation in July (Fig. 7). In August 2022, Prairie precipitation levels were decreased in large areas of the Prairie region having <40 to <60% of average precipitation (Fig. 8). Other smaller areas in the north Peace region, northeastern Saskatchewan and southeastern Manitoba had 85% to <115% of normal precipitation (Fig. 8). In 2022, the Normandin region had from 85 to 150% of normal August precipitation (Fig. 8).

B. Fungicide trials – 2022

Weather conditions again impacted sclerotinia risk at sites in 2022. Dry conditions generally prior to and during flowering limited inoculum production and disease development (Figures 6, 7, 10, 11, 12, 14, 15, 16, 18, 19, 20, 22, 23, 24, 26, 27, 28, 30, 31, 32, 34, 35, 36, 38, 39, 40, 42, 43, 44, 46, 47, 48). Even the irrigated sites at Brooks and Outlook had no to limited disease. Furthermore, even though moisture levels were increased somewhat at Melfort, Indian Head and Brandon disease levels were no to limited (Figs. 34-36, 38-40, 42-44). In the UK Young et al. (2020) reported the use of relative humidity measurements to indicate a risk of infection whereby ambient relatively humidity (RH) needs to be 80% or above for 23 hours for potential infections to occur. Due to mainly dry conditions at most sites in 2022, hourly RH levels of >=80% generally remained below the 23-hour threshold (Figures 12, 16, 20, 24, 28, 32, 36, 40, 44, 48). However, in-canopy RH more frequently approached or met this threshold, while generally being higher on many dates compared with ambient RH levels (Figures, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48). Occasionally, ambient RH was slightly higher than canopy RH. Trends observed in the 2022 fungicide trial sites were also consistent with observations as part of the M.Sc. companion project in 2019 and 2020 (McBain 2022).

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Overall drier weather conditions and generally no to trace stem rot inoculum, limited treatment effects occurred at most sites. The treatment effect that most affected response variables was seeding rate. For example, at Lethbridge, Brooks, Indian Head, and Brandon the high seeding rate either hastened the start of flowering or shortened the period of flowering slightly (< 1 to 2 days) versus the lower seeding rate, although there was a slight opposite trend at Indian Head and Brandon (Tables 3, 4, 8, 9). There was a significant interaction of seeding rate and fungicide timing for the final date of flowering at Indian Head, however, trends were variable and did not appear to be consistent with fungicide treatment (data not shown). For example, the check treatment for both seeding rates tended to have the earliest date of last flower, but some fungicide timing treatments were the same as the check for both seeding rates. At Lacombe (3.4 days), Lethbridge (0.5 days), Brandon (1 day), and Normandin (4 days) the higher seeding rate matured earlier versus the lower seeding rate (Tables 2, 3, 9, 10). Overall, the higher seeding rate likely increased inter-plant competition which could lead to faster plant development. Lodging was only impacted by seeding rate at Indian Head where it was slightly increased with the lower seeding rate, but differences were small and likely of limited practical significance (Table 8).

There were limited treatment effects on yield and grain parameters with seeding rate having the most consistent impact. Yields were increased with the high seeding rate at Beaverlodge, Brooks, Indian Head, Brandon, and Normandin (Tables 1, 4, 8, 9, 10). Thousand seed weight was increased by the higher seeding rate at Lacombe, Brooks, Indian Head, and Brandon (Tables 2, 4, 8, 9). Improvements in yield may have reflected improved weed competitiveness. Protein content was increased slightly with the higher seeding rate at Outlook, while it decreased slightly at Beaverlodge and Indian Head (Tables 1, 6, 8). Oil content was increased slightly with the higher seeding rate at Beaverlodge, Brandon, and Indian Head, but was decreased slightly with the higher seeding rate at Outlook (Tables 1, 6, 8, 9). Interestingly, fungicide timing had a significant impact on oil content at Brandon and Normandin, although trends were not consistent among treatments and differences were 1% or less (Tables 9, 10).

In general inoculum levels measured via the petal tests and rotorod assessments (J. Feng, AAI, Crop Diversification Centre North) were generally low, although occasional spikes in spore loads did occur (Table 14; Figs. 49-57). Generally low levels of inoculum were observed using the commercial passive spore trap (CPST) where all sample results were either *S. sclerotiorum* DNA was not detected or at the limit of detection prior to and during the flowering period (Table 12), while the CPT1 and CPT2 petal tests also had generally low levels of petal infestation at most sites for early, full and late bloom (Tables 11 and 13). The infrequent presence of sufficient *S. sclerotiorum* inoculum coupled with unfavourable RH conditions restricted disease development in 2022.

Given weather conditions and limited inoculum, there was limited disease development at most sites and no effects of fungicide timing and their interaction on yield (Tables 1-10). It is interesting to note that trial sites at both Outlook, SK. and Brooks, AB were irrigated yet inoculum loads, and weather conditions were not overly favourable for stem rot development. Some tests indicated increased inoculum levels exceeding the 1.0 x 10-4 ng of *S. sclerotiorum* DNA on occasion at Beaverlodge, Lethbridge, Brooks, Scott, Indian Head, and Normandin based on either qPCR testing of petals or rotorod samples by the APHL in Edmonton.

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However, RH conditions were generally not conducive with most dates having under 21 hours per day with RH >=80% (Figures 10, 12, 18, 20, 22, 24, 26, 28, 38, 40, 46, 48). Overall results in 2022 and 2021, and from some sites in 2019 indicate that when the risk of stem rot is low based on weather and inoculum conditions, fungicide application is not needed and provides no crop productivity or economic benefit in terms of yield. Moreover, the purported “stay green” effect of fungicide application is not of benefit as maturities were also not impacted by fungicide application. The “stay green” effect would be primarily associated with controlling disease when the risk is high enough and thus maintaining green healthy plant tissues that can contribute to grain filling and yield.

Eleanor McBain’s M.Sc. thesis (McBain 2022):

Sclerotinia stem rot, caused by *Sclerotinia sclerotiorum*, is an important disease of canola (*Brassica napus*). Disease development is highly dependent on weather conditions and is initiated by infection of the petals by airborne ascospores, followed by mycelial progression into leaf and stem tissues. Improved stem rot forecasts would facilitate improved fungicide application decisions, reducing costs and enhancing disease control.

To improve the benefit and efficacy of fungicide application, risk assessment tools should include a field-specific form of inoculum detection, since the presence of inoculum, together with weather conditions, are the best indicators for low to no risk areas (Turkington 1991; Young et al. 2018). There are only a few commercially available methods for *S. sclerotiorum* ascospore detection in Canada, including a passive spore trap and petal test kits from private sector seed testing laboratories. The objectives of the work in this thesis were to: 1) develop a better understanding of how environmental conditions (relative humidity (RH), temperature, and rainfall) influence *S. sclerotiorum* inoculum load and risk over the flowering period, and how these affect final stem rot incidence and severity; and 2) investigate the potential utilization of spore traps and DNA-based petal testing to assess airborne inoculum loads as a means of forecasting disease risk, and determine if a quantitative measure of risk is required for accurate predictions. Specific objectives included (1) to determine if inoculum pressure and final disease incidence were related to RH and temperature conditions, (2) to assess the relationship between results from a passive spore trap and those of a quantitative volumetric trap and determine how measurements from both types of traps were related to weather conditions and final disease levels, and (3) to evaluate three different methods of petal testing utilizing different qPCR methodologies and compare them with weather conditions and final disease levels. The ultimate goal of these objectives was to determine if spore traps alone could accurately predict SSR, or if petal tests were also required. Additional objectives also included providing insight into the placement of spore traps, including a commercial passive spore trap called the Spornado (2020 Seed Labs, Inc. 2021) and rotorod samplers, and determine how many would be required to provide an accurate prediction of stem rot when coupled with in-field and in-canopy monitoring of weather conditions. A secondary objective was to compare protocols for assessment of aerial spore loads.

For the current M.Sc. project various methods to monitor airborne inoculum of *S. sclerotiorum* were compared and related to stem rot incidence and severity. These included a passive spore trap (Spornado) and petal test kits from commercial private seed testing laboratories (CPT1 and CPT2), as well as a

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GRIPST-2009 rotation impact sampler (rotorod). Canola petal samples were also tested for *S. sclerotiorum* infection by the Plant Health Lab, AAI.

Weather data collected from all fields in this study was used to explore the relationship between ambient weather variables versus in-canopy weather variables and ambient versus recorded weather conditions at the nearest Environment Canada weather station (or ACIS station). The relationships between variables varied between years and locations; the only relationship that remained consistent between years and across all field locations was that the in-canopy RH was significantly different from the ambient RH. In-canopy temperature was also generally significantly different from ambient temperature, as only 16% of all fields, including AAFC/AAI sites, had similar in-canopy and ambient temperatures. From these observations, we can conclude that ambient RH and temperature may not provide an accurate representation of the in-canopy conditions. Based on the data collected in this study, canopy RH was generally about 6% above ambient RH. Thus, if in-canopy monitoring is not possible due to cost or practicality, then one may be able to use ambient RH, with the understanding that canopy RH will likely be 3 to 13 % above ambient RH. When the ambient RH measured in-field was compared with the nearest weather station, it was generally significantly different at most of the commercial field sites and AAFC/AAI locations. In contrast, ambient in-field temperatures tended to be closer to the weather station measurements (not significantly different in nearly half of the commercial fields). At the AAFC/AAI sites, the in-field ambient temperature was not significantly different from the public weather station data at 80% of the locations. This was likely because public weather stations were often located on government research stations associated with the AAFC/AAI sites; in contrast, public weather stations were between 2 km and 28 km away from the commercial field sites. The greatest extent of agreement between in-field weather data and data recorded at the nearest weather station occurred for rainfall, the values of which were similar for most commercial fields and AAFC/AAFRD sites. Wind speeds recorded at the commercial field sites were generally significantly different from the public weather station data, likely because this parameter may be affected by more factors at the field level, such as topography and nearby vegetation (Ruel et al. 1998).

The different petal tests evaluated as part of the 2020 M.Sc. project gave variable results (the two commercial tests were not evaluated in 2019 as part of the M.Sc. project). Nonetheless, CPT1 seemed to be the best correlated with final stem rot levels and petal tests conducted by the Plant Health Lab, especially in fields with low amounts of inoculum pressure and DI. At the AAFC/AAI sites, CPT1 (but not CPT2) was assessed in 2019, with similar correlations found between CPT1 and petal tests conducted by the Plant Health Lab. Potential reasons for discrepancies between the rotorod and Plant Health Lab inoculum assessments and those for the commercial passive spore trap and CPT1 and CPT2 may reflect inherent differences in the protocols, although the specificity of the molecular tests is likely also a factor. Ziesman (2016) and Ziesman et al. (2016) found specificity issues for tests reported in the literature, with some cross-reacting with fungi other than *S. sclerotiorum*. Previous research has already shown that the level of petal infestation varies over time (Almquist and Wallenhammar 2015; Turkington and Morrall 1993; Turkington et al. 1991a; Turkington 1991; Ziesman et al. 2016), which was confirmed in this study. Nonetheless, including petal tests or spore trapping in a Sclerotinia stem rot forecasting system, at least once during the critical flowering stages (BBCH 61-65, Meier

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1997, 2018), may be more reflective of accumulated risk conditions, helping to synthesize host, pathogen and environmental responses in relation to disease risk.

In terms of the relationship between ascospore detection methods and weather variables (CPT1 and CPT2 were not tested because of a low sample size), the weather variables could be used to predict *S. sclerotiorum* DNA levels on the rotorods and Plant Health Lab-tested petal samples. However, the models were significant only with averages for each variable obtained from the mid-late flowering period and over the total flowering period. No models were significant for predicting the commercial passive spore trap risk level or for any spore detection methods during early-mid flowering. The strongest relationships for both the rotorod and Plant Health Lab-tested petal samples occurred with averages from the total flowering period (adjusted R_2 = 0.54 and 0.53, respectively). The lack of strength in the models could indicate that additional factors need to be included, such as soil moisture, which other researchers have found to increase the strength of their models for predicting DI (Bom and Boland 2000; Sharma et al. 2015). While weather, especially moisture, is a critical factor in the stem rot cycle, another key factor is the population of sclerotia in the soil. Thus, relying exclusively on weather to predict spore load is problematic, as there may be scenarios where the weather is predicting increased ascospore loads, but due to no to low sclerotial populations, the pathogen is simply not present in sufficient quantities to respond to these favourable weather conditions. This was illustrated by the results from the AAFC/AAI fungicide trial sites in Brooks and Lacombe, AB, where weather conditions were somewhat favourable for stem rot, but limited to no inoculum was detected via spore sampling or petal testing. No relationship between early-mid weather variables and inoculum levels is significant because that is the time when fungicide decisions are made, and infections that occur during the same period are more likely to develop on the main stem of canola and become more established (Gugel 1986).

Comparison of two different spore trap methods, one passive and one volumetric, as well as the Plant Heath Lab petal results, highlighted two key findings. First, a single sample during early flowering does not provide an accurate representation of the overall airborne inoculum, and flushes of ascospores can occur throughout the flowering period. This is consistent with the observations of Qandah and del Río Mendoza (2011, 2012), Turkington and Morrall (1993), Turkington et al. (1991a) and Young et al. (2020). The rotorod sampler better monitored flushes of ascospores that occurred during the flowering period, detecting the fluctuations in *S. sclerotiorum* DNA associated with these flushes; in contrast, the Commercial passive spore trap did not catch the smaller flushes of ascospores. Second, while a definitive amount of ascospore pressure can be helpful for forecasting Sclerotinia stem rot, it does not guarantee the presence or absence of lesions, nor the severity of disease, if only ascospore pressure is being monitored. Overall and on its own, the Commercial passive spore trap did not accurately reflect final disease levels, and could potentially indicate false positives in relation to inoculum levels that suggested the need for fungicide. Ultimately, there was a higher amount of airborne inoculum captured by the rotorod samplers in 2019; however, this was not reflected in the results obtained with the Commercial passive spore trap. In general, the use of inoculum load assessments will be more beneficial if coupled with a forecasting system, as is done in the UK, where ambient weather is monitored for risk during the flowering period, and an alert issued if conditions are met (Young et al. 2018). Moreover, monitoring aerial spore load and necessary weather conditions (RH >80%) prior to and during flowering may

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help to guide fungicide timing, whether at or just prior to early bloom or later as the crop progresses into full bloom. For example, favourable weather and increased inoculum loads prior to and during the start of flowering may indicate the need for fungicide application earlier in the bloom period. If these favourable conditions persist into full bloom then a second application of fungicide may be warranted depending on yield potential and commodity price. Conversely, if weather and inoculum loads are not favourable prior to and during early flowering, but then become more favourable as the crop progresses towards full bloom, a full bloom application of fungicide may be more effective.

Petal infestation levels (coupled with weather variables) provided the strongest linear relationship to disease incidence (R_2 = 86%) and severity (R_2 = 87%) during early-mid flowering, when fungicide application decisions are made. However, the strength of the relationship varied during the flowering period. The airborne spore traps did not show as strong of a relationship to stem rot levels as the petal tests, with the Commercial passive spore trap accounting for 48% and 40% of the variation in disease incidence and severity, respectively, and the rotorod accounting for 52% and 50% of the variation. Significance testing of petal, Commercial passive spore trap and rotorod samples taken from five different locations within a field did not show different population means, suggesting that one sample per field may be sufficient for monitoring purposes; however, more testing is required, especially across fields of different sizes. Overall, the M.Sc. project results suggest that only one spore sampler may be required to provide a reasonable estimation of aerial ascospore levels and the potential risk of stem rot of canola. Concerns regarding variability of results are inherently less of a concern for petal testing, given that petal samples are typically collected throughout the field. For spore traps such as the Commercial passive spore trap, a single trap is likely sufficient, while also limiting cost, although locating the trap in the centre of a field may provide better exposure to inoculum from all areas of the field. Alternatively, if field site access and time are concerns, one could look at locating the trap in a downwind area of the field, depending on prevailing wind directions. In this study, there was variability in stem rot severity among locations within the fields in both years, while differences in disease incidence were only significant in 2019. It is important to note that factors other than inoculum load, including variable environmental conditions in the canopy, crop canopy density, lodging, etc., may affect final stem rot levels for different locations within a field. Nonetheless, disease levels were broadly similar across each field for the M.Sc. project in 2019 and 2020, and the canola crops would have likely benefited from fungicide application.

Overall, from the M.Sc. study, quantification of *S. sclerotiorum* DNA on petal and rotorod samples by quantitative PCR indicated that $1.0 \times 10_{-4}$ ng DNA per canola petal or per cubic meter of air per hour during early flowering would result in a disease incidence >15%, the level at which fungicide application is generally recommended. Given the wide range of variables affecting Sclerotinia stem rot development, an integrated disease forecasting approach, which includes monitoring of ambient weather conditions and an inoculum detection method, should be employed to determine the optimal timing of fungicide applications.

General conclusions from the fungicide timing study and the M.Sc. project

Overall, the results of this study highlight the need for an integrated forecasting system to generate the most accurate stem rot predictions. As others have found (Turkington 1991; Young et al. 2020), the

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most precise stem rot forecasts occurred when there was no risk of disease due to a lack of inoculum, as determined by petal infestation levels or airborne ascospores, coupled with unfavourable weather conditions. Much like what was proposed by Bom and Boland (2000), a stepwise sampling technique can be employed if conditions are favorable and there has been some indication that airborne ascospore pressure is present. For example, if there is a significant history of Sclerotinia stem rot in a particular field, or spore traps give a positive result (a Commercial passive spore trap result of at least "detected" or a rotorod sampler result of $\geq 1.0 \times 10^{-4}$ ng DNA/m^3 air/h), then a petal test or further spore trapping tests during flowering could be used to confirm if inoculum is sufficiently high to result in a DI >10-20%, while also providing guidance in terms of fungicide need either via single or dual applications from early to full bloom. Specific fungicide application decisions could then be made depending on commodity price and overall yield potential. The current results suggest that stem rot risk and the potential need for fungicide are elevated at an infestation level of $\geq 1.0 \times 10^{-4}$ ng DNA/petal, >30-45% petal infestation or $\geq 1.0 \times 10^{-4}$ ng DNA/m^3 air/h during flowering, a high average canopy RH (>80%). This was best demonstrated in all commercial fields in 2019 and 2020 as part of the M.Sc. project (McBain 2022) and the fungicide sites in 2019 at Beaverlodge, AB. In general, the fungicide trials sites in 2019, 2021 and 2022 did not have the combination of moderate to high inoculum loads and RH levels above 80% during flowering.

The advent of DNA-based testing technologies, improved pathogen identification and rapid results can greatly enhance our ability to assess *S. sclerotiorum* inoculum loads and stem rot risk in canola in a timely fashion (Ziesman 2016; Ziesman et al. 2016). Nonetheless, while existing tests for the occurrence and severity of stem rot can provide an indication of risk, further refinements in testing procedures may improve forecasts. Overall, at a particular point in time, inoculum load assessments synthesize the favourability of the weather (for inoculum production) and the potential for the stem rot pathogen to be present in sufficient quantities. This latter aspect is in relation to sclerotial load in the field and adjacent fields and the extent of sclerotial germination and apothecia production. Ultimately, measures of pathogen (ascospore) inoculum level, while important, need to be considered along with environmental conditions, especially RH levels in the canopy. It is recognized that measuring RH in commercial fields may represent an added cost and hassle; however, RH data from weather networks could be used to estimate canopy RH levels which based on the M.Sc. project (McBain 2022) are 3 to 13 % above ambient RH. It will also be important to also account for field and disease history (e.g., presence of apothecia and/or of moderate to high levels of stem rot in previous crops or adjacent fields). An integrated forecasting system, which considers all components of the disease triangle, will be most effective for predicting Sclerotinia stem rot of canola as well as other diseases.

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