PROJECT DETAILS

- **Funders:** Agriculture and Agri-Food Canada, Canola Council of Canada, Alberta Canola, SaskCanola and Manitoba Canola Growers
- **Research program:** Growing Forward 2
- **Principal investigator:** Rishi Burlakoti
- **Collaborators/additional investigators:** Andy Nadler, Paul Bullock, Kelly Turkington, Aston Chipanshi and Nathaniel Newlands
- **Year completed:** 2018

Supplementary Document for Operational models to forecast canola growth stage, Sclerotinia risk, and yield in Western Canada (2013 to 2017)

SUMMARY

2013/14

The aim of this study is to develop models for forecasting i) canola growth stage, ii) sclerotinia stem rot risk and iii) canola yield. These models will be operational and made available to growers and industry on a near real-time basis so that they can be used as decision support tools, thus benefiting growers through improved environmental stewardship, agronomic management, risk management, and profitability. To achieve these objectives, field experiments will be conducted in all the three Canadian Prairie provinces in collaboration with other stake holders including the Canola Council of Canada, the University of Manitoba and AAFC. In addition, the study will utilise available data from other resources such as Sclerotinia stem rot data from the Canada Disease Survey (CDS) and canola yield data from the Canola Performance Trial (CPT).

Due to the late (February 2014) approval of the project, no field activities were undertaken during the 2013 growing season. Nonetheless, a significant amount of work has already been undertaken and preparations for the 2014 growing season are at an advanced stage. Following are some notable achievements so far: i) networking and recruitment of collaborators (government, university, private sector and individual farmers); ii) a comprehensive literature review has been undertaken and will continue to be updated as new research is being published; iii) research protocols have been developed and sent to collaborators; iv) requests for the Canada Disease Survey (CDS) data have been sent to all three provinces (Manitoba has already provided the data); v) seven field sites to be used for the study have been secured in Manitoba, negotiations for more field sites are ongoing; vi) a Research Coordinator has been hired (vii) significant progress is being made in developing a canola web platform for collecting field data and delivering an integrated decision support tool.

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In addition, we are also anticipating that Dr. Lone Buchwaldt's (AAFC, Saskatoon) research work for predicting spore germination and Dr. Aston Chipanshi and other collaborators` work will be supplementary to develop the integrated crop management tools.

2014/15

In order to maximise canola production and profits, growers need to closely monitor the conditions in their crops. Current varieties have the genetic potential to produce a much higher than average yield but their full potential will not be realised unless each field is properly managed. With increasing farm size, any tools that can assist with up-to-minute knowledge of canola growth and condition can represent significant value to producers and the industry as a whole. Weather Innovations Consulting (WIN), together with collaborators is conducting research to develop and implement weather-based decision support tools (models) for canola to benefit Western Canadian canola producers through improved environmental stewardship, agronomic management, risk management and profitability.

The aim of this four-year study is to develop models for forecasting:

i) Canola growth (phenological) stage,
ii) Sclerotinia risk to aid producers with fungicide treatment decisions and
iii) Canola yield.

2015/16

The major objectives of the project were to develop and deploy forecasting tools for canola growth stages, sclerotinia stem rot risk and canola yield. To achieve the objectives, field trials were conducted in 11 locations in Manitoba during the 2014 and 2015 growing seasons. In addition, field trials were conducted in 2 locations in Saskatchewan and 3 locations in Alberta in 2015. Field trials were conducted in collaboration with the University of Manitoba and Agriculture and Agri-Food Canada (AAFC) as well as private industry partners including Bayer Crop Science, DL Seeds and canola farmers in Manitoba; Conservation Learning Centre and Indian Head Agricultural Research Foundation (IHARF) in Saskatchewan; and Battle River Research Group (BRRG) in Alberta. In both years, trials included small plot trials and field-scale trials. Small plot trials were conducted in 3 locations while field scale trials were conducted in 8 locations in both years. All 5 field trials in Saskatchewan and Alberta were small plot trials. Each small plot trial had three varieties (representing short-, medium- and long-season cultivar groups) with four replications. The field-scale trials had one cultivar with four replicates within a large field. In all locations, canola growth stages were recorded using time-lapse cameras and also observed manually once a week. On-site, in-canopy and outside-canopy weather conditions

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were monitored during the entire growing season. In 3 locations in Manitoba, Sclerotia depots (from Dr. Lone Buchwaldt) were deployed and Sclerotia germination (Apothecia) was counted. Sclerotinia stem rot (SSR) was recorded 2-3 times after crop maturity before swathing. Canola yield was obtained at maturity.

Canola growth stages extracted from the pictures taken by automated time lapse cameras and manual observations were used to compare specific growth stages (BBCH 9 to 89) with accumulated growing degree day (GDD), physiological days (P-days), and crop heat units (CHU). We compared accumulated heat units from the three thermal models required for 14 selected crop stages from emergence (BBCH 9) to ripe (BBCH 89). Among the three thermal models, accumulated p-days had less coefficient of variation (CV) and standard error, therefore, we selected accumulated P-days threshold to predict the growth stages. The growth stages prediction thresholds for short-, mid-, and long-season cultivars were also compared and we found differences among cultivar groups i.e., each cultivar group required different accumulated P-days for corresponding growth stages.

Using knowledge on the Sclerotinia biology and disease cycle as well as SSR checklists previously developed, a SSR score card has been developed. The score card has both weather and agronomic variables as input variables. The score card was validated using two year field data from all the locations. The SSR model will be refined using field data to be collected during the 2016 and 2017 cropping seasons. We are also currently analyzing 5-year (2009 to 2014) provincial Sclerotinia survey data obtained from MAFRD to understand the relationship between weather variables and SSR incidence. For the yield forecasting model, we will provide growth stage prediction models to Dr. Aston Chipanshi (AAFC, Regina) to improve the yield forecasting models that are being developed by AAFC. Also, the yield data from our trials will be shared with AAFC to refine the yield models that are already in development. We will also closely work with AAFC scientists to refine the yield model and help with its deployment.

Based on the outcome of the 2014 and 2015 trials, the prototype of the growth stage prediction tool and Sclerotinia risk calculation index will be deployed at http://canoladst.ca for 2016 field season in Manitoba, Saskatchewan, and Alberta. Both growth stage prediction and Sclerotinia risk calculation tools will be refined using field data to be collected during the 2016 and 2017 cropping seasons.

2016/17

The major objectives of this project were to develop and deploy forecasting tools for canola growth stages, sclerotinia stem rot risk and canola yield. During the 2016 cropping season, canola trials were conducted in Manitoba, Saskatchewan and Alberta in collaboration with industry and the University of Manitoba. The small-

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plot trials were conducted in collaboration with DL Seeds in Manitoba, Indian Head Agricultural Research Foundation (IHARF) in Saskatchewan and Battle River Research Group (BRRG) in Alberta. In total there were 15 trials consisting of eight (8) small-plot trials in; Holland, Portage la Prairie North, Pilot Mound, Elm Creek and Kelburn Farm in Manitoba, Indian Head in Saskatchewan and Forestburg and Castor in Alberta and seven (7) field-scale trials in Balmoral, Brunkild, Headingley, Portage la Prairie South, Netley Colony, Glenlea and La Rivière in Manitoba. The majority of the trials were conducted in Manitoba, where a summer student was employed to help with data collection.

In all three years 2014, 2015 and 2016, trials included small plot trials and field-scale trials. Each small plot trial had three varieties (representing short-, medium- and long-season cultivar groups) with four replications. The field-scale trials had one cultivar with four replicates within a large field. In all locations, canola growth stages were recorded using time-lapse cameras and also observed manually once a week. On-site, in-canopy and outside-canopy weather conditions were monitored during the entire growing season. In one location in Manitoba, sclerotia depots were deployed and sclerotia germination (Apothecia) was counted. Sclerotinia stem rot (SSR) was recorded 2-3 times after crop maturity before swathing. Canola yield was obtained at maturity.

Canola growth stages extracted from the pictures taken by automated time lapse cameras and manual observations were used to compare specific growth stages (BBCH 9 to 89) with accumulated growing degree day (GDD), physiological days (P-days), and crop heat units (CHU). We compared accumulated heat units from the three thermal models required for 14 selected crop stages from emergence (BBCH 9) to ripe (BBCH 89). Among the three thermal models, we selected accumulated P-days threshold to predict the growth stages. The growth stages prediction thresholds for short, mid, and long season cultivars were also compared and we found differences among cultivar groups i.e., each cultivar group required different accumulated P-days for corresponding growth stages.

Using knowledge on the sclerotinia biology and disease cycle as well as SSR checklists previously developed, a SSR score card has been developed. The score card has both weather and agronomic variables as input variables. The score card was validated using three year field data from all the locations. The SSR model will be refined using field data to be collected during the 2017 cropping seasons. For the yield forecasting model, we will provide growth stage prediction models to Dr. Aston Chipanshi (AAFC, Regina) to improve the yield forecasting models that are being developed by AAFC. Also, the yield data from our trials will be shared with AAFC to refine the yield models that are already in development. We will also closely work with AAFC scientists to refine the yield model and help with its deployment.

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The system of ongoing communication with canola producers at the end of this project is a critical task. It is important to have two way communications with individual producers and crop advisors. The inbound communication, where producers provide input on their individual observations and experience must be extremely easy and efficient for producers to use. To this end, our approach is to piggyback other data collection systems instead of creating a new reporting task for producers. Outbound communication will be direct for anyone who provides in season data and/or requests, as well as generally in the usual extension channels. These communication tools will be tested in 2017.

2017/18

The major objectives of this project were to develop and deploy forecasting tools for canola growth stages, sclerotinia stem rot risk and canola yield. During the 2017 cropping season, canola trials were conducted in Manitoba in collaboration with industry and the University of Manitoba. The small-plot trials were conducted in collaboration with DL Seeds and Kelburn Farm in collaboration with Richardson International while the field scale trials were conducted in collaboration with Bayer Crop Science. In total there were 13 trials consisting of six small-plot trials and seven field-scale trials. A summer student was employed at the end of May 2017 to help with data collection.

In all four years 2014, 2015, 2016 and 2017 trials included small plot trials and field-scale trials. Each small plot trial had three varieties (representing short-, medium- and long-season cultivar groups) with four replications. The field-scale trials had one cultivar with four replicates within a large field. In all locations, canola growth stages were recorded using time-lapse cameras and also observed manually once a week. On-site, in-canopy and outside-canopy weather conditions were monitored during the entire growing season. In one location in Manitoba, sclerotia depots were deployed and sclerotia germination (Apothecia) was counted. Sclerotinia stem rot (SSR) was recorded 2-3 times after crop maturity before swathing and canola yield was obtained at maturity.

Canola growth stages extracted from the pictures taken by automated time lapse cameras and manual observations were used to compare specific growth stages (BBCH 9 to 89) with accumulated growing degree day (GDD), physiological days (P-days), and crop heat units (CHU). We compared accumulated heat units from the three thermal models required for 14 selected crop stages from emergence (BBCH 9) to ripe (BBCH 89). Among the three thermal models, we selected accumulated P-days threshold to predict the growth stages. The growth stages prediction thresholds for short, mid, and long season cultivars were also compared and we found differences among cultivar groups i.e., each cultivar group required different accumulated P-days for

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corresponding growth stages.

Using knowledge on the sclerotinia biology and disease cycle as well as SSR checklists previously developed, a SSR score card was developed. The score card has both weather and agronomic variables as input variables. The score card was validated using three year field data from all the locations.

The system of ongoing communication with canola producers at the end of this project is a critical task. It is important to have two way communications with individual producers and crop advisors. The inbound communication, where producers provide input on their individual observations and experience must be extremely easy and efficient for producers to use. To this end, our approach is to piggyback other data collection systems instead of creating a new reporting task for producers. Outbound communication will be direct for anyone who provides in season data and/or requests, as well as generally in the usual extension channels.

OBJECTIVES AND OUTCOMES

2013/14

Canola growers in western Canada are facing several production challenges and having access to proper crop management tools will help them to minimise the production constraints and maximise crop yield. With increasing farm size, any tools that can assist with up-to-the-minute knowledge of canola growth and condition can represent significant value to producers and the industry as a whole. Many critical crop management decisions are highly dependent on crop stage. For example, the optimum stage to swath canola is up to an average of 60% seed colour change on the main stem. Delaying canola swathing up to this stage can typically improve yield and quality through increased seed size, reduced green seed and higher oil content but largely avoid shattering losses prior to or during swathing. Sclerotinia stem rot is one of the most devastating diseases of canola and the disease risks are driven by weather conditions and agronomic practices. To control Sclerotinia stem rot (SSR) effectively, fungicides have to be applied at the 20% to 30% bloom stage, before symptoms of the disease are visible. Currently, no reliable operational forecasting tools for crop growth stages, Sclerotinia stem rot risk, or yield are available in western Canada.

The objectives of this project therefore are to develop: i) a canola phenology model to forecast key development stages of the crop; ii) a weather-based sclerotinia stem rot (SSR) risk model to help producers with fungicide treatment decisions; and iii) a yield model to forecast canola production at local and regional scales. To achieve these objectives field studies will be conducted in all three provinces of the Canadian Prairies in collaboration with other stakeholders. Additionally, data from existing sources such as the Canada Disease

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Survey (CDS) and Canola Performance Trials (CPT) will be used.

Approaches/Methodologies and Achievements

Due to the late (February 2014) approval of the project, no field work was conducted in the 2013 crop growing season; however, significant progress has been made in preparation for the 2014 growing season. Detailed approaches and achievements are highlighted below.

- Literature review on SSR, phenology and yield modelling: A comprehensive literature review has been undertaken and knowledge from the literature review has been utilised to develop protocols for field trials and conceptual frame work for model development.
- Mining existing data: Canada Disease Survey (CDS) data to be used in developing a model for forecasting sclerotinia have been secured from Manitoba Agriculture and Rural Development (MAFRD). Requests for the same CDS data were sent to Alberta and Saskatchewan; we are yet to receive these data. Efforts are being made for networking with other partners and collaborators to access more data on Sclerotinia stem rot, yield and phenology. Yield data of the past few years will be obtained from Canola Performance Trials to develop a yield model.
- Database management, model programming, web development, web delivery: The web platform (www.canoladst.com) is being developed (Appendix 1). This web platform will be used to locate the field trial sites, plan field activities, and track field data. Weather and agronomic data will be managed in the web system. In the webpage, the predicted date of major growth stages (based on available literature) and their corresponding pictures will be available for the 2014 season; improvements will be made based on collected data and model refinements. A prototype of sclerotinia risk model will be available for the 2015 growing season.

Research & field activity coordination for 2014

- A Research Coordinator (Dr. Manasah Mkhabela) for the project has been recruited.
- Networking and preparation for field trials:
- Several meetings have been held with potential collaborators including Agriculture and Agri-Food Canada (AAFC), Canola Performance Trial (CPT) coordinators, provincial agriculture departments, University of Manitoba, DL Seeds, Bayer CropScience, and Kelburn Farm (owned by Richardson). Most of these organisations have agreed to collaborate and share resources and expertise with WIN. For example, DL Seeds will provide 3 field sites; they will seed and manage the sites in exchange for weather data; AAFC will share some field sites and summer staff resources. Kelburn Farm will be providing WIN with one site, which they (Kelburn Farm) will seed and manage. The University of

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Manitoba has contributed 38 micro-weather stations and also provided an office for the Project Coordinator. This kind of arrangement will reduce costs and also avoid duplication of work.

- To date, 7 sites (locations) that will be used for the field study have been secured in Manitoba (see attached map). There is a high probability that the number of sites may increase, negotiations are still ongoing with other potential collaborators.
- Most of the required field equipment has been purchased including time lapse cameras, laptop computers, and weather monitoring equipment.
- Research protocols have been developed and sent to collaborators. These protocols detail the plot plans, equipment deployment and how/what data will be collected.

For yield modelling, yield data from canola performance trials (CPT) from all three provinces will be used. To collect weather data we will utilise WeatherFarm and Weather INnovations' weather network. Additional collaborations with AAFC researchers (Dr. Aston Chipanshi and others) will work towards integrating their research work to develop the yield model.

2014/15

During the 2014 cropping season a total of 13 trials were conducted at various sites in Manitoba. The trials comprised of *small-plot*, *field-scale* and *farmers-field trials*. Small-plot trials were conducted in Holland, Portage la Prairie and Kelburn Farm. The Holland and Portage la Prairie sites were established and maintained by DL Seeds, while the Kelburn Farm trials were established and maintained by Richardson International. At each of these sites three varieties representing short-, medium- and long-season cultivars were grown. The short-, medium- and long-season varieties were Monsanto 73-15, Monsanto 73-75 and DL Seeds 60-60, respectively. Plot establishment, maintenance and harvesting were done in accordance with the collaborators standard practise and using their normal equipment.

At each site, there were 12 small plots in total (i.e., 4 replicates x 3 varieties) laid out in a randomised complete block (RCB) design and separated by a 2-3m buffer (Figure 1). The plot layout and randomisation was similar for all the three sites. Plots in Holland and Portage la Prairie measured 7m x 1.4m, while at Kelburn Farm they measured 8m x 1.3m. The plot width was determined by the collaborators seeding equipment. All 12 plots at each site were seeded on the same day; the target seeding rate at all sites was 5.5 lbs./ac. Fertilizer rates and herbicides were determined by the collaborator. No fungicides were applied at all three small-plot sites.

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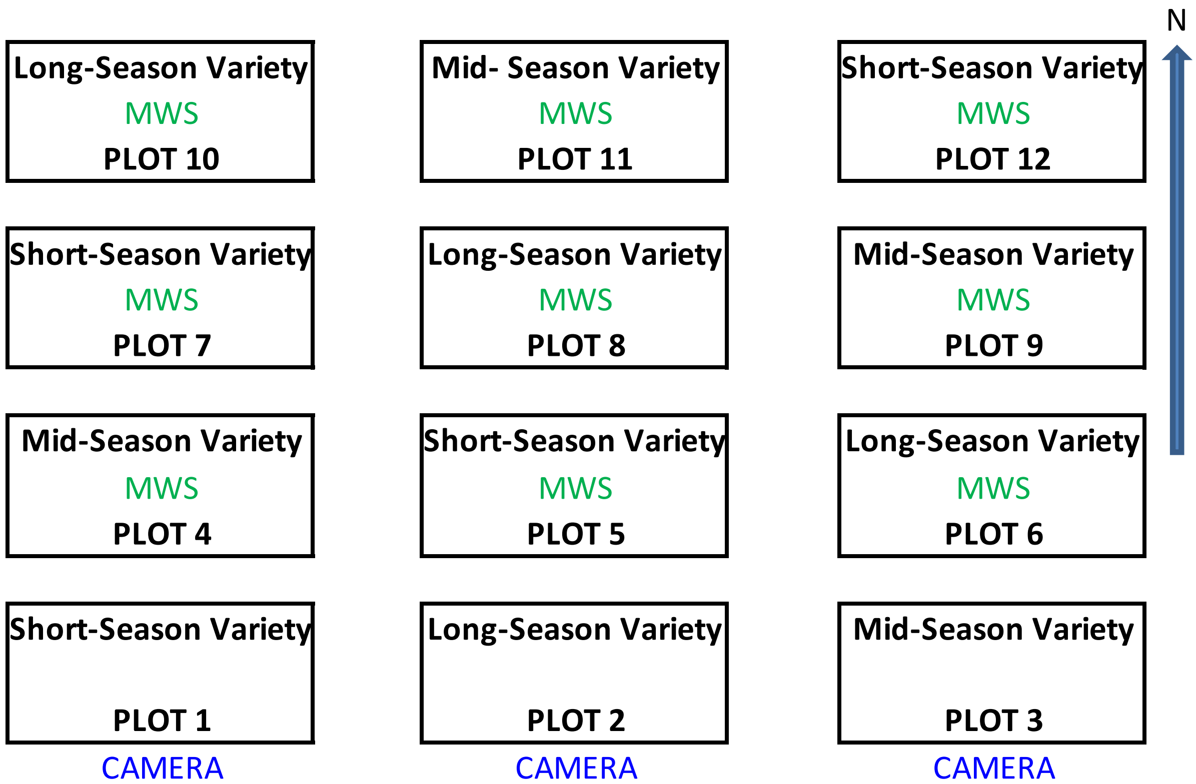

Figure 1: General plot plan: - randomised complete block (RCB) design, with 3 varieties and 4 replications. Plot sizes were 7m x 1.4m in Holland and Portage la Prairie, and 8m x 1.3m at Kelburn Farm.

The field-scale trials were conducted in Pilot Mound and Oak Bluff in collaboration with Bayer CropScience and in Carman in collaboration with the University of Manitoba, Ian N. Morrison Research Farm. Meanwhile, the farmers-field trials were conducted in Haywood, Carman and Beausejour in collaboration with different producers. There were two fields in both Haywood and Beausejour.

In an already established/planted canola field, 4 small plots were demarcated. Each of these plots represented a replication (i.e., there were 4 replications x 1 cultivar). The plots measured 6m x 2m and separated by a 1m buffer (Figure 2). Similar to the small-plot trials, seeding, field maintenance and harvesting were done in accordance with the collaborators standard practise and using their normal equipment. Fertilizer rates, seeding rates and herbicides were determined by the collaborator.

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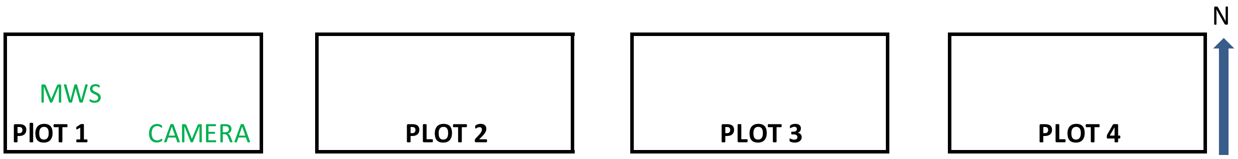

Figure 2: General plot plan for the field-scale and farmers-field trials showing the positions of the HOBO micro-weather station (MWS) and the camera in plot 1. Plot sizes were 6m x 2m at all locations.

Canola Phenological Observations

At the southern edge of plots 1, 2 and 3 (in Portage la Prairie and Kelburn Farm), plots 10, 11 and 12 (in Holland) weather proof time-lapse digital cameras (i.e., 1 outside each plot) were installed as soon as possible following seeding (Figure 1). However, in the field-scale and farmers-field trials, a camera was position inside the plot but on the southern edge as shown in Figure 2. The mount (mast) was always located on the south side of the plot. The cameras were mounted at 50 cm height (above ground) facing north and oriented at 45° from horizontal. The camera position (height) was adjusted upwards in response to plant growth. The cameras were programmed to photograph the same footprint (a portion of the plot) 5 times per day (i.e., 6 am, 9 am, 12 noon, 3 pm and 6 pm) throughout the growing season. Pictures from the cameras were used to determine the exact occurrence date of each crop phenological stage at each location.

Physical canola growth stages were recorded in the plots where there was no camera, i.e., plots 4 to 12 in the small-plot trial (plots 1 to 9 in Holland) and plots 2 to 4 in the field-scale and farmers-field trials. After seeding, a metre stick was used to delineate 1 metre section in 2 randomly selected rows and pin flags were used to mark either end. During weeks 1, 2 and 3, plant counts were taken on the marked metre rows and recorded. The plant counts were the number of plants that had emerged between the pin flags on each date of the count. At this time, the *Principal Growth Stage* for each count location was determined using the BBCH-scale.

Canola growth stage (phenological) observations were done once a week, however, it was very difficult to maintain the exact schedule due to unforeseen circumstances e.g., weather conditions. Ten (10) plants (5 from one row and 5 from another row) were randomly selected from the 2 rows marked for plant count. A plastic ring (zip tie) was placed around each plant for easy identification later on. These 10 plants were used for phenological recording during the growing season. In case a plant died, it was replaced with another that was as close as possible in growth stage to the one that died. Average phenological stage was derived by taking an average of all 10 plants. Later on in the season, it became very difficult to identify the selected 10 plants (plants became too bushy), thus average phenological development stages were recorded for each plot. The plant counts and phenological observations were recorded in a prior designed form. After recording the phenological stage, photographs of the plants and the plots in general were taken to capture as much detail of the phenological development as possible. A high resolution camera was used for this purpose.

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Sclerotinia stem rot incidence observations

Sclerotinia stem rot (SSR) disease incidence was determined after fruit development (BBCH 80 to 87) before swathing. The SSR determination was similar for the small-plots and field-scale plots. SSR incidence was recorded in the plots without cameras (i.e., plots 4 to 12 or 1 to 9 in the small-plot trials and 2, 3 and 4 in the field-scale trials). However, in the field-scale trials there were 2 sites where SSR incidence was also determined in plot 1 albeit, away from the camera foot-print. At all sites except at Haywood 2, in each plot (replication) 3 x 1m rows were measured and the total number of plants in each row was counted. Thereafter, the number of diseased (infected) plants was counted in each row and the disease severity was estimated. The severity ratings ranged from 0-5, with zero being no symptoms and 5 being the most severe. At Haywood 2 the field was broadcast-seeded, thus there were no rows. At this site, in each replication 3 x (0.5m x 0.5m) plots were measured and the total number of plants in each 0.25 m^2 plot was counted, and thereafter the number of diseased plants was counted and severity estimated. The rows/areas where SSR incidence was monitored were randomly selected. The % SSR incidence was calculated by dividing the total number of diseased (infected) plants by the total number of plants in all three rows (or three 0.25 m^2 plots in case of Haywood 2) and then multiplying by 100. The total number of SSR observations at each site ranged from 1 to 3. At the sites where 3 observations were recorded, the observations were recorded once a week.

Sclerotia depots

During the 2014 cropping season 10 sclerotia depots we received from Agriculture and Agri-Food Canada (AAFC) in Saskatchewan; three of these depots were buried in Holland (small-plot trials), another three in Portage la Prairie, another three at Kelburn Farm and one at the University of Manitoba, Ian N. Morrison Research Farm in Carman. The sclerotia depots were buried when the canola crop was at the 5-6 leaf stage (Figure 3). A hole about 5cm deep and big enough to hold the depot was dug between rows in plots 1, 2, and 3 (small-plot trials) and plot 1 (field-scale trial), however, away from the camera footprint. The depots were monitored weekly for apothecia germination.

Figure 3: Sclerotia depots buried between rows of canola at Kelburn Farm

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Yield observations

At all the sites canola harvesting/combining was done by the collaborator/producer using their own equipment. The only exception was at Kelburn Farm where it was done by a WIN staff using the collaborators equipment. In the small-plot trials, each plot was harvested and the grain weight and moisture content were recorded. Thus, the grain weight recorded was for the whole plot (i.e., 9.8 m^2 in Holland and Portage la Prairie and 10.4 m^2 at Kelburn Farm). At all the small-plot sites a desiccant was applied to the canola to enhance drying and then straight-combined. The yield for the field-scale trials and farmers-field trials was an average of the whole field (i.e., where WIN plots were located) and was supplied by the collaborator. However, at the University of Manitoba, Ian N. Morrison Research Farm the yield was an average of the whole farm.

Weather data recording

In the small-plot trials, HOBO micro-weather station (MWS) were installed (1 in each plot) in the middle of plots 4 to 12 (Figure 1) to record in-canopy micro-climate. In Holland however, the MWS were installed in plots 1 to 9. In both the field-scale and farmers-field trials, the MWS were installed slightly off the middle of the plot, so that it did not interfere with the camera footprint (Figure 2), since both (MWS and camera) were installed in the same plot. Weather parameters collected inside the canopy included air temperature, relative humidity (RH), leaf wetness (LW), soil temperature and soil moisture both at 2.5 cm depth. The RH and air temperature sensors were housed in a Stevenson screen and mounted at 30 cm above ground. The leaf wetness sensor was installed at 30 cm above ground facing north and oriented at 45° from horizontal. The positions of these sensors were not adjusted as the canola grew. For the measurement of soil temperature and soil moisture, a hand trowel was used to expose a shallow vertical profile and a tape measure was used to determine the 2.5 cm depth below the surface. At this depth the soil temperature thermocouples and the ECHO soil moisture probes were installed horizontally. Generally, the ECHO probes do not require any site specific calibration, thus, no calibration was done. At Kelburn Farm, Holland, Portage la Prairie and Beausejour 1 additional MWS were installed outside the plots/field to record outside-canopy weather, with the sensors in similar height/depth as those inside the canopy. In addition, at some sites (i.e., Holland, Portage la Prairie, Beausejour 2) ADCON automatic weather stations were installed outside the plots/fields to record air temperature, RH, LW and rainfall. At Haywood 1, Beausejour 1 and Oak Bluff sites Spectrum tipping-bucket rain gauges were installed to record rainfall. The HOBOs were run in the laboratory for at least a month before deployment in the field. Similarly, the tipping-bucket rain gauges were calibrated before deployment.

Results and discussion

Weather Data Analysis

In-canopy micro-weather conditions were similar i.e., there was no significant difference ($p>0.05$) in the prevailing *in-canopy* micro weather conditions among the cultivars at both sites for the combined data (whole season) and also for the months (June, July and August) separately (Table 1). The only exception was soil moisture and soil temperature, which were both significantly different ($p<0.05$) among the cultivars (Table 1). At Kelburn, soil moisture was significantly higher ($p<0.05$) in the short-season cultivar compared to the other

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cultivars, while the soil temperature was significantly lower ($p<0.05$) in the short-season cultivar (Table 1). This was probably caused by the negative relationship between soil moisture and soil temperature, i.e., generally a wet soil has lower temperature compared to a dry soil. At Portage la Prairie, soil moisture was significantly lower ($p<0.05$) in the short-season cultivar, while soil temperature was similar among the cultivars. The difference in soil moisture and soil temperature among the cultivars may have been caused by differences in sensor placement and also the fact that when the soil dries up some of the sensors may be in cracked soil zones, thus recording significantly different values compared to sensors in non-cracked soil zones. Overall, these results suggest that there is no need for installing in-canopy micro-weather stations in all plots at each site; three in-canopy micro-climate stations per site (one in each cultivar) would be adequate. Having three micro-weather stations would be helpful in case of a breakdown.

Table 1: ANOVA results for comparison of ***in-canopy*** micro-climate conditions among three canola cultivars (short-, medium- and long-season) at Potage la Prairie and Kelburn Farm during the 2014 cropping season.

Portage la Prairie				
	All Data Combined	June	July	August
Variable	**P-value**	**P-value**	**P-value**	**P-value**
Max Temp	0.670	0.989	0.754	0.736
Min Temp	0.688	0.740	0.919	0.985
Average Temp	0.672	0.824	0.818	0.880
Max RH	0.681	0.994	0.988	0.811
Min RH	0.748	0.905	0.673	0.847
Average RH	0.614	0.937	0.873	0.903
Average Soil Temp	0.160	0.469	0.257	0.889
Average SWC	**<0.001 (S)***	**<0.001 (S)***	**0.021 (S)***	0.102
Kelburn Farm				
Variable	**P-value**	**P-value**	**P-value**	**P-value**
Max Temp	0.755	0.993	0.457	0.871
Min Temp	0.879	0.999	0.762	0.981
Average Temp	0.783	0.997	0.543	0.975
Max RH	0.258	0.844	0.211	0.10
Min RH	0.536	0.991	0.130	0.852
Average RH	0.420	0.962	0.083	0.641
Average Soil Temp	0.031 (S)*	0.838	0.004 (S)*	0.565
Average SWC	<0.001 (S)*	<0.001 (S)*	<0.001 (S)*	<0.001 (S)*

*Significant at $p<0.05$

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In-canopy versus outside-canopy climate (Paired T-test)

In-canopy climate was significantly different (p<0.05) from the outside-canopy climate at both sites (Table 2). Generally, RH and minimum temperature were higher inside the canopy compared to outside the canopy, while maximum temperature was generally higher outside the canopy. However, during the month of June some of the weather variables measured were not significantly different (p>0.05); this was most likely due to the fact that in June the canopy was not fully developed. These results suggest that there is a need to measure climate both *inside* and *out-side* the canopy. This would help in developing a model to relate in-canopy and outside canopy climate.

Table 2: T-test result of the comparison of *in-canopy* versus *outside-canopy* micro-climate conditions at Potage la Prairie and Kelburn Farm during 2014 cropping season.

Portage la Prairie				
	All Data Combined	June	July	August
Variable	**P-value**	**P-value**	**P-value**	**P-value**
Max Temp	0.61 (NS)	0.02	0.05	0.56 (NS)
Min Temp	0.01	0.30 (NS)	0.26 (NS)	0.003
Average Temp	<0.001	0.02	<0.001	0.22 (NS)
Max RH	<0.001	0.04	<0.001	0.04
Min RH	<0.001	0.62	<0.001	<0.001
Average RH	<0.001	0.91 (NS)	<0.001	<0.001
Average Soil Temp	<0.001	0.04	<0.001	<0.001
Average SWC	<0.001	<0.001	<0.001	<0.001
Kelburn Farm				
Variable	**P-value**	**P-value**	**P-value**	**P-value**
Max Temp	<0.001	0.466 (NS)	0.01	<0.001
Min Temp	<0.001	0.145 (NS)	0.716 (NS)	<0.001
Average Temp	<0.001	0.10 (NS)	<0.001	<0.001
Max RH	0.003	0.003	<0.001	0.355 (NS)
Min RH	<0.001	0.011	<0.001	<0.001
Average RH	<0.001	<0.001	<0.001	<0.001
Average Soil Temp	<0.001	0.135 (NS)	<0.001	<0.001
Average SWC	<0.001	<0.001	0.69 (NS)	<0.001

NS= Not Significant at p<0.05

Paired T-test comparing ADCON/HOBO data to the nearest MAFRD weather station

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At Kelburn Farm, minimum and average temperatures were similar for the HOBO and the MAFRD (St. Adolphe) weather station; however, the maximum temperature for the HOBO was slightly higher than that for the MAFRID station. The difference may have been caused by the fact that the MAFRD station was about 500m away from the HOBO and also the fact that the HOBO sensors were mounted close to the ground at about 30cm above ground. Some of the sensors at the MAFRD station are as high as 10m above ground. The main reason for mounting the HOBO instruments a 30cm above ground was to be able to compare *in-canopy* to *outside-canopy* climate as already elaborated above. At Portage la Prairie, all the measured weather variables were significantly different (p<0.05) between the ADCON and the HOBO and also between the HOBO and the nearest MAFRD (Portage East) weather station.

Table 3: T-test results of the comparison of ADCON to HOBO, HOBO to MAFRD and ADCON to MAFRD weather stations at Potage la Prairie during 2014 cropping season.

	ADCON vs. HOBO	HOBO vs. MAFRD	ADCON vs. MAFRD
Variable	P-value	P-value	P-value
Max Temp	<0.001	<0.001	0.873 (NS)
Min Temp	0.018	0.566	0.835 (NS)
Average Temp	<0.001	<0.001	0.610 (NS)
Max RH	0.187	NA	NA
Min RH	<0.001	NA	NA
Average RH	<0.001	NA	NA

NS = Not Significant at p<0.05; NA = data not available for the MAFRD weather station

However, there was no significant difference (p>0.05) between the ADCON and the nearest MAFRD (Portage East) weather station (Table 3). Generally, the ADCON and the MAFRD (Portage East) weather station had lower values compared to the HOBO. This was most likely due to the height of the sensors. The HOBO sensors were mounted at about 30cm above ground, while the ADCON sensors were mounted at about 120 cm above ground. These results emphasise the importance of having a weather station at each experimental site. Data from these infield weather stations can then be used to develop models to relate infield weather data to a nearby weather station. This is important because the phenology, sclerotinia and yield models that are being developed will run on weather data from nearby stations.

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Canola Phenology Modelling

Understanding and predicting crop phenological development is fundamental to many aspects of crop production including optimising crop management practices such as fungicides, herbicide, pesticides and fertilizer applications. Thermal time units such as growing degree-days (GDD) are commonly used to assess the rate of plant growth and development as impacted by temperature and can be correlated to plant development. While GDDs are useful, their main failing is that they assume that plant response to temperature is linear with no maximum, and as a result, using GDDs tend to overestimate growth rate at both low and high temperatures, both of which are a common occurrence in Western Canada. The Physiological Day (P-Day) thermal time model with minimum, optimum and maximum temperatures of 5^oC, 17^oC and 30^oC, respectively, has been suggested as a better model for modelling canola development in western Canada. The objectives of this analysis therefore were to:

1. Evaluate the suitability/accuracy of the Growing Degree Days>5^0C (GDD_5) and the Physiological days utilising base, optimal, and upper temperature thresholds of 5, 17, and 30°C (Pdays 5,17,30) models to predict canola growth stages in Western Canada.
2. To compare accumulated GDD_5 and Pdays (5,17,30) values required by canola to reach different growth stages to those currently used for canola growth stage forecasting in Western Canada.

Methods

To evaluate the above objectives, GDD_5 and P-Days (5,17,30) were calculated and accumulated at each site over the growing season from seeding to physiological maturity (ripe), and there after the average of all the sites combined was calculated. Daily minimum and maximum temperature were used to calculate daily GDD/P-Days values. The average accumulated GDDs/Pdays required by canola to reach several growth stages (Table 1) were then compared to values from previous studies. Canola growth stages were identified from daily time-lapse photos and also weekly manually collected phenological data. The varieties from all the sites were then categorised into short-, medium and long-season and by date of planting and their GDD requirements were compared to see if varieties from the same category and relatively same planting date had similar total GDDs.

Results

There is no advantage of using Pdays over GDD for modelling canola growth stage; both models produce similar results. The average accumulated Pdays (5,17,30) required by canola to reach different growth stages observed by WIN are relatively similar to those observed by Dickson (2014), but slightly higher than those observed by Wilson (2002) (Table 1). However, there is a good agreement on the average Pdays required from planting to bolting and planting to end of flowering for all three studies. Overall, the Wilson study had lower total Pdays requirements from planting to maturity compared to both the WIN and Dickson studies. The Dickson Pdays are slightly higher than the WIN Pdays probably due to the fact that in all but one of the seven sites used by Dickson one canola variety (5020) was grown. Nonetheless, there is a good correlation between the WIN and Dickson and the WIN and Wilson Pdays with R^2 of 0.99 and 0.98, respectively (Figure 1).

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Table 1: Comparison of accumulated Pdays (5,17,30) required to reach several canola growth stages.

			Accumulated Pdays (5,17,30)		
Crop Stage	BBCH Scale	HB* Scale	WIN (all 2014 data)	Dickson (2009)	Wilson (2002)
Planting	00	0.0	0	0	0
Emergence	09	1.0	82	88	NR
First Leaf unfold	11	2.1	112	110	NR
Fourth Leaf unfold	14	2.4	204	215	NR
Bolting (Stem elongation)	30	3.1	297	300	299
Yellow Bud	59	3.3	333	NR	NR
Early Flowering	60	4.1	348	318	NR
30% Flowering	63	NI	393	NR	NR
Full Bloom (50% Flowering)	65	4.2	444	405	419
End of Flowering	69	4.4	493	479	479
Beginning of Ripening	81	5.2	695	735	583
Ripe	89	5.3	779	815	758

*HB scale was developed bb Harper and Berkenkamp (1975) and was used by Morrison et al. (1989), Wilson (2002) and Dickson (2014). NR= not recorded; NI= not identified

Meanwhile, the average total accumulated GDD_5 required by canola from planting to ripe observed by WIN are much higher than those currently used by both North Dakota Agricultural Weather Network (NDAWN) and Manitoba Agriculture, Food and Rural Development (MAFRD); but slightly higher than those observed by Morrison (Tables 2 and 3). The most likely reason for the difference is that the NDAWN, MAFRD and Morrison GDDs were derived from older canola cultivars, while the WIN GDDs are derived from current cultivars. It is well documented that current canola cultivars yield higher than older cultivars, which may be a result of the fact they take longer to reach maturity (i.e., longer-season varieties normally yield higher than shorter-season varieties). The GDD difference between WIN and Morrison from planting to ripe is about 50 GDDs. Assuming that on average 11 GDDs are recorded per day during the growing season, this indicates that compared to older cultivars current cultivars require an extra 4 to 5 days to reach maturity. Table 4 shows the revised GDD_5 requirements for several canola growth stages derived from the WIN data. Conversely, there is a good correlation between the WIN and Morrison GDD_5 with R^2 of 0.97; however, the correlation between the WIN and NDAWN/MAFRD GDD_5 is poorer with R^2 of 0.93. The GDD_5 requirements for the short-, medium- and long-season cultivars grown in Kelburn Farm and Portage la Prairie are highly correlated with R^2>0.98. However, total GDD requirements from planting to ripe for the short- and medium-season cultivars in Kelburn Farm are slightly higher (20-50 GDDs) than at Portage la Prairie, indicating that plant development is not only affected by temperature but also by other environmental and soil factors. Table 5 shows the GDD_5 requirements for the categorised cultivars: the short- and medium-season cultivars require similar total GDDs (1212) from planting

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to ripe. The total GDD requirements (planting to ripe) for the long-season cultivars are not available due to the fact that recording of growth stages stopped before the majority of the long-season cultivars reached the ripe stage. Unfortunately, there is not enough information to draw a valid conclusion. For instance, the number of cultivars in both the short- and medium-season categories is only two, while the long-season category has five cultivars.

Table 2: Comparison of average accumulated GDD_5 required by canola to reach several selected growth stages.

			Accumulated GDD_5		
Crop Stage	**BBCH Scale**	**HB* Scale**	**WIN 2014**	**Morrison 1989**	**NDAWN**
Planting	00	0.0	0	0	0
Emergence	09	1.0	115	98	0-142
First Leaf unfold	11	2.1	154	246	NR
Fourth Leaf unfold	14	2.4	286	374	221-404
Bolting (Stem elongation)	30	3.1	416	449	NR
Yellow Bud	59	3.3	478	531	NR
Early Flowering	60	4.1	500	576	519-647
30% Flowering	63	NR	576	NR	NR
Full Bloom (50% Flowering)	65	4.2	655	617	NR
End of Flowering	69	4.4	727	796	NR
Beginning of Ripening	81	5.2	1081	1004	777-908
Ripe	89	5.3	1207	1157	>1041

*HB scale was developed Harper and Berkenkamp (1975) and was used by Morrison et al. (1989), Wilson and Shaykewich (2002) and Dickson and Bullock (2014); NR= not recorded.

Table 3: GDD_5 and growth stages of canola used in the Sclerotinia Risk Forecast Program in Manitoba compared to GDD_5 observed by WIN in 2014 for the same growth stages.

Crop Stage	**GDD_5 MAFRD**	**GDD_5 WIN**
Planting to Seedling	0 – 142	0 – 154
Seedling to Rosette	142 – 221	154 – 286
Rosette to Budding	221 – 404	286 – 416
Budding to Flowering	404 – 518	416 – 500
Flowering to Ripening	518 – 776	500 – 1083
Ripening to Maturity	766 – 1041	1083 – 1207

Table 4: Revised GDD_5 required by canola to reach different phenological stages based on the data collected by WIN during the 2014 cropping season in Manitoba.

Crop Stage	GDD_5 all data used	GDD_5 Holland small-	GDD_5 Haywood 2	GDD_5 Holland small-plot

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		plot removed	removed	and Haywood 2 removed
Planting to Emergence	0-115	0-125	0-104	0-112
Emergence to Rosette	115-286	125-275	104-279	112-263
Rosette to Bud/Bolting	286-416	275-415	279-408	263-401
Bolting to Early Flowering	416-500	415-501	408-493	401-492
Early Flowering to Full Bloom	500-655	501-642	493-645	492-624
Full Bloom to End of Flowering	655-727	642-715	645-716	624-697
End of Flowering to Early Ripe	627-1081	715-1057	716-1069	697-1045
Early Ripe to Ripe	1081-1207	1057-1183	1069-1207	1045-1183

Table 5: GDD_5 requirements for the ***short-, medium- and long-season*** cultivars based on WIN data collected in 2014 in Manitoba.

		GDD_5 Requirements		
Crop Stage	**BBCH Scale**	**Short-season cultivars**	**Medium-season cultivars**	**Long-season cultivars**
Planting	00	0	0	0
Emergence	09	111	100	134
First Leaf unfold	11	149	143	172
Fourth Leaf unfold	14	272	272	305
Bolting (Stem elongation)	30	391	432	422
Yellow Bud	59	463	489	478
Early Flowering	60	478	504	506
30% Flowering	63	563	553	596
Full Bloom (50% Flowering)	65	618	654	675
End of Flowering	69	701	717	746
Beginning of Ripening	81	1051	1064	1110
Ripe	89	1212	1212	NR*

*NR = not recorded due to the fact that recording stopped before most of the cultivars reached the ripe stage.

The currently used GDD_5 values grossly underestimate the GDD requirements for canola, especially during the ripening period (i.e., from end of flowering to maturity). GDD requirement for the older and newer cultivars are

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generally similar from planting to flowering; however, the newer cultivars require much more heat units from flowering to maturity. Thus, there is clearly a need to refine/revise the currently used GDD models for canola phenological development in Western Canada and this study will help in that respect.

Sclerotinia Stem Rot (SSR) Modelling

Sclerotinia stem rot (SSR) data were collected from all the trial sites in Manitoba as described in the data collection section. These SSR data were compared to microclimate data collected at these sites during the growing season to establish if there is any relationship between SSR incidence and the microclimate. At some sites, sclerotia depots were buried and monitored for apothecia germination. In addition, SSR data collected in Manitoba for the Canada Disease Survey (CDS) programme for years 2009 to 2014 were analysed and maps showing SSR incidence were developed. SSR data from Saskatchewan and Alberta were not available.
At all the sites, there was no apothecia germination. This is in line with results from Saskatchewan where no apothecia germination was recorded at all sites studied. This was partly attributed to dry conditions during the canola flowering period.

Results of the Canada Disease Survey (CDS) in Manitoba from 2009 to 2014 are shown in Figure 1. The results show that the occurrence of sclerotinia is very variable. Overall, the highest SSR incidence was in 2010, when a lot of the surveyed fields recorded SRR incidence greater than 50%, particularly in south eastern and western Manitoba. The rest of the years had only a few fields where SSR incidence was greater than 50%. The lowest SSR incidence was recorded in 2014, when all fields surveyed had lower than 50% incidence. This is somehow contrary to the SSR incidence recorded by WIN in 2014 where some field recorded higher than 50% SSR incidence. Currently the CDS data have not yet been correlated with weather data. CDS data from Saskatchewan for the 2014 season have just been received and prior years are being processed.

The SSR incidences (%) recorded by WIN at all the sites in Manitoba in 2014 are shown in Table 1. The highest incidence was recorded in the small-plot trials both in Kelburn Farm and Portage la Prairie. At both sites, the short-season cultivar was the worst affected by sclerotinia, with the incidence as high as 73% at Kelburn Farm and 46% at Portage la Prairie. At the other sites, the SSR incidence was lower than 10%, except at Pilot Mound where it was ~12%. The low SSR incidence recorded by WIN (excluding Kelburn Farm and Portage la Prairie) is in line with the SSR results from the 2014 CDS for Manitoba (Figure 2). Interestingly, at Carman both WIN and CDS programme recorded around 10% SSR disease incidence and at Beausejour less than 5%.

There is no discernible relationship between the WIN SSR incidences and micro-climate conditions. Most likely this was caused by the dry conditions around flowering time and the inherent variability of sclerotinia. More details of this analysis are in a separate report (2014 Field Trials: Comparison of Weather Data and SSR Incidence).

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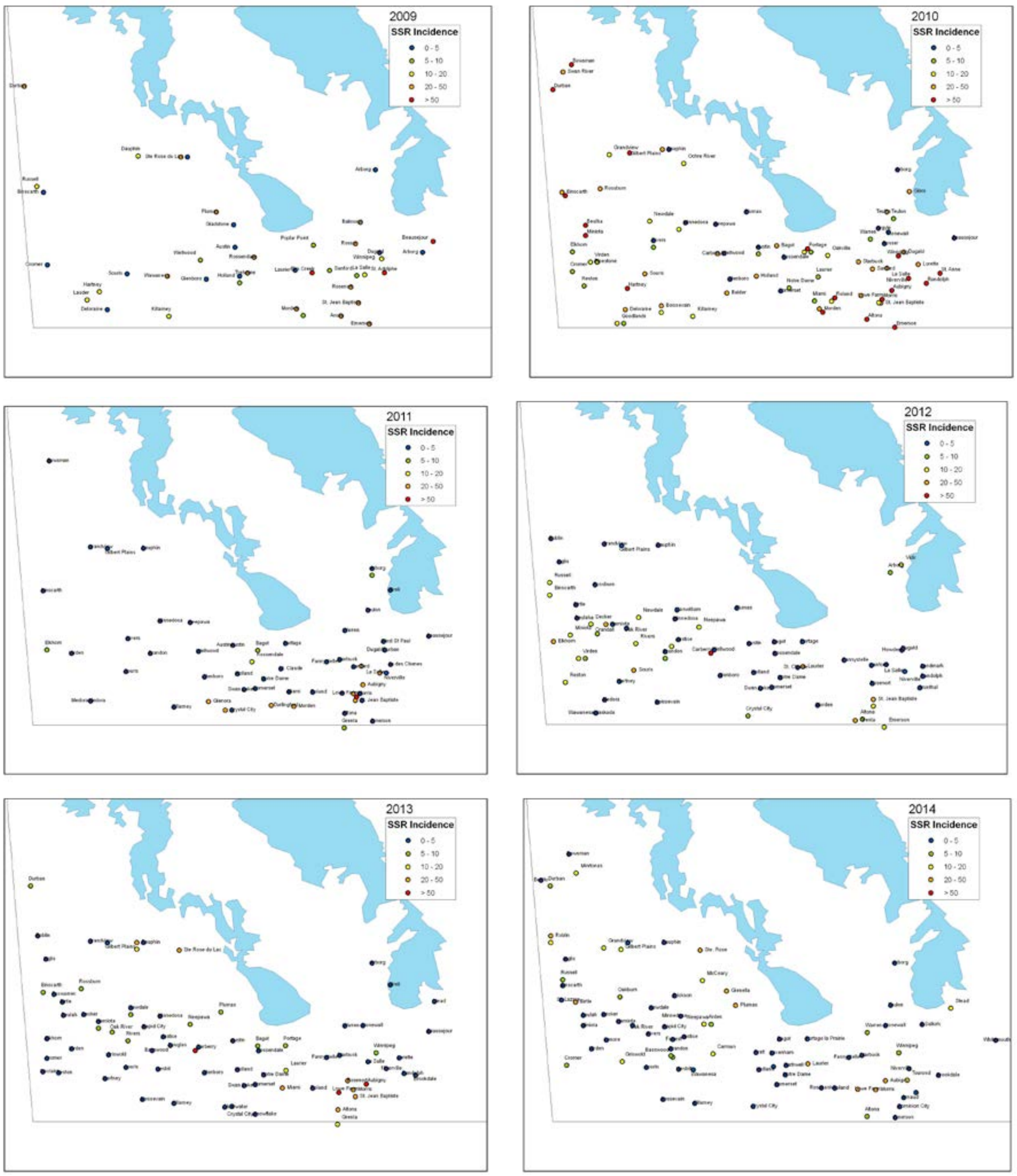

Figure 1: Sclerotinia Disease Survey in Manitoba from 2009 to 2014.

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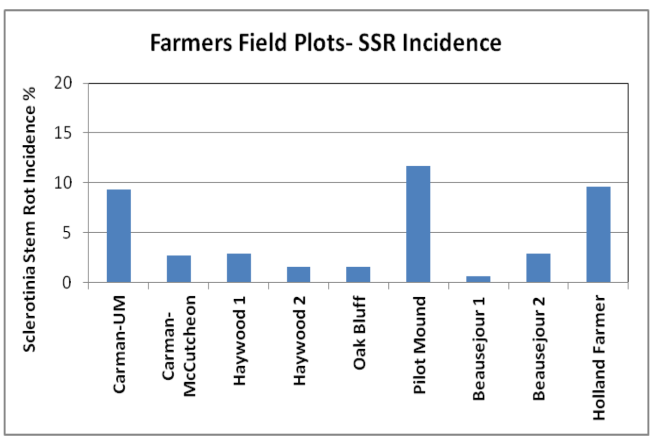
Table 1: Sclerotinia disease incidences (%) recorded by WIN at different sites in Manitoba during the 2014 cropping season.

Site	Cultivar	Disease Incidence (%)		
		Survey 1	*Survey 2*	*Survey 3*
Portage la Prairie	73-15 (Short-season)	22.4	44.5	NR
	73-75 (Medium-season)	3.1	33.5	NR
	60-60 (Long-season)	6.8	32.4	NR
Kelburn Farm	73-15 (Short-season)	34.1	50.4	72.5
	73-75 (Medium-season)	5.8	29.4	52.2
	60-60 (Long-season)	17.4	29.0	41.5
Holland	Monsanto 73-15 (Short-season)	6.0	NR	NR
	Monsanto 73-75 (Medium-season)	1.3	NR	NR
	DL Seeds 60-60 (Long-season)	7.7	NR	NR
Farmers-field	Cantera 1990 (Long-season)	9.6	NR	NR
Pilot Mound	InVigor 5440 (Medium-season)	1.8	11.7	NR
Oak Bluff	InVigor 5440 (Medium-season)	0.0	0.8	1.6
Carman (University of Manitoba Farm)	L5020 (Short-season)	9.3	NR	NR
Carman-Fertilised	Nexera 2016 (Long-season)	1.2	1.2	2.9
Carman-Unfertilised	Nexera 2016 (Long-season)	1.6	NR	NR
Haywood 1	Pioneer 45S54 (Long-season)	1.2	1.2	2.9
Haywood 2	Cantera 1990 (Long-season)	1.6	NR	NR
Beausejour 1	Liberty 5440 (Medium-season)	0.0	0.6	NR
Beausejour 2	Liberty 156 (Long-season)	0.0	2.9	NR



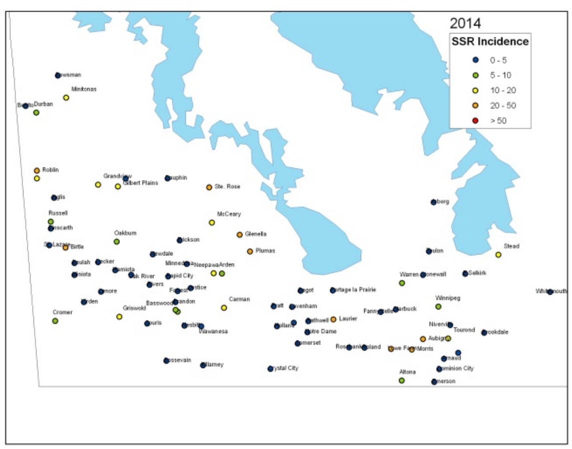


Figure 2: Comparison of SSR incidence (%) between WIN data (farmers-field) and Canada Disease Survey (CDS) data in Manitoba in 2014.

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2015/16

Introduction and Research Objectives

There is a strong association between Sclerotinia stem rot (SSR) incidence and prevailing weather conditions during and close to the canola flowering period. The success of developing a Sclerotinia stem rot forecasting system relies on the ability to precisely predict the canola flowering stage. In addition, there is a linkage between growth stages and insect damage on crops. For example, flea beetle cause severe damage during seedling stage, where as several insects, such as lygus bug, pod weevil make significant damage after flowering stages. Although studies have been conducted to understand the relationship between weather variables and canola growth and development as well as SSR incidence, precise models to predict growth stages and SSR are not available to canola growers in western Canada. Agriculture and Agri-Food Canada developed a yield forecasting model for canola at regional level. The integration of growth stage prediction tool will help to refine the yield forecasting model.

The objectives of this project are to develop: i) a model to forecast key growth stages of canola; ii) a Sclerotinia stem rot (SSR) risk model to help producers with fungicide treatment decisions and other agronomic activities; and iii) a yield model to forecast canola production at local and regional scales. To achieve these objectives field trials were conducted in 2014 and 2015 and field trials will continue in 2016 and 2017 in three provinces in western Canada. The field trial outcomes will be deployed as agronomic tools in the integrated web platform, which will be available to canola growers in Manitoba, Saskatchewan, and Alberta.

Field trials

Field trials were conducted in 11 locations in Manitoba in 2014 and 2015 (**Fig.1A**). Field trials were also conducted in 2 locations in Saskatchewan and 3 locations in Alberta in 2015. In Saskatchewan, field trials were conducted in Prince Albert in collaboration with the Conservation Learning Centre and in Indian Head in collaboration with the Indian Head Research Foundation. In Alberta, field trials were conducted in Castor, Forestburg, and Settler in collaboration with the Battle River Research Group. In Manitoba, field trials were conducted in collaboration with the University of Manitoba, Bayer Crop Science, DL Seeds, and canola growers. In both years, there were (i) Small Plot Trials, which included three varieties representing short-, medium-, and long-season cultivars with four replications; and (ii) Field Scale Trials, which included one cultivar with four replications. In 2014 and 2015, we had small plot trials in 3 locations and field scale trials in 8 locations in Manitoba. In 2015, all field trials in 2 locations in SK and 3 locations in AB were small plot trials. Plot establishment, agronomic management (seeding, spraying), maintenance and harvesting were done in accordance with the collaborators' standard practices using their own equipment. At each small-plot site, there were 12 plots (4 replicates x 3 varieties) laid out in a randomised complete block (RCB)

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design, separated by a 2-3m buffer. Within the field-scale trials, 4 small plots were demarcated and used to collect growth stage, SSR, and yield data. Seeding dates ranged from mid-May to the first week of June. In addition, we obtained 6 years (2009 to 2014) of SSR incidence data from the Canada Disease Survey (CDS) from Manitoba Agriculture, Food and Rural Development (MAFRD) as well as 4 years (2011 to 2014) canola yield data from Canola Performance Trials (CPT) from all three provinces.

Figure 1. Maps showing field trial locations in Manitoba, Saskatchewan and Alberta

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Data collection and analysis

At all trial sites, HOBO micro-weather stations (MWS) were installed to monitor in-canopy microclimate. Weather parameters collected by the HOBO micro-weather stations included air temperature, relative humidity (RH), leaf wetness (LW), soil temperature and soil moisture. In 5 locations in 2014 and 8 locations in 2015, ADCON Telemetry automatic weather stations were also installed outside the plots/fields to record air temperature, RH, LW and rainfall. These stations are equipped with cellular modems which provided near-real-time data throughout the season.

Canola growth stage observation and modelling
In all trial sites, canola growth stage pictures were taken using time-lapse digital cameras. The cameras were installed immediately after seeding and were programmed to take pictures of the canola crop 5 times per day throughout the growing season. The pictures were used to determine the exact occurrence date of each growth stage. Canola growth stage was also recorded manually once per week. Growth stages were then identified from the time-lapse photos and compared with manually collected data. Three thermal-based models were tested for their ability to forecast canola growth stages. These models include Growing degree days with base temperature 5^0C (GDD_5) and Physiological days (P-Days) and crop heat units,

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respectively. The accumulated threshold values of all three models for each growth stage from seeding to maturity were compared using data from all locations over two years. The GDD_5 and P-days requirements for each growth stage of the three variety groups (short-, medium-, and long- season) were also compared. To compare the models, coefficient of variation (CV) and standard error were also calculated. The model with lower values of CV and standard error were considered better model and selected to predict the growth stages.

Sclerotinia stem rot (SSR) modelling

SSR incidence was recorded after fruit development (BBCH 80 to 87) and before swathing at all trial sites. To assess the disease, the number of SSR-infected plants and the total number of plants were recorded from three-one metre rows in each plot (replicate) and SSR incidence was estimated. In 2015, few sites in field scale trials in Manitoba were sprayed with fungicides; therefore, SSR incidence data from those sites were excluded in the analyses. Sclerotia depots were provided by Dr. Lone Buchwaldt of AAFC, Saskatoon. Each depot contains 50 sclerotia and is meant to provide an indication of sclerotia germination. Sclerotia depots were buried in 4 locations in 2014 and 3 locations in 2015. The depots were buried when the canola crop was at the 5-6 leaf stage and monitored weekly for sclerotia germination. SSR incidence was recorded at all locations and the disease incidences from all locations were compared along with their relationship to microclimate data. In addition, the sclerotia germination and final SSR incidence data were compared. Furthermore, using knowledge of the pathogen biology, SSR epidemiology and their relationship with weather variables, SSR risk index has been developed. Using weather variables during flowering time and agronomic variables, the SSR risk index calculates the levels of risk: low, moderate and high. The predicted risk levels were also compared with the SSR incidence data from your field trials in 2014 and 2015.

Yield observation and modelling

Canola yields from all small plot and field scale trials were recorded in both years. The yield data will be used in validating yield prediction model. The refined growth stage tool will be provided to Dr. Aston Chipanshi, Agriculture and Agri-Food Canada to refine the canola yield prediction model currently deployed in Canada by AAFC.

RESULTS AND DISCUSSION

Phenological modelling

We compared the accumulated GDD_5 and P-days corresponding to each 14 growth stages between emergences (BBCH 9) to fully ripe (BBCH 89) using growth stages picture taken by time-lapse camera as well as growth stages recorded manually from all 11 field trials in 2014 and 16 field trials in 2015. Compared to GDD_5

thresholds, P-days (physiological day) thresholds had lower coefficient of variation (CV) and lower standard error, indicating P-days values are more consistent to predict the growth stages than the GDD (Table 1). In addition, there was a less variability in accumulated P-days values between two years compared to accumulated GDD_5. P-days include minimum (5°C), optimum (17°C) and maximum temperature (30°C), which make sense with crop growth and physiology. Based on these results, P-days threshold were selected to deploy the growth stage prediction tools. These thresholds will be also compared using field data from 2016 and 2017.

Table 1. Comparison of standard error and coefficient of variation (CV) among the thresholds of P-days, GDD_5, and CHU corresponding to each growth stages in 2015

BBCH Stage	Description	n†	Accumulated P-days		Accumulated GDD_5		Accumulated CHU	
			Std error	CV	Std error	CV	Std error	CV
9	Emergence	31	3	26	5	27	9	28
11	First leaf unfold	32	3	13	4	12	7	13
14	4th leaf unfold	31	4	11	6	11	8	11
30	Rosette /stem elongation	28	4	9	5	7	7	7
33	3rd Internode/Rosette	27	4	8	5	7	7	6
51	Green bud initiation	31	4	8	6	8	9	8
58	Yellow bud	31	4	7	6	7	10	7
60	Early flowering	32	4	7	7	7	11	7
63	30% flowering	32	4	7	8	8	12	8
65	Full bloom	32	5	7	9	9	14	9
69	End of the flowering	30	5	6	9	6	14	6
75	50% pod development	29	6	5	15	8	17	6
81	Beginning of ripening	29	10	8	15	7	20	6
89	Fully ripe	25	12	8	18	7	22	6

† Number of observations

We found variability in accumulated P-days for corresponding growth stages among short-, mid-, and long-season cultivars. However, there was less variability in earlier growth stages before stem elongation (BBCH 30) than the growth stages after BBCH 30 (Table 2). Within a same cultivar group, there was some variability between years and among locations, but variability was less within the cultivar with same maturity group than

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in cultivars with different maturity groups. In 2015 field trials, we had mid-season cultivars in 15 locations out of 16 locations. The accumulated P-days thresholds for corresponding growth stages of mid-season cultivar group were compared among three provinces. There were no substantial differences on the accumulated P-days thresholds among provinces indicating that accumulated P-days thresholds can be used to predict the growth stages of canola across three provinces. However, we had field trials in 3 provinces only in 2015. We will have field trials in all 3 provinces in 2016 and 2017. The multi-year data will help more to compare thresholds among three provinces.

Table 2. Comparison of accumulated physiological days (P-days) required for each growth stages of short-, mid- and long-season canola cultivars

BBCH Stage	Description	Average over 3 cultivar groups		Short-season cultivar		Mid-season cultivar		Late-season cultivar	
		2014	2015	2014	2015	2014	2015	2014	2015
9	Emergence	74	76	76	68	74	81	73	64
11	First leaf unfold	104	126	101	128	110	127	98	124
14	4th leaf unfold	199	188	192	181	197	191	206	184
30	Rosette /stem elongation	289	240	273	213	304	244	279	240
33	3rd Internode/Rosette	NA	262	NA	236	NA	266	NA	263
51	Green bud initiation	NA	288	NA	258	NA	291	NA	291
58	Yellow bud	328	314	321	296	341	315	318	323
60	Early flowering	344	334	331	321	350	334	345	342
63	30% flowering	385	357	378	337	391	359	375	364
65	Full bloom	442	380	425	359	451	382	448	387
69	End of the flowering	489	475	473	444	493	478	496	483
75	50% pod development	NA	570	NA	549	NA	572	NA	576
81	Beginning of ripening	690	694	674	674	685	697	713	701
89	Fully ripe	780	765	778	742	787	764	NA	788

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Sclerotinia stem rot (SSR) incidence and modelling

The sclerotinia stem rot incidences were low to moderate in 2014 and 2015. Out of 11 field trials in in 2014 and 2015 in Manitoba, only 2 field trials in 2014 and 4 field trials in 2015 had SSR incidence higher than 10% (Table 3). In all locations in Saskatchewan and Alberta, Sclerotinia stem rot incidence was very low. In addition, there was 0% Sclerotia germination in all locations in 2014 and 2015.

We developed the SSR risk index using weather variables during flowering time as well as agronomic variables. The risk index provides levels of risk: high (score ≥25 out of 37), moderate (score 20 to 24) and low (<20). The predicted risk levels at all field trial locations in 2014 and 2015 were compared with the observed SSR incidence data. We defined ≥10% SSR incidence as a high disease threshold to compare with the risk level. Our preliminary analyses showed about 63% accuracy i.e. SSR risk index showed high risk when observed SSR incidence was ≥10% (27 out of 43 data point). However, about 20% data showed false positive and 16% data point showed false negative indicating that there is opportunity to refine the sclerotinia risk index using field data from additional years. The major challenges in SSR modelling efforts were that SSR incidence was low in the majority of trial locations in both years.

Table 3: Sclerotinia stem rot (SSR) incidence in canola fields in our trials in 2014 and 2015

Province	**Location**	**2014**	**2015**
Manitoba	Beausejour	1.8	-
	Carman	9.3	13.3
	Holland	5.0	14.0
	Gleanlea	55.4	0.0
	Haywood	2.3	1.7
	Landmark	-	17.4
	Oak Bluff	1.6	-
	Portage	36.8	10.8
	Teulon	-	23.3
Saskatchewan	Indian Head	-	0.0
	Prince Albert	-	0.0
Alberta	Castor	-	8.2
	Settler	-	0.0

We also analyzed the provincial SSR survey data (2009 to 2014) obtained from MAFRD. There was wide

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variability in the SSR incidence among years and among locations within year (Table 3). For example, there was 53% and 66% locations had ≥10% SSR incidence in 2009 and 2010, respectively. Whereas, only 17% and 20% locations had ≥10% SSR incidence in 2011 and 2013, respectively.

Table 4: Sclerotinia stem rot (SSR) incidence in Manitoba provincial survey during 2009 to 2014

Year	No. of fields (n)	Average SSR Incidence	% Frequency of locations with	
			SSR incidence ≥ 10%	SSR incidence ≥ 20%
2009	43	17.3	53	37
2010	89	28.1	66	52
2011	70	6.3	17	14
2012	77	7.3	29	10
2013	87	7.6	20	11
2014	90	6.9	22	10

To analyze the relationship between weather variables and SSR incidence, weather variables (rainfall, temperature, and RH) of each location during flowering period (-14 days to +7 days) were created. The flowering date (50% flowering) was estimated using phenology models developed in this project. We did not find any strong relationship between the weather variables and SSR incidence at provincial level. The major challenge with the provincial survey data was that the actual GPS coordinates of survey locations could not be obtained due to confidential issue. We used the nearby town of those field locations to acquire weather data of the fields, which may increase noise in weather data. If GPS coordinates were known, we could exactly know how far weather station from that field locations is and there would be chances to reduce the noise in weather data. Also, the survey data were collected from both fungicide sprayed and non-sprayed fields. According to MAFRD, they have no way of knowing whether a field was sprayed with fungicides or not.

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Yield modelling

The refined growth stage tools developed using field trial data in 2014 and 2015 will be shared with Dr. Aston Chipanshi, Agriculture and Agri-Food Canada to refine the canola yield prediction model currently deployed by AAFC. We will discuss with Dr. Chipanshi and his team for integration of canola growth model with yield model. We will further discuss about the potentialities to develop site-specific yield forecasting model.

Deployment of operational models

The custom webpage (http://canoladst.ca) were designed for this canola project in 2014. The website was used in 2014 and 2015 to collect and record field trial data as well as deploy and test the model prototype internally. In 2016 field season, growth stage prediction model and SSR risk calculator will be deployed in http://canoladst.ca to provide site-specific advisories to canola growers in western Canada. The weather data from WEATHER FARM programs and other networks of Weather INnovations stations from Environment Canada is integrated with GIS system to provide field-specific advisory.

The information about model deployment will be provided to the project collaborators, public and private researchers, provincial crop specialists as well as agronomists of canola council. Canola growers are also encouraged to use the website to get field-specific advisories. Inputs and comments from expert panel and growers will be used to further improvement in model deployment. Both phenology and SSR model will be further refined using field trials data will be conducted in 2016 and 2017.

2016/17

Introduction and Research Objectives

There is a strong association between Sclerotinia stem rot (SSR) incidence and prevailing weather conditions during and close to the canola flowering period. The success of developing a sclerotinia stem rot forecasting system relies on the ability to precisely predict the canola flowering stage. In addition, there is a linkage between growth stages and insect damage on crops. Although studies have been conducted to understand the relationship between weather variables and canola growth and development as well as SSR incidence, precise models to predict growth stages and SSR are not available to canola growers in western Canada. Agriculture and Agri-Food Canada developed a yield forecasting model for canola at regional level. The integration of growth stage prediction tool will help to refine the yield forecasting model.

The objectives of this project are to develop: 1) a model to forecast key growth stages of canola; 2) a sclerotinia stem rot (SSR) risk model to help producers with fungicide treatment decisions and other agronomic activities;

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and 3) a yield model to forecast canola production at local and regional scales. To achieve these objectives field trials were conducted in 2014, 2015 and 2016 and field trials will continue in 2017 in western Canada. The field trial outcomes will be deployed as agronomic tools in the integrated web platform, which will be available to canola growers in Manitoba, Saskatchewan, and Alberta.

Field TRIALS

Small-plot trials were conducted in Holland, Portage la Prairie North, Pilot Mound, Elm Creek and Kelburn Farm in Manitoba (Figure 1), Indian Head in Saskatchewan and Forestburg and Castor in Alberta (Figure 2) for a total of 8 small-plot trials. At each of these sites three varieties representing short, medium and long season cultivars were grown. The short, medium and long season varieties were Monsanto 73-15, Monsanto 73-75 and DL Seeds 60-60, respectively. Plot establishment, maintenance and harvesting were done in accordance with the collaborators standard practise and using their equipment. The small-plot trials were conducted in collaboration with DL Seeds in Manitoba, Indian Head Agricultural Research Foundation (IHARF) in Saskatchewan and Battle River Research Group (BRRG) in Alberta. At each site, there were 12 plots in total (4 replicates x 3 varieties) laid out in a randomised complete block design and separated by a 2-3m buffer. The plot layout and randomisation was different for each collaborator. Plots in Holland, Portage la Prairie North, Pilot Mound, Elm Creek, Forestburg and Castor measured 7m x 1.4m, while at Kelburn Farm they measured 8m x 1.3m and at Indian Head they measured 21.3m x 2.4m. The plot width was determined by the collaborators seeding equipment. All plots at each site were seeded on the same day; the target seeding rate at all sites was 5.5 lbs/ac. Fertilizer rates and herbicides were determined by the collaborator. No fungicides were applied at all eight small-plot sites.

All Field-Scale Trials were conducted in collaboration with Bayer Crop Science and were located in Balmoral, Brunkild, Headingley, Portage la Prairie South, Netley Colony, Glenlea and La Rivière in Manitoba for a total of 7 trials. In an already established/planted canola field, 4 small plots were demarcated. Each of these plots represented a replication (i.e., there were 4 replications x 1 cultivar). The plots measured 6m x 2m and separated by a 1m buffer. Similar to the small-plot trials, seeding, field maintenance and harvesting were done in accordance with the collaborators standard practise and using their normal equipment. Fertilizer rates, seeding rates and herbicides were determined by the collaborator.

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Figure 1. Maps showing field trial locations in Manitoba

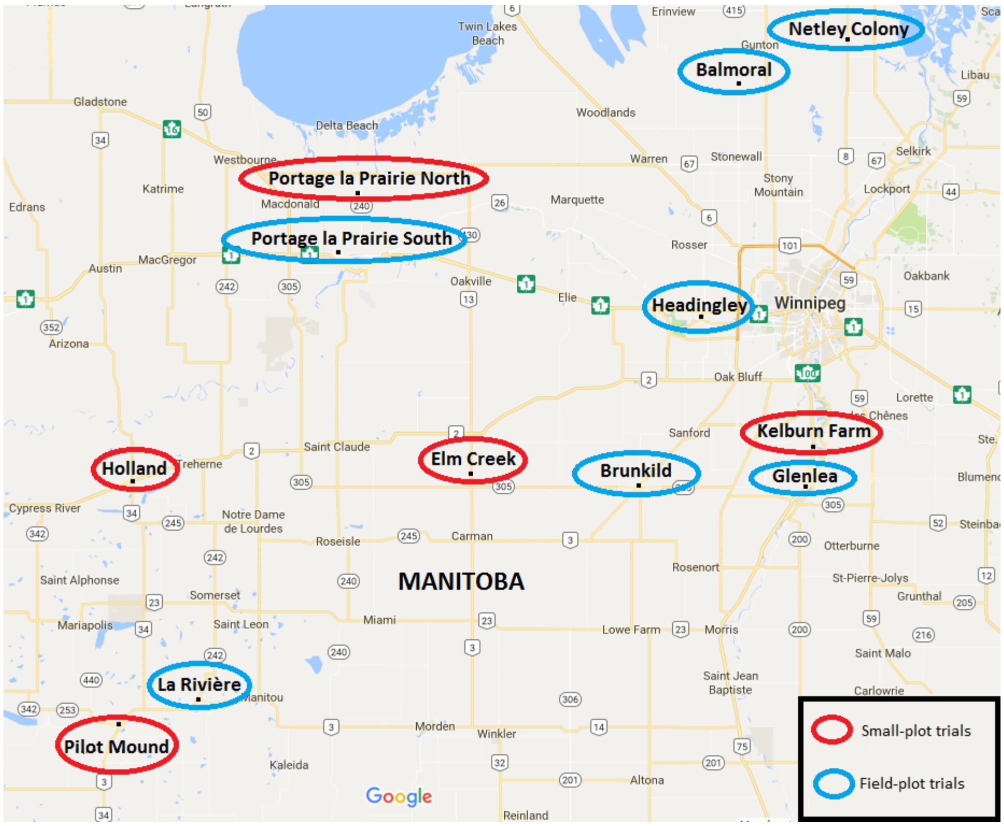

Figure 2. Map showing field trial locations in Saskatchewan and Alberta

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Data collection and analysis

In both the small-plot and field-plot trials, HOBO micro-weather stations (MWS) were installed next to the camera to record in-canopy micro-climate. In the small-plot trials, 3 cameras per-site (one in each variety) were installed, while in the field-scale plots a maximum of two MWS were installed. Weather parameters collected inside the canopy included air temperature, relative humidity (RH), leaf wetness duration (LW), soil temperature at 2.5 cm depth and soil moisture at 2.5 cm depth. The RH and air temperature sensors were housed in guild shields and mounted at 30 cm above ground. The leaf wetness sensor was installed at 30 cm above ground facing north and oriented at 45° from horizontal. For the measurement of soil temperature and soil moisture, a hand trowel was used to expose a shallow vertical profile and a tape measure was used to determine the 2.5 cm depth below the surface. At this depth the soil temperature thermocouples and the ECHO soil moisture probes were installed horizontally. In addition, at some sites (Holland, Portage la Prairie North, Pilot Mound, Portage la Prairie South, Elm Creek, La Rivière, Netley Colony, Indian Head, Forestburg and Castor) ADCON automatic weather stations were installed outside the plots/fields to record air temperature, RH, LW and rainfall. The HOBOS were run in the laboratory for at least a month before deployment in the field.

Canola growth stage observation

At the southern edge of plots 1, 2 and 3, weather proof time lapse digital cameras (i.e., 1 in each plot) were

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installed as soon as possible following seeding. However, in the field-scale trials a camera was position inside the plot but on the southern edge of the field. The cameras were programmed to photograph the footprint (a portion of the plot) 5 times per day (i.e., 6 am, 9 am, 12 noon, 3 pm and 6 pm) throughout the growing season. The mount (mast) was always located on the south side of the plot. The cameras were mounted at 50 cm height (above ground) facing north and oriented at 45° from horizontal. The camera position (height) was adjusted upwards in response to plant growth. Pictures from the cameras were used in determining the exact date of each crop phenological stage at each location.

Manual canola growth stages were recorded at all sites in all plots using the BBCH-scale. Care was taken to make sure that the cameras were not disturbed/ obstructed during this exercise. Canola growth stage (phenological) observations were done once a week; however, it was very difficult to maintain the exact same schedule due to unforeseen circumstances e.g., weather conditions. Crop stage was recorded as an average of randomly selected plants. After recording the phenological stage, photographs of the plants and the plots in general were taken to capture as much detail of the phenological development as possible. A high resolution camera was used for this purpose. The plant counts and phenological observations were recorded in a prior designed form.

Sclerotinia stem rot (SSR) observations

Sclerotinia stem rot (SSR) disease incidences were determined after fruit development (BBCH 80 to 87) but before swathing. The SSR determination was similar for the small-plots and field-scale plots. SSR incidence was recorded in all the plots but making sure that the camera was not disturbed. At all sites, 3 x 1m rows were measured and the total number of plants in each row was counted. Thereafter, the number of diseased (infected) plants was counted in each row and the disease severity was estimated. The severity ratings ranged from 0-5, with zero being no symptoms and 5 being the most severe. The rows/areas where SSR incidence was monitored were randomly selected. The percent SSR incidence was calculated by dividing the total number of diseased (infected) plants by the total number of plants in all rows and then multiplying by 100. The total number of SSR observation at each site ranged from 1 to 3. At the sites where more than one sclerotinia incidence observation was recorded, the recording was done once a week.

Sclerotia depots

During the 2016 cropping season sclerotia depots were buried only at Kelburn Farm. The sclerotia depots were buried when the canola crop was just beginning to flower on July 6, 2016. A hole about 5 cm deep and big enough to hold the depot was dug between rows; however, away from the camera footprint. The depots were

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monitored weekly for apothecia germination.

Yield observation

At all the sites canola harvesting/combining was done by the collaborator/producer using their own equipment. The only exception was at Kelburn Farm where WIN staff helped with harvesting. In the small-plot trials, each plot was harvested and the grain weight and moisture content were measured. Thus the harvest grain weight is for the whole plot. The yield for the field-scale trials is an average of the whole field (i.e., where WIN plots were located) and was supplied by the collaborator.

Results and discussion

Phenological modelling

Last year we compared the accumulated GDD_5 and P-days corresponding to the 14 growth stages between emergences (BBCH 9) to full maturity (BBCH 89) using the growth stage pictures taken by time-lapse camera as well as the growth stages recorded manually from 11 field trials in 2014, 16 field trials in 2015 and 7 field trials in 2016. As outlined in last year's report we decided to use P-days (physiological day) since when we compared GDD_5 thresholds, P-days thresholds had lower coefficient of variation and lower standard error, indicating P-days values are more consistent to predict the growth stages than the GDD. In addition, there was less variability in accumulated P-days values between the three years compared to accumulated GDD_5. Based on these results, P-days threshold were selected to deploy the growth stage prediction tools. When 2014, 2015 and 2016 data was tabulated we found that there was less variability in earlier growth stages before stem elongation (BBCH 30) than the growth stages after BBCH 30 (Table 1).

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Table 1. Comparison of accumulated physiological days (P-days) required for each growth stage of short, mid and long season canola cultivars

BBCH Stage	Description	Average over 3 cultivar groups			Short-season cultivar			Mid-season cultivar			Late-season cultivar		
		2014	2015	2016	2014	2015	2016	2014	2015	2016	2014	2015	2016
9	Emergence	74	76	69	76	68	66	74	81	74	73	64	72
11	First leaf unfold	104	126	136	101	128	126	110	127	141	98	124	145
14	4th leaf unfold	199	188	224	192	181	179	197	191	226	206	184	215
30	Rosette /stem elongation	289	240	266	273	213	215	304	244	273	279	240	265
33	3rd Internode/ Rosette	NA	262	287	NA	236	240	NA	266	294	NA	263	285
51	Green bud initiation	NA	288	307	NA	258	277	NA	291	310	NA	291	306
58	Yellow bud	328	314	328	321	296	304	341	315	328	318	323	333
60	Early flowering	344	334	354	331	321	330	350	334	357	345	342	358
63	30% flowering	385	357	400	378	337	347	391	359	409	375	364	397
65	Full bloom	442	380	442	425	359	369	451	382	457	448	387	436
69	End of the flowering	489	475	542	473	444	457	493	478	537	496	483	544
75	50% pod development	NA	570	634	NA	549	567	NA	572	628	NA	576	641
81	Beginning of ripening	690	694	777	674	674	694	685	697	763	713	701	809
89	Fully ripe	780	765	840	778	742	763	787	764	833	NA	788	871

For all three years, 2014, 2015 and 2016, early season canola cultivars matured as expected, see graph 1. However, in 2014 and 2015, both mid and late season cultivars matured earlier than expected and ripened at the same time as short season cultivars. As one can see in graphs 2 and 3 the 2014 and 2015 lines are not

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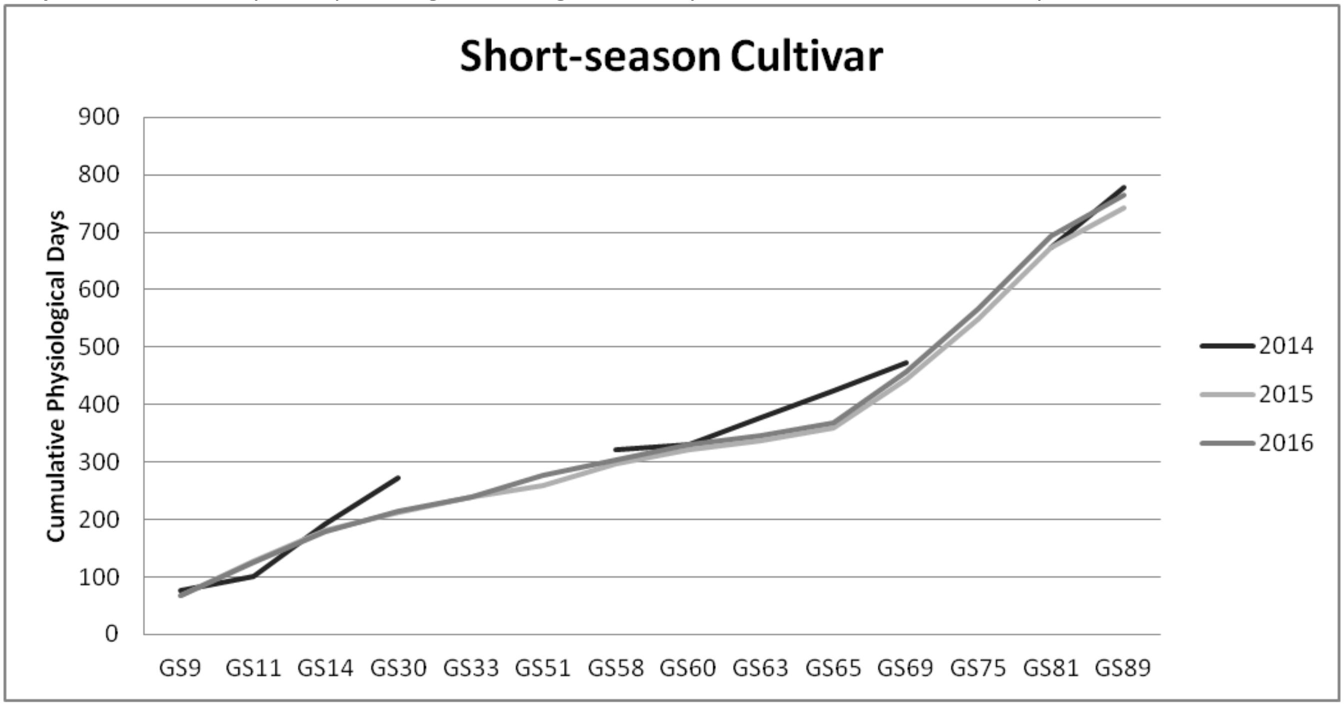
overlapping with the 2016 line indicating earlier than normal maturity. In 2016 the mid and late season cultivars matured as one would expect and hence matured later than the short season cultivars. With another years worth of data we will investigate why the mid and late cultivars in 2014 and 2015 matured like early season cultivars. We will look into if this occurrence is influenced by weather, nutrients, temperature, light etc.

Graph 1. Canola P-days compare to growth stages for early season cultivars over three years



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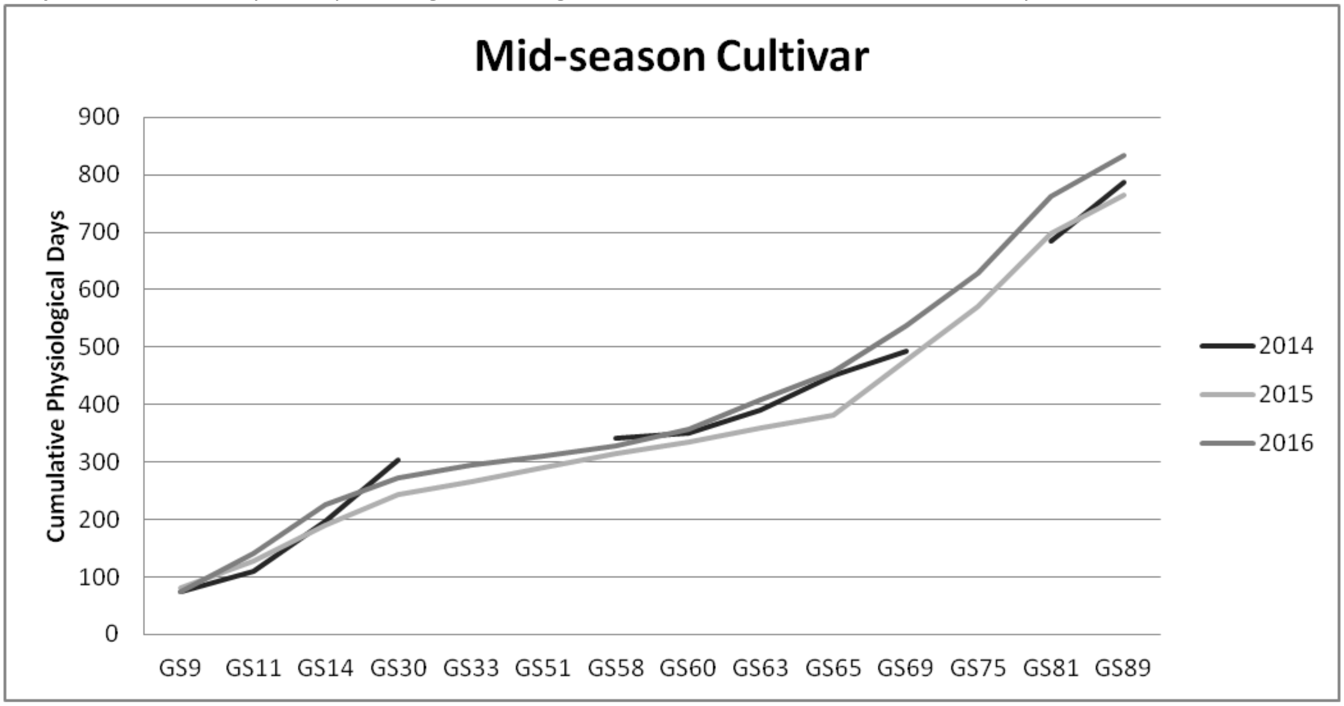
Graph 2. Canola P-days compare to growth stages for mid season cultivars over three years



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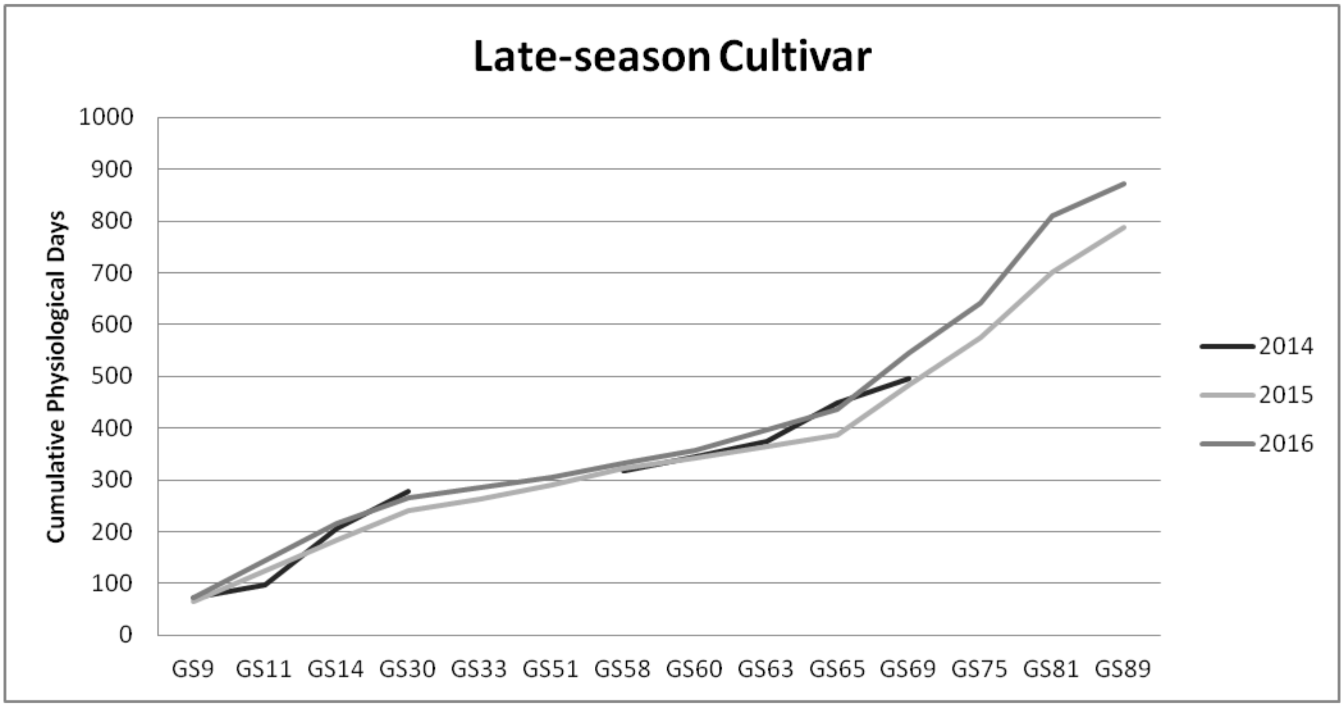
Graph 3. Canola P-days compare to growth stages for late season cultivars over three years



Sclerotinia stem rot (SSR) incidence and modelling

The sclerotinia stem rot incidences were low to moderate in 2014, 2015 and 2016. Out of 11 field trials in 2014 and 2015 in Manitoba, only 2 field trials in 2014 and 4 field trials in 2015 had SSR incidence higher than 10% (Table 2). In 2016, sclerotinia incidence was slightly higher in Manitoba since 5 out of the 12 sites the incidence was greater than 12% and was highest in Pilot Mound where it was 17%. Average severity was about 3 on a scale of 0-5 (0 = none, 5 = highest severity) at the sites where the incidence was higher. The rest of the sites had incidences lower than 5%. There was no sclerotia germination in the sites where sclerotia depots were buried. In IHARF (Indian Head, Saskatchewan), the incidence was 13%, however, the severity was about 1. Meanwhile in Alberta, the incidence was 2% in Castor and 0% in Forestburg.

We developed the SSR risk index using weather variables during flowering time as well as agronomic variables. The risk index provides levels of risk: high (score ≥25 out of 37), moderate (score 20 to 24) and low (< 20). The predicted risk levels at all field trial locations in 2014 and 2015 were compared with the observed SSR incidence

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data. We defined ≥10% SSR incidence as a high disease threshold to compare with the risk level. Data analysis for the past three years, 2014, 2015 and 2016, is inconclusive as we have found that one of the major challenges in SSR modelling is that the SSR incidence was low in the majority of trial locations in all 3 years. We are hopeful that the data for the 2017 year will provide significant SSR incidences in which we can draw appropriate conclusions from.

Table 2: Sclerotinia stem rot (SSR) incidence (%) in canola fields in our trials in 2014, 2015 and 2016

Province	Location	2014	2015	2016
Manitoba	Beausejour	1.8%	-	-
	Carman	9.3%	13.3%	-
	Holland	5.0%	14.0%	4%
	Gleanlea	55.4%	0.0%	3%
	Haywood	2.3%	1.7%	-
	Landmark	-	17.4%	-
	Oak Bluff	1.6%	-	-
	Portage North	36.8%	10.8%	13%
	Portage South	-	-	13%
	Teulon	-	23.3%	-
	Pilot Mound	-	-	17%
	Elm Creek	-	-	2%
	Kelburn	-	-	12%
	Balmoral	-	-	7%
	Brunkild	-	-	15%
	Headingley	-	-	2%
	Netley Colony	-	-	3%
	La Rivière	-	-	3%
Saskatchewan	Indian Head	-	0.0%	13%
	Prince Albert	-	0.0%	-
Alberta	Castor	-	8.2%	2%
	Settler	-	0.0%	0.0%

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Yield modelling

The refined growth stage tools developed using field trial data in 2014, 2015 and 2016 will be shared with Dr. Aston Chipanshi, Agriculture and Agri-Food Canada to refine the canola yield prediction model currently deployed by AAFC. We will discuss with Dr. Chipanshi and his team for integration of canola growth model with yield model. We will further discuss about the potentialities to develop site-specific yield forecasting model.

2017/18

Introduction and Research Objectives

There is a strong association between Sclerotinia stem rot (SSR) incidence and weather conditions during and close to the canola flowering period. The success of developing a sclerotinia stem rot forecasting system relies on the ability to precisely predict the canola flowering stage. In addition, there is a linkage between growth stages and insect damage on crops. Although studies have been conducted to understand the relationship between weather variables and canola growth and development as well as SSR incidence, precise models to predict growth stages and SSR are not available to canola growers in western Canada. Agriculture and Agri-Food Canada developed a yield forecasting model for canola at regional level. The integration of growth stage prediction tool will help to refine the yield forecasting model.

The objectives of this project are to develop:

1) a model to forecast key growth stages of canola;
2) a sclerotinia stem rot (SSR) risk model to help producers with fungicide treatment decisions and other agronomic activities; and
3) a yield model to forecast canola production at local and regional scales. To achieve these objectives field trials were conducted in 2014, 2015, 2016 and 2017 in western Canada. The field trial outcomes will be deployed as agronomic tools in the integrated web platform, which will be available to canola growers in Manitoba, Saskatchewan, and Alberta.

Field trials

In 2014 small and field plot trials were conducted in Manitoba at Beausejour, Carman, Holland, Gleanlea, Haywood, Oak Bluff, Portage la Prairie. In 2015, there were field and small plot trials in Manitoba located at Carman, Holland, Gleanlea, Haywood, Portage North, Landmark Teulon, in Saskatchewan located at Indian Head and Prince Albert and in Alberta located at Castor and Settler. In 2016, there were trials in

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Holland, Portage la Prairie, Pilot Mound, Elm Creek, Balmoral, Brunkild, Headingley, Portage la Prairie South, Netley Colony, Glenlea, La Rivière and Kelburn Farm in Manitoba, Indian Head in Saskatchewan and Forestburg and Castor in Alberta.

In 2017, small-plot trials were conducted in Holland, Portage la Prairie, Pilot Mound, Morden, Thornhill in collaboration with DL Seeds and Kelburn Farm in collaboration with Richardson International for a total of 6 small-plot trials (see Figure 1). Each of these six sites had three varieties representing short-, medium- and long-season cultivars. The short-, medium- and long-season varieties were Monsanto 73-15, Monsanto 73-75 and DL Seeds 60-60, respectively. Plot establishment, maintenance and harvesting were done in accordance with the collaborators standard practise and using their normal equipment. At each site, there were 12 plots in total (4 replicates x 3 varieties) laid out in a randomised complete block design and separated by a 2-3m buffer (Figure 2).The plot layout and randomisation was different for each collaborator. Plots in Holland, Portage la Prairie, Pilot Mound, Morden measured 7m x 1.4m, while at Kelburn Farm they measured 8m x 1.3m. The plot width was determined by the collaborators seeding equipment. All plots at each site were seeded on the same day; the target seeding rate at all sites was 5.5 lbs/ac as recommended by the Canola Council of Canada. Fertilizer rates and herbicides were determined by the collaborator and no fungicides were applied to any of the six small-plot sites

All Field-scale Trials were conducted in collaboration with Bayer Crop Science and were located in Kronsgart (Winkler), Chortitz, Starbuck, Pilot mound, Rosser, Arborg and Holland for a total of 7 trials (see Figure 1). In already established/planted field-scale canola trials (several varieties planted), two varieties were selected and 4 small plots were demarcated. Each of these plots represented a replication (i.e. there were 4 replications). The plots measured 6m x 2m and separated by a one meter buffer (Figure 2). Similar to the small-plot trials, seeding, field maintenance and harvesting were done in accordance with the collaborators standard practise and using their normal equipment. Fertilizer rates, seeding rates and herbicides were determined by the collaborator.

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Figure 1. Maps showing field trial locations in Manitoba.

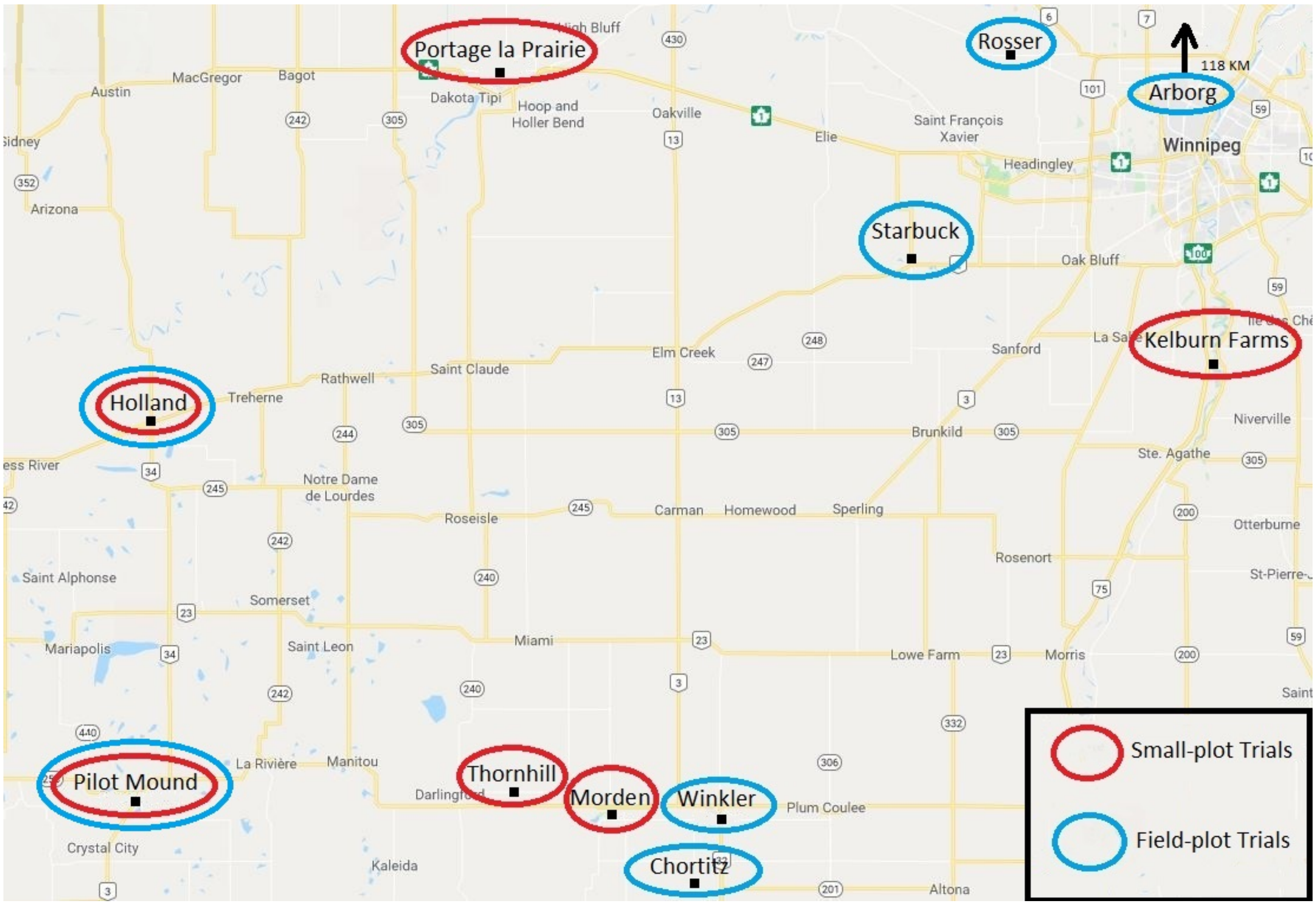

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Figure 2. Example of small-plot trial layout

RANDOMISED PLOT PLAN: DL SEEDS

N ↑

Short-Season Variety 73-15 PLOT 10	Mid-Season Variety 73-75 PLOT 11	Long-Season Variety 60-60 PLOT 12
Long-Season Variety 60-60 PLOT 7	Short-Season Variety 73-15 PLOT 8	Mid-Season Variety 73-75 PLOT 9
Mid-Season Variety 73-75 PLOT 4	Short-Season Variety 73-15 PLOT 5	Longt-Season Variety 60-60 PLOT 6
Mid-Season Variety 73-75 PLOT 1	Short-Season Variety 73-15 PLOT 2	Long-Season Variety 60-60 PLOT 3
CAMERA	CAMERA	CAMERA

DATA COLLECTION AND ANALYSIS

In both small-plot and field-plot trials, HOBO micro-weather stations were installed next to the time lapse camera to record in-canopy micro-climate. In the small-plot trials, 3 cameras per-site (one in each variety) were installed, while in the field-scale plots a maximum of two micro-weather stations were installed. Weather parameters collected inside the canopy included air temperature, relative humidity, leaf wetness duration, soil temperature at 2.5 cm depth and soil moisture at 2.5 cm depth. The relative humidity and air temperature sensors were housed in guild shields and mounted at 30 cm above ground. The leaf wetness sensor was installed at 30 cm above ground facing north and oriented at 45° from horizontal. For the measurement of soil temperature and soil moisture, a hand trowel was used to expose a shallow vertical profile and a tape measure was used to determine the 2.5 cm depth below the surface. At this depth the soil temperature thermocouples and the ECHO soil moisture probes were installed horizontally. In addition, at some sites ADCON automatic weather stations were installed outside the plots/fields to record air temperature, relative humidity, leaf wetness and rainfall. The HOBOS were run in the laboratory for at least a month before deployment in the

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field.

Canola growth stage observation

At the southern edge of plots 1, 2 and 3, weather proof time lapse digital cameras (i.e., 1 in each plot) were installed as soon as possible following seeding. However, in the field-scale trials a camera was position inside the plot but on the southern edge of the field. The cameras were programmed to photograph the footprint (a portion of the plot) 5 times per day (i.e., 6 am, 9 am, 12 noon, 3 pm and 6 pm) throughout the growing season. The mount (mast) was always located on the south side of the plot. The cameras were mounted at 90 cm height (above ground) facing north and oriented at 45° from horizontal. Pictures from the cameras were used in determining the exact date of each crop phenological stage at each location.

Manual canola growth stages were recorded at all sites in all plots using the BBCH scale. Care was taken to make sure that the cameras were not disturbed/ obstructed during this exercise. Canola growth stage (phenological) observations were done once a week; however, it was very difficult to maintain the exact same schedule due to unforeseen circumstances e.g., weather conditions. Crop stage was recorded as an average of randomly selected plants. After recording the phenological stage, photographs of the plants and the plots in general were taken to capture as much detail of the phenological development as possible. A high resolution camera was used for this purpose. The plant counts and phenological observations were recorded in a prior designed form.

Sclerotinia stem rot (SSR) observations

Sclerotinia stem rot (SSR) disease incidences were determined after fruit development (BBCH 80 to 87) but before swathing. The SSR determination was similar for the small-plots and field-scale plots. SSR incidence was recorded in all the plots but making sure that the camera was not disturbed. At all sites, 3m x 1m rows were measured and the total number of plants in each row was counted. Thereafter, the number of diseased (infected) plants was counted in each row and the disease severity was estimated. The severity ratings ranged from 0-5, with zero being no symptoms and 5 being the most severe. The rows/areas where SSR incidence was monitored were randomly selected. The percent SSR incidence was calculated by dividing the total number of diseased (infected) plants by the total number of plants in all rows and then multiplying by 100. The total number of SSR observation at each site ranged from 1 to 3. At the sites where more than one sclerotinia incidence observation was recorded, the recording was done once a week.

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Sclerotia depots

Sclerotia depots were provided by Dr. Lone Buchwaldt of AAFC, Saskatoon. Each depot contains 50 sclerotia and is meant to provide an indication of sclerotia germination. Weather INovations (WIN) staff buried sclerotia depots in 4 locations in 2014 and 3 locations in 2015. The depots were buried when the canola crop was at the 5-6 leaf stage and monitored weekly for sclerotia germination. During the 2016 and 2017 cropping season sclerotia depots were buried only at Kelburn Farm and the sclerotia depots were buried when the canola crop was just beginning to flower. SSR incidence was recorded at all locations and the disease incidences from all locations were compared along with their relationship to microclimate data. A hole about 5 cm deep and big enough to hold the depot was dug between rows and away from the camera footprint.

Yield observation

For all years, at all locations, canola harvesting/combining was done by the collaborator/producer using their own equipment. In the small-plot trials, each plot was harvested and the grain weight and moisture content were measured and therefore the harvest grain weight is for the whole plot. The yield for the field-scale trials is an average of the whole field (i.e., where WIN plots were located) and was supplied by the collaborator.

Results and discussion

Phenological modelling

Last year we compared the accumulated GDD5 and P-days corresponding to the 14 growth stages between emergences (BBCH 9) to full maturity (BBCH 89) using the growth stage pictures taken by time lapse camera as well as the growth stages recorded manually from 11 field trials in 2014, 16 field trials in 2015, 7 field trials in 2016 and 7 field trials in 2017. As outlined in previous year's reports we decided to use P-days (physiological day) since when we compared GDD5 thresholds, P-days thresholds had lower coefficient of variation and lower standard error, indicating P-days values are more consistent to predict the growth stages than the GDD. In addition, there was less variability in accumulated P-days values between the three years compared to accumulated GDD5. See table 1 for a comparison of accumulated physiological days (P-days) required for each growth stage of short, mid and long season canola cultivars. Based on these results, P-days threshold were selected to deploy the growth stage prediction tools. Using 2014, 2015, and 2016 trial data for the basis of a generalized growth stage model we found that the generalized model meets expectations for the most important canola stages of flowering - BBCH60/65. For example, when looking at 21 plots with start of flowering observations at BBCH60 we found that, 66.6% of predictions were within 3 days of actual, 90.5% of predictions were within 5 days of actual with the average prediction was within 2.5 days (Figure 1). For BBCH65

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(50% of plant flowering) average prediction within 3.2 days of actual 50% flowering, 66.6% of predictions were within 3 days of actual and 95.2% of predictions are within 5 days of actual flowering (Figure 2). Figure 3 shows how close our generalized model is to accurately predicting canola flowering stages in Pilot Mound, Manitoba, as the model is correct for growth stage BBCH60 and only one day off for BBCH69. In Figure 4, using Rosser, Manitoba, as the example, flowering stages are still predicted accurately however early and late stages are not as easily predicted by the model. We used a generalized model because we found that no matter what the season type, early, mid or late season, they flowered within a day or 2 of each other (Figure 5). Lastly, we found that for all four years of data, early, mid and late season canola cultivars bloomed and matured within 2 or 3 days from each other.

Table 1. Comparison of accumulated physiological days (P-days) required for each growth stage of short, mid and long season canola cultivars

Description	BBCH Stage	Average over 3 cultivar groups				Short season cultivar				Mid-season cultivar				Long season cultivar			
		2014	2015	2016	2017	2014	2015	2016	2017	2014	2015	2016	2017	2014	2015	2016	2017
Emergance	GS9	74	76	76	120	76	68	72	125	74	81	81	127	73	64	79	110
1st leaf unfold	GS11	104	126	144	142	101	128	135	143	110	127	148	154	98	124	152	136
4th leaf unfold	GS14	199	188	232	219	192	181	222	219	197	191	233	230	206	184	222	213
Rosette /stem elongation	GS30	289	240	274	299	273	213	255	296	304	244	280	305	279	240	273	298
3rd internode/ rosette	GS33	NA	262	294	309	NA	238	273	303	NA	266	301	310	NA	263	292	312
Green bud initiation	GS51	NA	288	315	323	NA	258	294	315	NA	291	317	323	NA	291	314	331
Yellow bud	GS58	328	314	336	343	321	296	317	339	341	315	335	340	318	323	340	348
Early flowering	GS60	344	334	361	358	331	321	344	350	350	334	364	359	345	342	366	363
30% flowering	GS63	385	357	408	376	378	337	376	371	391	359	416	377	375	364	404	379
Full bloom	GS65	442	380	450	418	425	359	418	415	451	382	464	420	448	387	443	420
End of flowering	GS69	489	475	550	522	473	444	540	503	493	478	544	541	496	483	551	526
50% pod development	GS75	NA	570	642	564	NA	549	625	550	NA	572	635	590	NA	576	649	562
Beginning of ripening	GS81	690	694	784	722	674	674	767	712	685	697	770	727	713	701	817	726
Fully ripe	GS89	780	765	847	802	778	742	825	780	787	764	841	813	NA	788	878	809

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Figure 1. Difference between actual versus predicted BBCH60

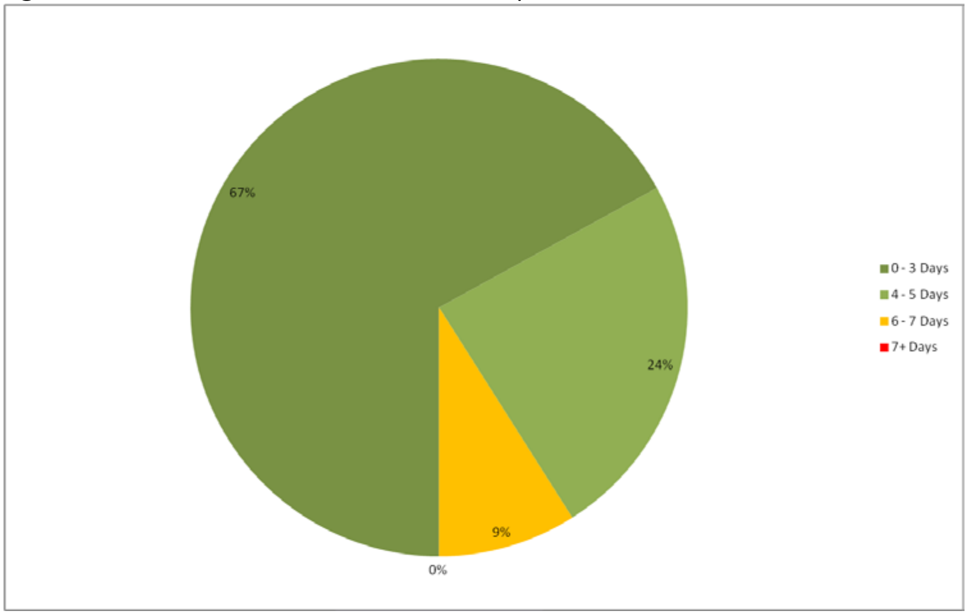

Figure 2. Difference between actual versus predicted BBCH65

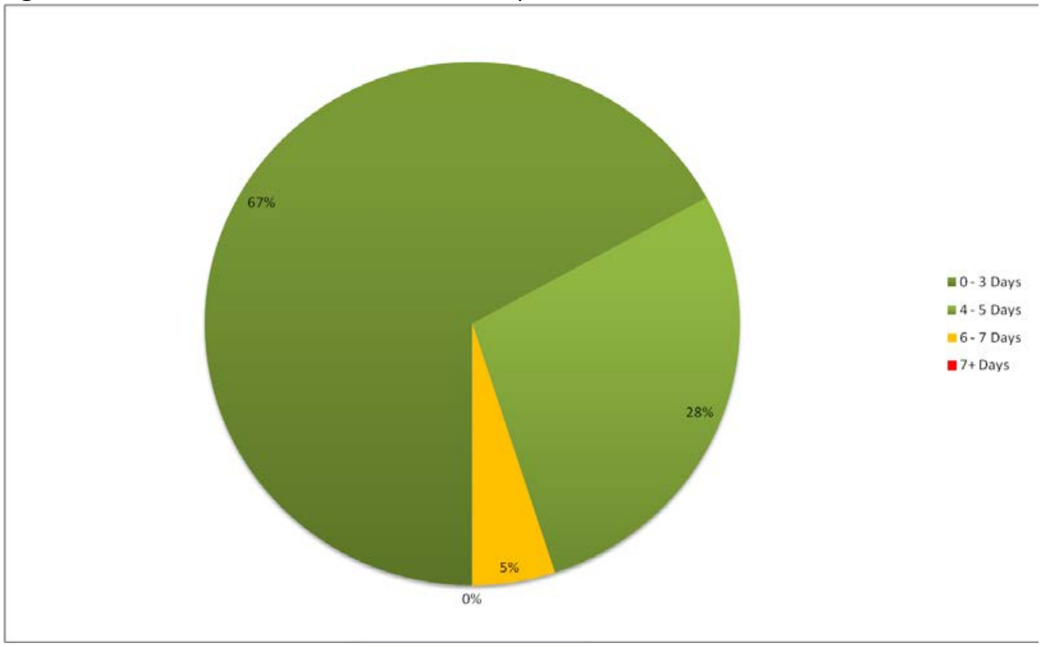

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Figure 3. Days from planting versus BBCH Stage for Pilot Mound

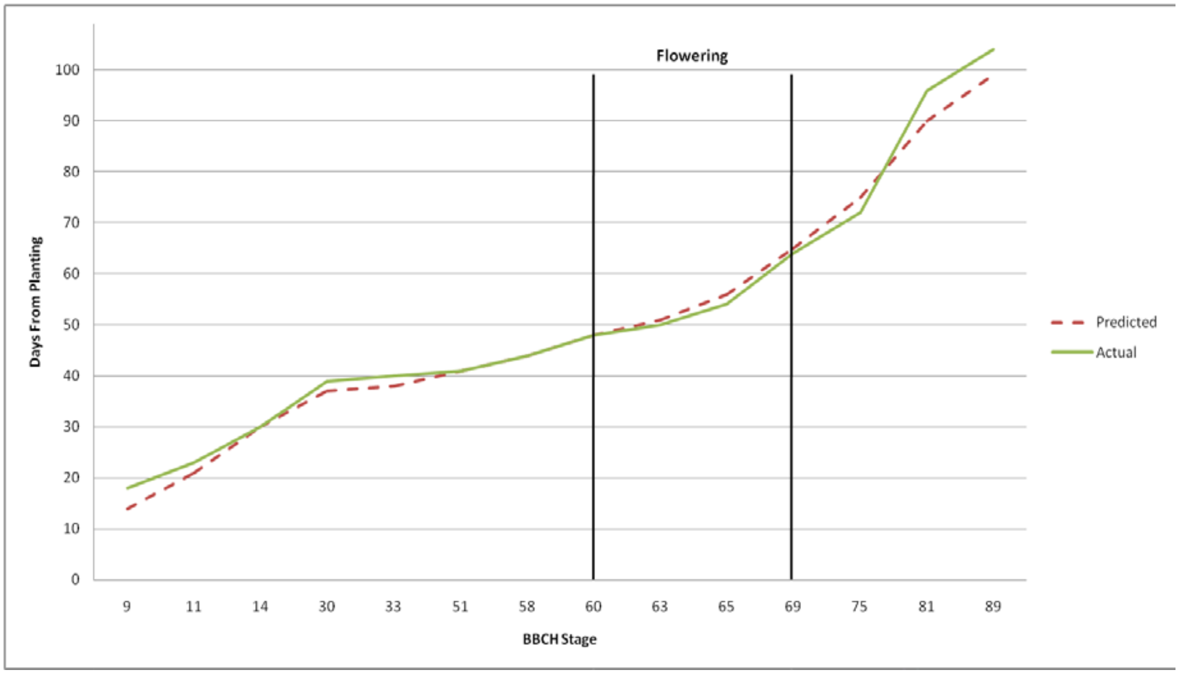

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Figure 4. Days from planting versus BBCH Stage for Rosser

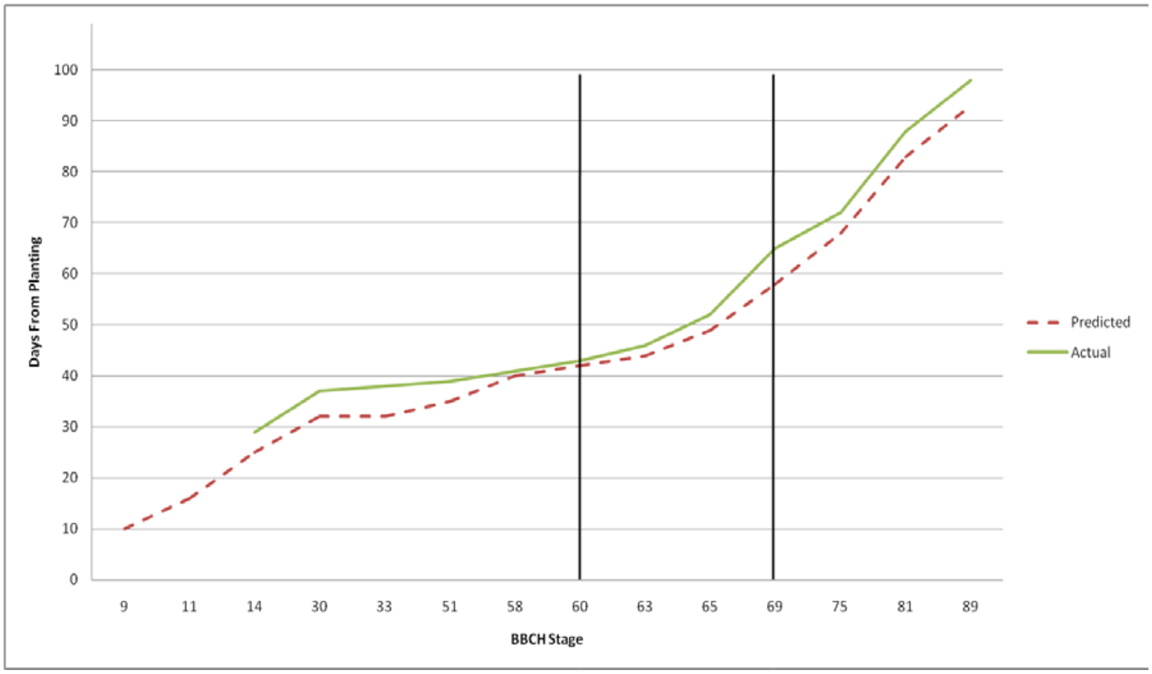

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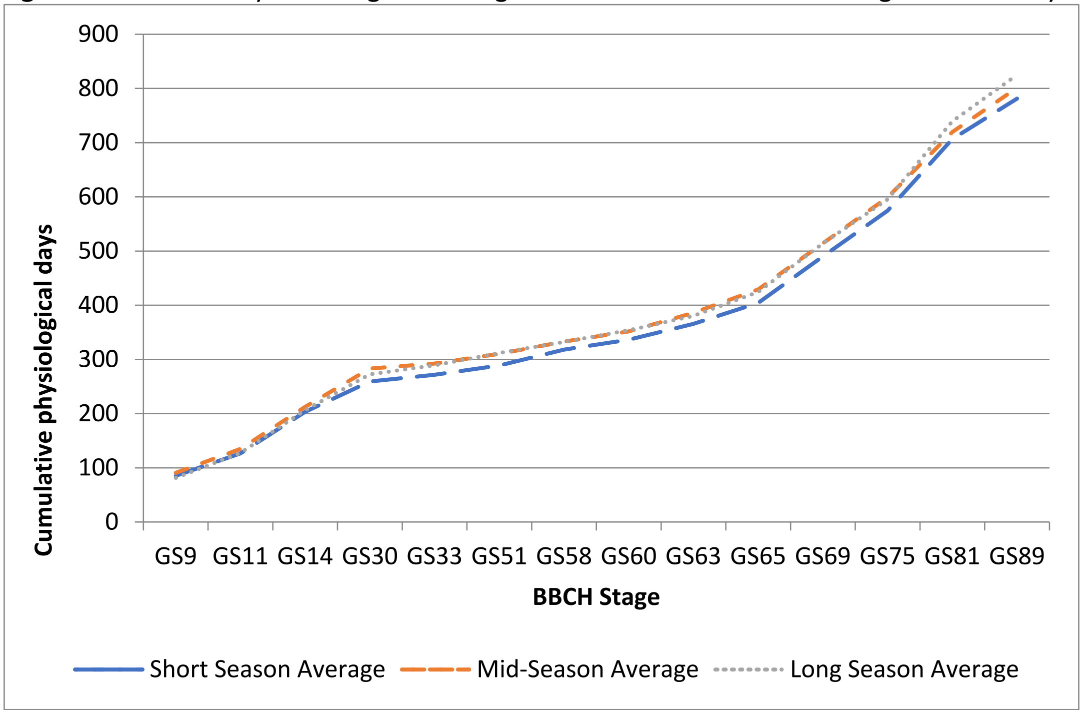
Figure 5. Canola P-days verses growth stages for all season cultivars averaged over four years



Sclerotinia stem rot (SSR) incidence and modelling

The sclerotinia stem rot incidences were widespread ranging from 0% (numerous years) to 55% (Gleanlea, Manitoba in 2014) in the four years of research trials. Out of the 7 field trials in Manitoba in 2014 only 2 had SSR incidence higher than 10% and in 2015, 5 field trials had SSR incidence higher than 10% (Table 2). In 2016, sclerotinia incidence was slightly higher in Manitoba since 5 out of the 12 sites the incidence was greater than 12% and was highest in Pilot Mound where it was 17%. Average severity was about 3 on a scale of 0-5 (0 = none, 5 = highest severity) at the sites where the incidence was higher. The rest of the sites had incidences lower than 5%. In IHARF (Indian Head, Saskatchewan), the incidence was 13%, however, the severity was about 1. Meanwhile in Alberta, the incidence was 2% in Castor and 0% in Forestburg. In 2017, sclerotinia incidence was again low as in Manitoba it ranged from 0% in Portage la Prairie to 8.8% in Kelburn. For all years, there was no sclerotia germination at the sites where sclerotia depots were installed.

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Table 2: Sclerotinia stem rot (SSR) incidence (%) in canola in 2014, 2015, 2016 and 2017

Province	Location	2014	2015	2016	2017
Manitoba	Arborg	-	-	-	-*
	Beausejour	1.8%	-	-	-
	Carman	9.3%	13.3%	-	-
	Chortitz	-	-	-	3.3%
	Holland	5.0%	14.0%	4%	1.2%
	Gleanlea	55.4%	0.0%	3%*	-
	Haywood	2.3%	1.7%	-	-
	Landmark	-	17.4%	-	-
	Oak Bluff	1.6%	-	-	-
	Portage North	36.8%	10.8%*	13%	0.0%
	Portage South	-	-	13%	-
	Teulon	-	23.3%*	-	-
	Thornhill	-	-	-	2.6%
	Pilot Mound	-	-	17%	5.0%
	Elm Creek	-	-	2%	-
	Kelburn	-	-	12%	8.8%
	Balmoral	-	-	7%*	-
	Brunkild	-	-	15%*	-
	Headingley	-	-	2%	-
	Netley Colony	-	-	3%	-
	La Rivière	-	-	3%*	-
	Morden	-	-	-	0.26%
	Winkler	-	-	-	-*
	Starbuck	-	-	-	-*
	Rosser	-	-	-	-*
Saskatchewan	Indian Head	-	0.0%	13%	-
	Prince Albert	-	0.0%	-	-
Alberta	Castor	-	8.2%	2%	-
	Settler	-	0.0%	0.0%	-

**represents field scale trials that were treated with a fungicide, small plot trials were never treated*

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For the sclerotinia model we focused on trials instead of specific locations since each trial potentially had different flowering periods. When all years were combined we had 77 trials with sclerotinia records however 28 of those trials were treated with fungicide. Therefore we used the 49 trials that were not treated with fungicide and found that 18 trials had a high incidence of sclerotinia (a high incidence of sclerotinia was determined to be greater than 10%). Specifically, in 2014 there were 7 trials with high sclerotinia incidence out of 14, 2015 had 3 of 11 trials, 2016 had 7 of 15 trials and lastly 2017 had 1 of 9 trials with a high incidence of sclerotinia. Also, for this model we did not use varietal sclerotinia susceptibility as all canola varieties used were susceptible to sclerotinia as referenced from the Canola Council of Canada website (https://www.canolacouncil.org/canola-encyclopedia/diseases/sclerotinia-stem-rot/) and the Manitoba Agriculture, Food and Rural Initiatives (https://www.gov.mb.ca/agriculture/crops/plant-diseases/print,sclerotinia-canola.html).

For the SSR score card that was developed for the SSR model, Weather Innovations studied numerous research papers and models, including: 1) the France model based on Oilseed Rape by Makowski et al. 2005, Crop Protect. 527-531), 2) the Swiss model which was adopted directly from Twengstrom et al. 1998, Swedish model and 3) the Nebraska score card for dry bean white mold by Harveson et al. 2013, NebGuide Oct. 2013. From these 3 models we combined specific agronomic variables including:

Agronomic Risk Factor	Possible Answers	Risk Points
Number of years that canola or host crops where present in trials within the last 6 years	0 host crops	1
	1 host crop	2
	2 to 3 host crops	3
	≥ 4 host crops	4
Disease incidence in last year's crop	Low	1
	Medium	3
	High	4
Plant Density	Low	1
	Normal	2
	High	3

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Varietal Resistance	Resistant	1
	Intermediate/Unknown	2
	Susceptible	4

For the weather parameters for the scorecard, WIN studied different weather parameters around BBCH 65 when the plant is in full bloom. Using temperature, precipitation, and relative humidity, WIN came up with 6 different risk factors which enables the score card to have more emphasis on weather parameters which supports the sclerotinia apothecia to adhere to the canola plants. These weather parameters include:

Weather Risk Factor	Possible Answers	Risk Points
Cumulative rainfall - 2 weeks before BBCH 65	< 7 mm	1
	7 to 15 mm	2
	15 to 30 mm	3
	> 30 mm	4
Average Temperature max (Tmax) - 2 weeks before BBCH 65	< 21°C	3
	21 to 28°C	2
	> 28°C	1
Average Daily Wet Hours (RH > 85%) - 1 week before BBCH 65	< 5 hours	1
	5 to 10 hours	2
	11 to 17 hours	3
	18 to 24 hours	4
Cumulative rainfall - 5 days before to 3 days after BBCH 65:	< 2.5 mm	1
	2.5 to 12.5 mm	2
	12.5 to 25 mm	3
	> 25 mm	4
Days of rain (>1 mm) - 1 week before BBCH 65	0 days	0
	1 day	1
	2 days	2
	3 days	4

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Average Tmax - 5 days before to 3 days after BBCH 65	< 21°C	3
	21 to 28°C	2
	> 28°C	1

Summing up all of the risk factors creates 3 risk categories:

- low risk: < 20 risk points,
- moderate risk: 20 to 24 risk points and
- high risk: > 25 risk points.

WIN's modified scorecard is based around the BBCH 65 growth stage because there is a higher opportunity of infection at this stage because canola plants are at full bloom and flower petals start to drop which creates an environment for sclerotinia germination. Other models use BBCH 63 (30% of flowers are fully open) but in our research the model over predicted sclerotinia infection at this stage. However, our modified model is still able to accurately predict sclerotinia risk at the BBCH 63 stage because it utilizes WIN's 15 day forecast.

When trials were put through our modified model we found that 15 of 26 trials were classified correctly as low or high sclerotinia incidence. Out of the 26 trials, 7 of 8 trials were accurately predicted as low and 8 of 18 were accurately predicted as high. However, the 10 trials out of 18 that were incorrectly classified as high (they were actually low) is not a bad prediction. The fact that an incorrect classifications happens with a high prediction means that the model errs on the side of caution. This outcome is good for farmers because if the model predicted a low sclerotinia incidence when it is actually a high incidence farmers would not be alerted to treat their canola with fungicide and therefore could have a reduced yield because of the damage done by unreported high sclerotinia infestations.

Yield modelling

In 2014, 2015, 2016 and 2017 we had 87 trials with yield results. We found that 60 of these trials were not treated with fungicide, 23 trials were treated with fungicide and 4 trials could not be determined if they were treated or not, therefore, these 4 trials were excluded from our data.

As outlined in Table 3, we found that for years 2014 and 2016 (which had a high incidence of sclerotinia in our

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trials), showed that there was a low average yield for trials that were not treated with fungicide when compared to trials that were treated. In 2015, which had a low presence of sclerotinia incidence in our trials, both treated and untreated fields had similar average yields while in 2017 (also a low SSR incidence year) our trial average yields showed a large difference between fungicide treated and untreated trials. This shows that canola yield cannot be explained only by sclerotinia incidence alone as the untreated trials yielded much lower than the treated but we would have expected the yields to be similar as occurred in 2015 – both treated and untreated trials having similar average yields.

When we looked only at the trials which were not treated with fungicide we found that for all 4 years, trials that had an incidence of less than 10% had a higher average yield then the average yields of trials with an incidence of greater than 10%. For example in 2015, there were 8 trials that had a sclerotinia incidence of less than 10% and averaged a yield of 3391 whereas trials in the same year but had a sclerotinia incidence greater than 10% yielded much lower on average – 2386 (Table 4). However, when we looked at the trials which were treated with fungicides but had less than 10% incidence of sclerotinia we found that the 2015 and 2016 average yields were similar for both fungicide treated and untreated canola trials. However in the 2017 fungicide treated trials we found that when the sclerotinia incidence was not less than 10% it had a much lower average yield then compared to the trials which had less than 10% incidence. We have found that other variables are skewing the data as one would expect that no matter if there was higher than 10% sclerotinia incidence or not the yields should be similar since all of the trials were treated with fungicide - as occurred in 2015 and 2016 (table 5).

Table 3: Sclerotinia incidence and the use of fungicide on average canola yield

Year	High sclerotinia (Yes or No)	Fungicide application (Yes or No)	Number of Trials	Average yield (kg/ha)
2014	Yes	No	14	1871
		Yes	1	3339
2015	No	No	22	3190
		Yes	7	3285
2016	Yes	No	15	2834
		Yes	7	3212

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2017	No	No	9	1900
		Yes	8	3988

Table 4: Sclerotinia incidence greater than 10% and average canola yield in non fungicide treated trials

Year	Sclerotinia incidence > 10%	Number of Trials	Average Yield (kg/ha)
2014	No	7	2063
	Yes	7	1679
2015	No	8	3391
	Yes	3	2386
2016	No	8	2914
	Yes	7	2743
2017	No	8	1970
	Yes	1	1343

Table 5: Low incidence of sclerotinia and treated/untreated with fungicide

Year	Fungicide Treatment	Number of Trials	Average Yield (kg/ha)
2014	No	1	1882
	Yes	0	-
2015	No	8	3391
	Yes	4	3374
2016	No	8	2914
	Yes	6	3214
2017	No	8	1970
	Yes	4	4169

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Since there are numerous variables not associated with weather that were outside of Weather INnovations control, a yield model was not produced. Some of these uncontrollable variables include but are not limited to; fungicide application on trials that were not supposed to have a fungicide applied, flooding (see figure 6), insect damage – in 2017 our Thorndale, Manitoba trial had severe flea beetle damage (see figure 7). Also in 2017, some trials had blackleg (numerous locations – see figure 8), root rot (Holland, Manitoba), lodging (see figure 9), possible nutrient deficiencies and club root damage (Morden, Manitoba) which could all contribute to the lack of consistent yield data for this project. Other inconsistencies include changing of trial locations from one year to the next and using different canola varieties from year to year.

The variables described above showed to have a major impact on yield totals, and were beyond the scope of developing a yield model with weather parameters only. For Weather INnovations to create a canola yield model we would need to conduct trials in a controlled environment where we could control these variables.

Figure 6: Flooding at Beausejour

Figure 7: Flea beetle infestation at Thorndale, Manitoba plots.

Figure 8: Black Leg damage

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Figure 9: Lodging in plots

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ISSUES

2013/14

The major challenge/concern is that the project did not receive final approval until February 2014, which means the start of the project was delayed by 10 months. Another challenge was that we had hoped that the existing canola performance trial (CPT) sites could be utilised for growth stage and SSR observations. However, due to the rigid CPT protocols that are in place, it was decided that we would be better off using other sites. We intend to use yield data from 2014 and onwards (and possibly from previous years) from the CPT to develop the yield model. Nonetheless, we managed to secure seven field sites in Manitoba where the experiments will be conducted in 2014; both growth stages and SSR data will be collected.

2014/15

One issue encountered in 2014 is that the small-plot trials at Holland had a poor emergence and subsequently a poor stand: this was most probably caused by low soil temperature at planting, leaf beetle damage and herbicide damage. This delayed crop development earlier in the season, which resulted in higher total GDD requirements in Holland compared to the other small-plot sites (i.e., Kelburn Farm and Portage la Prairie) for the same cultivars. Another issue was that the Haywood 2 site was broadcast seeded and thus it took longer to emerge. This again resulted in much higher GDD requirements compared to the same variety grown in Holland and planted at almost the same time. The last issue encountered is that there was flooding at Portage la Prairie in mid-July, which made it impossible to visit the site for about 2 weeks. This affected data collection during a critical time when the canola crop was flowering. By the time we were able to get back to the site, the canola had grown higher than the camera and thus some growth stages could not be identified from the pictures.

2015/16

In 2014, we were unable to conduct field trials in Saskatchewan and Alberta due to late start of the project. However, in 2015 the field trials we extended to Saskatchewan and Alberta in 2015. The field trials will be continued in all three provinces in 2016 and we have already confirmed with most collaborators. Sclerotinia stem rot (SSR) incidences were low in most of the locations in both 2014 and 2015, which presents a significant challenge for SSR modelling. We also analyzed the 5-year provincial SSR survey data (2009 to 2014) from Manitoba. We acquired weather data from network of Weather Farm/WIN and Environment Canada. We did not find a strong correlation with weather variables with SSR incidence in survey data. Due to confidentiality issues, actual GPS coordinates for field locations were not obtained. We used nearby town names to acquire weather data, which may increase noise in the data. Also, the survey data were collected from both fungicide sprayed and non-sprayed fields. According to MAFRD, they have no way of knowing whether a

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field was sprayed with fungicides or not. Nevertheless, we developed a SSR risk index and we validated the model using SSR incidence data from our own field trials. The model will be deployed during the 2016 growing season in www.canoladst.com. The model will be further improved and validated using data from the 2016 and 2017 growing seasons.

2016/17

In 2014, we were unable to conduct field trials in Saskatchewan and Alberta due to late start of the project. However, in 2015 and 2016 the field trials were extended to Saskatchewan and Alberta.
Sclerotinia stem rot (SSR) incidences were low in most of the locations in 2014, 2015 and 2016 which presents a significant challenge for SSR modelling. We also analyzed the 5-year provincial SSR survey data (2009 to 2014) from Manitoba. We acquired weather data from network of Weather Farm/WIN and Environment Canada. We did not find a strong correlation with weather variables with SSR incidence in survey data. Due to confidentiality issues, actual GPS coordinates for field locations were not obtained. We used nearby town names to acquire weather data, which may increase 'noise' in the data. Also, the survey data was collected from both fungicide sprayed and non-sprayed fields. According to MAFRD, they have no way of knowing whether a field was sprayed with fungicides or not. Nevertheless, we developed a SSR risk index and we validated the model using SSR incidence data from our own field trials. The model will be deployed during the 2016 growing season in www.canoladst.com. The model will be further improved and validated using data from the 2017 growing season.

2017/18

In 2014, we were unable to conduct field trials in Saskatchewan and Alberta due to the late start of the project, but in 2015 and 2016 the field trials were extended to Saskatchewan and Alberta. Sclerotinia stem rot (SSR) incidences were variable from year to year which presents a significant challenge for SSR modelling. Also, the data was collected from both fungicide sprayed and non-sprayed fields. According to MAFRD, they have no way of knowing whether a field was sprayed with fungicides or not. Nevertheless, we developed a SSR risk index and we validated the model using SSR incidence data from our own field trials. In 2017, our field contractors were not available to look after canola plots in Alberta or Saskatchewan and therefore Weather Innovations focused all of the trials in Manitoba with the help of University of Manitoba personnel. We also had some of the trials sprayed with fungicides by farmers and industry partners which made it difficult to get good sclerotinia population and therefore some trials were not used. For the sclerotinia model to run correctly it requires field data such as host crops for the past five years and the number of canola crops in the past ten years. For locations that did not have sufficient cropping history data we relied on data from Agriculture and

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Agri-Food Canada Annual Crop Inventory website (http://www.agr.gc.ca/atlas/aci). Lastly, in all years, sclerotinia depots did not germinate as field conditions were too dry because of a lack of rainfall which made it difficult to get sclerotinia infections.

As described in the above yield model description, there were numerous variables not associated with weather that are outside of Weather Innovations control. Some of these uncontrollable variables include flooding in the spring and other environmental issues. In some occasions we had time lapse cameras that were not properly installed or that broke mid way into the season. Some trials had flea beetle damage, blackleg damage, root rot, lodging, nutrient deficiencies and club root damage which could all contribute to inconsistent data.

LESSONS LEARNED

2015/16

This project used collaborative efforts in conducting field trials, installing and maintaining equipment/weather stations as well as data collection. We collaborated with Indian Head Agricultural Research Foundation (IHARF) and Conservation Learning Centre to conduct field trials and data collection in Indian Head and Prince Albert in Saskatchewan. We collaborated with Battle River Research Group in Alberta. We let our collaborators hire summer research assistants to collect data. Periodic monitoring of the sites by the Project Coordinator helped to ensure the weather stations and time-lapse cameras were working well and data were downloaded on time.

2016/17

In 2016, we collaborated with DL Seeds and Bayer Crop Science in Manitoba, Indian Head Agricultural Research Foundation in Saskatchewan and Battle River Research Group (BRRG) in Alberta. We let our collaborators hire summer research assistants to collect data. Periodic monitoring of the sites by the Project Coordinator helped to ensure the weather stations and time-lapse cameras were working well and data were downloaded on time.

2017/18

In 2017, we collaborated with the University of Manitoba, DL Seeds and Bayer Crop Science in Manitoba. We let our collaborators hire summer research assistants to collect data. Periodic monitoring of the sites by the Project Coordinator helped to ensure the weather stations and time-lapse cameras were working well and data were downloaded on time. Due to the inconsistencies in the yield data as described in the above write up we believe that if we had another 4 years of data in a controlled environment we could establish a better yield model which would be useful to farmers.

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FUTURE RELATED OPPORTUNITIES

2013/14

Field research will start during the 2014 growing season and preparations are well underway. Seven field sites have been secured and equipment has been purchased. The integrated web platform (www.canoladst.com) is being developed and will be available for 2014 cropping season (Appendix 1). Prototype-prediction models for phenology, SSR are expected to be developed for the 2015 cropping season and will be demonstrated for web delivery at www.canoladst.com. We are also expecting that complimentary work being undertaken by Dr. Lone Buchwaldt (AAFC, Saskatoon) for predicting spore germination and by Dr. Aston Chipanshi and other collaborators work will improve the forthcoming integrated crop management tools.

2014/15

N/A

2015/16

For SSR modelling, we were intending to integrate data from the 'Sclerotia germination' project lead by Dr. Buchwaldt (AAFC). However, there was very low to no germination of Sclerotia in all locations in Saskatchewan and Manitoba in 2014 and 2015 since both years were relatively dry, particularly during the flowering period. The 'Sclerotia germination' project will be continued in 2016. For yield modelling, the model being developed by Dr. Chipanshi (AAFC) will be improved using the phenology model that is being developed and the yield data collected through this project.

During the 2016 growing season, both the growth stage prediction model and the SSR risk calculator will be deployed to provide site-specific advisories to canola growers in western Canada. A webpage (http://canoladst.ca) has already been designed to make these models operational in all three Prairie Provinces. The information about model deployment will be provided to the project collaborators, public and private researchers, provincial crop specialists as well as agronomists of canola council. Inputs and comments from expert panel and growers will be used to further improvement the models and deployment of the models. Weather Innovations will do networking with other private companies and also discuss with the Canola Council of Canada and grower groups for continuous deployment of these crop management tools in the future.

2016/17

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Both the growth stage prediction model and the SSR risk calculator are deployed to provide site-specific advisories to canola growers in western Canada. A webpage (http://canoladst.ca) has already been designed to make these models operational in all three Prairie Provinces. The information about model deployment will be provided to the project collaborators, public and private researchers, provincial crop specialists as well as agronomists of canola council. Inputs and comments from expert panel and growers will be used to further improvement the models and deployment of the models. Weather INnovations will test the new producer communications tools in 2017 to be sure there is support for continuous deployment of these crop management tools in the future.

2017/18

Additional years of research would be ideal as many compilations occurred which may have created noise with the data. If we had more years to carry out the research we would only choose locations in which we could get the past 10 year history on the fields and make sure that collaborators do not use fungicides on any of the trials. We would also try to get better sclerotinia population by inculcating canola with sclerotinia and/or irrigation techniques to help promote sclerotinia germination. With further years of data we could obtain better yield data by growing canola in a controlled environment.