Project No. R21013P
Date: March 31, 2023
Humboldt, Saskatchewan

Quantifying Combine Auto-Adjusting Capabilities in Canola

TECHNICAL REPORT

Submitted To: **Saskatchewan Canola Development Commission (SaskCanola)**
Western Grain Research Foundation (WGRF)

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ACKNOWLEDGEMENTS

The Prairie Agricultural Machinery Institute (PAMI) acknowledges funding for this project from the Saskatchewan Canola Development Commission (SaskCanola) and Western Grains Research Foundation. PAMI also acknowledges Bushel Plus and Schergain for providing support for this research program. PAMI also acknowledges the many canola producers throughout Saskatchewan and Manitoba who volunteered to participate in this project.

1. EXECUTIVE SUMMARY

Canola is an essential crop in the Canadian Prairies, and canola losses are an unfortunate part of harvest that must be managed by producers. Canola losses can be categorized as either environmental losses, header losses, or combine losses. Environmental losses occur prior to cutting or gathering; header losses occur during swathing, swath pickup, or when straight cutting; and combine losses occur during harvesting and refer to grain lost (discarded with the chaff and straw) from the separation and cleaning systems. In 2019, the Prairie Agricultural Machinery Institute (PAMI) conducted a survey of canola losses in Western Canada to identify the harvest factors that impact canola harvest losses. This study found that weather conditions are a key factor influencing combine losses, and that combines should be set based on these conditions. It is important for producers to reassess their combine losses as conditions change both throughout the day and harvest season (PAMI, 2019). Auto-adjusting separation and cleaning systems being introduced by the major combine manufacturers may provide a daily opportunity for producers to retain more seed by automatically adjusting settings to reduce losses throughout a harvest day as environmental conditions change.

The objective of this project was to build on the study completed in 2019 and further investigate the effect of changing environmental conditions during a harvest day and the methods used to adjust “on-the-fly” to minimize losses. A total of 22 combines were tested (11 with auto-adjusting capabilities and 11 without).

The data collected and analyzed in this study found that mean daily temperature had a significant effect ($P<0.05$) on harvest yield loss while variation of temperature and humidity throughout the day (represented by standard deviation) did not appear to have a significant effect on the variability of percentage yield loss throughout the day.

Further, for the 22 combines tested, of which half had auto-adjusting capabilities, the auto-adjusting combines had slightly lower variation in yield loss compared to the manual adjusting capabilities, but this was not a significant difference, statistically. More importantly though, it was observed that the range of variation for the manual adjusting combine types was much lower than the auto-adjusting types. This indicates that auto-adjusting combine types still need calibration and monitoring to ensure that they are operating properly to respond to changing conditions and losses.

There is not a standard set of combine settings that can be attributed to specific losses. Each combine, operating in particular conditions for a specific crop, must be optimized for the given environment. Auto-adjusting capabilities in new combines have the potential to effectively respond to changing environmental conditions, but they cannot just be set and forgotten. They should be calibrated regularly, and it is important to regularly measure losses to ensure adjustments are made to properly optimize harvest yield by reducing combine losses. While it may allow more frequent adjustment to changing conditions without the inefficiencies of conducting loss measurements manually, auto-adjust feature does not negate the requirement to measure. Further, it can be said that any method to check for losses is better than not checking at all.

It should be noted that most data collected during this project was obtained directly from producers; therefore, the accuracy and consistency of this data greatly relied on the calibration methods used by each producer. This should be considered when assessing the results of this project.

2. INTRODUCTION

Canola production is an essential part of Canada's economy. A study commissioned by the Canola Council of Canada revealed that Canadian-grown canola contributes $26.7 billion to the Canadian economy, along with 250,000 jobs (Canola Council of Canada, 2016). Approximately 43,000 farms grow canola in Canada, the majority of which are in Alberta, Saskatchewan, and Manitoba (Canola Council of Canada, 2016). **Table 1** lists the major canola-producing provinces and the total 2018 and 2019 harvested area for each. **Figure 1** illustrates the density of canola production throughout Canada.

Table 1. Harvested areas of canola, by province.

Province	2021 Harvested Area of Canola[a]	2022 Harvested Area of Canola[a]
Saskatchewan	11,920,511 ac (4,824,100 ha)	11,348,400 ac (4,592,500 ha)
Alberta	6,619,132 ac (2,678.700 ha)	6,476,300 ac (2,620,900 ha)
Manitoba	3,389,984 ac (1,371,900 ha)	3,219,500 ac (1,302,900 ha)

[a] Statistics Canada, 2023

Figure 1. Canola growing region map (Statistics Canada, 2023)

With such a large fraction of arable land being dedicated to the annual production of canola, there is significant opportunity for increased production efficiency by making technical resources available to producers for management decisions that decrease losses. However, research results regarding yield losses during canola production are currently insufficient to guide producer management practices. Research is essential to enhance the understanding of factors affecting harvest losses and determining methods to aid in alleviating some of the challenges faced by producers.

Total canola harvest losses can be divided into three main types: environmental loss, header loss, and combine loss. A regional study conducted by Gulden et al. in Western Canada revealed that for the fields and producers tested, the average total harvest loss was 5.79% (Gulden, Shirtliffe, & Thomas, 2003). Environmental losses occur prior to cutting or gathering. Header losses occur during swathing, picking up swaths, or when straight cutting. Combine losses occur during combining and refers to grain that has passed through the combine and is discarded with the chaff and straw. Of the three harvest losses considered, combine losses offer the greatest opportunity for reduction by operator adjustment. For the purposes of this project, only combine losses will be considered and investigated, with the goal being to determine how much canola loss is attributed to combine loss.

The 2019 study revealed that ambient temperature, relative humidity, and general weather conditions had a significant impact on losses experienced by producers (PAMI, 2019). For the tests completed, it was found that ambient temperatures below 73.4°F (23.0°C), relative humidity above 45%, and cloudy weather all caused significantly higher combine losses. The general trend of lower temperatures and higher relative humidity causing increased losses was identified to producers. Environmental conditions not only change over the course of a harvest season, but also throughout each day of harvest. It is important for an operator to understand how changing ambient conditions impact the losses of a particular combine and when adjustments to their machine are needed.

Since total combine loss has been shown to be statistically different according to ambient conditions (PAMI, 2019), the opportunity exists to control losses by adjusting combine settings. Adjustments that can be made include any combination of fan speed, rotor/cylinder speed, concave clearance sieve openings, and ground speed. The challenge with manually adjusting combine settings to compensate for changing conditions is the need to check losses at regular intervals to inform that decision. Then, with each adjustment comes the need for another loss check to confirm that the desired loss reduction has been achieved. The loss check process must be repeated for each combine in the field each day if an optimized set-up is to be realized.

Recently, auto-adjusting separation and cleaning systems introduced by the major combine manufacturers may provide a daily opportunity for producers to retain more seed by automatically adjusting settings to reduce losses throughout a harvest day. These manufacturers have invested millions of dollars into the development and testing of their unique control systems. In theory, these control systems should translate into a combine operator being free to use a “set it and forget it” process, where the combine performs the adjustments to optimize a particular operating set point based on current ambient conditions.

The challenge for canola producers is the small seed size and large amount of material other than grain (MoG) to process. The relative seed weight compared to MoG makes setting a combine for canola more challenging than large-seed crops, like corn. If combines with new auto-adjusting technology can compensate to optimize capacity while reducing losses in canola, producers stand to realize tremendous gains. Quantifying the performance in small grain, such as canola, will allow producers a way to potentially improve field performance and reduce losses. This is especially important as less experienced combine operators are needed to fill the void of increasingly scarce experience farm labour.

The objectives of this project are presented as follows:

1. Quantify the change in conditions during a typical harvest day and the effect on combine losses while harvesting canola.
2. Measure the performance potential of combines with auto-adjusting settings while harvesting canola.

3. MATERIALS AND METHODS

This project can be separated into three distinct phases: project planning and preparation, field testing, and data analysis and reporting. The tasks and methodology completed for each of these phases are explained in the following sections.

3.1 Project Planning and Preparation

The scope of this project targeted a voluntary participation of 40 combines from across Western Canada. Producers in Saskatchewan (SK) and Manitoba (MB) were targeted due their proximity to PAMI test sites to most efficiently utilize resources. The high amount of effort required to collect combine loss data is highlighted in the report for the 2019 survey (**Appendix A**). PAMI promoted the project by contacting interested producers from a database compiled from previous research projects, such as PAMI's 2019 combine loss survey and other social media campaigns to engage producers. In total, approximately 40 canola producers demonstrated interest in participating. These producers were then prioritized by harvest timing, location, and equipment type to determine from which sites data would be collected.

A survey was used to obtain preliminary information from producers. The survey requested information such as farm location, contact information, combine type, canola variety, canola acres, and total acres. This information was then used to ensure producers met the requirements for the research project.

A total of 22 combines were tests from a total of 13 producers. Half (11) of the combines had auto-adjusting capabilities. Harvest windows in 2022 were short and intense, and because only one site could be completed per day, not all interested producers could be visited. Further, each combine tested had to operate for an entire day to collect three unique timing samples for the procedure; as such, late starts or half days were not conducive to the testing. However, even with fewer combines tested than targeted, the data set that was collected, evenly balanced, and provided quality data to analyze.

3.2 Field Testing

Field testing was conducted between September 9 and October 10, 2022, throughout the Saskatchewan and Manitoba. It was important that the collected data represent a cross section of canola producers in the Canadian Prairies. This meant testing as many different brands and types of combines as possible while ensuring an even split of auto- and manually adjusting combines to balance the data set for analysis.

3.2.1 Biosecurity and Safety Measures

Biosecurity and safety were extremely important aspects of field testing. A biosecurity protocol was developed using the Canola Council of Canada field entry policy (Canola Council of Canada) and adapted for the specifics of this project. To avoid bio-contamination between test fields, it was important to take the appropriate steps to prevent transfer of crop contaminants, such as weed seeds, insects, and pathogens. Key points were identified for the biosecurity protocol, and included only entering fields on foot, using boot covers, and spraying down equipment with disinfectant.

Safety is essential for any project work, and field projects are no exception and often require more attention due to extensive work with ever-changing groups of producers and project volunteers. Field-work safety meetings were completed with every producer prior to conducting in-field loss measurement testing. The safety meeting included discussions on machinery and the hazards associated with working around moving combines, hazards associated with using disinfectant, as well as sound levels, dust conditions, and working alone.

All of the above information was shared with the producer prior to beginning field testing. Each producer was asked to sign the data collection sheet to acknowledge that the biosecurity protocol, safety form, and testing protocol had been reviewed with them.

3.2.2 Equipment

The combines tested throughout the duration of this project were provided by the producers who volunteered to participate. Four different manufacturers were represented: Case IH, Claas, John Deere, and New Holland. For this study, only the losses between combines with and without auto adjust were compared. The combine losses between combine manufacturers were not compared.

Drop pans are the primary tool used to measure combine losses. The pans are dropped to the ground from the rear of the combine, below the machine's separation and cleaning system, where they collect any refuse material exiting the machine (chaff, seed, etc.). There are a few commercially available systems that producers can purchase to measure and manage their own losses. This project used Bushel Plus loss pans; there are other loss pan manufacturers, such as Schergain; however, it was decided that only one pan type would be used to minimize any potential variability in the collection method, and PAMI owns a set of Bushel Plus loss pans.

The Bushel Plus drop pan comprised a cover that was directly attached to the combine and a drop pan that is secured to the cover with magnets. This drop pan has interior dimensions of 10.0 in (25.4 cm) by 59.3 in (150.6 cm), with a catch area of 4.11 ft^2 (0.38 m^2). The pans are equipped with remote controls that allow release of the drop pan at the optimum time during combine loss testing.

Figure 2. Bushel Plus drop pan. (image source: http://bushelplus.ca/bushel-plus-harvest-loss-system/)

The canola samples were collected from the pans and weighed with calibrated scales. These weights were then entered into the loss equation shown in **Section 4.2.4**.

3.2.3 Combine Loss Testing

Extensive communication occurred between PAMI and the producers prior to any field testing. This provided PAMI with the best opportunity to successfully visit as many of the cooperating producers during their canola combining window. With ongoing changes to harvest schedules (due to weather), this constant line of communication was essential to the success of this project. Once producers had communicated an estimated timeframe for their canola harvesting, they were added to the schedule. As their estimated timeframe approached, emails and phone calls were exchanged to confirm the timing. If weather and schedule aligned, the producers received a call from the PAMI team the day prior to testing. During this call, location and arrival time were confirmed.

The objective of this methodology was to collect data at three times throughout the day for a single combine to investigate the effect of changing environmental conditions on combine losses as well as an operator's or machine's ability to adjust to current conditions.

The following procedure was completed at the beginning of the harvest day, then repeated mid-afternoon and again at the end of the day.

An in-field survey was completed with the participating producers (**Appendix B**). This survey included questions related to

- weather conditions (relative humidity, ambient air temperature, wind speed),
- crop information (seeding date, seeding rate, canola variety),
- harvest method (swathing, straight-cut),
- combine information (make, model, year, type, hours),
- harvest information (yield, discharge width, canola moisture content),
- combine auto-adjusting capability (yes or no), and
- combine settings (fan speed, rotor/cylinder speed, sieve opening, ground speed).

The weather conditions were taken from Environment Canada's weather app, which was used in the 2019 study as well as cross referenced with an in-field, non-calibrated temperature and RH meter.

Producers were instructed to operate as normal and were allowed to make adjustments (either enabling auto-adjusting or completing manually) as they would during normal operation.

When this information was collected, PAMI field-test personnel observed the following test procedure:

1. A photo of the test combine was taken.
2. The producer was asked to disengage the chopper and spreader, if feasibly possible.
3. Field-test personnel worked with the producer to safely attach a drop pan to their combine. The Drop pan was attached to either the back axle or belly of the combine, in a location where canola could not be prematurely collected (always ensuring that the combine operator was aware of field test personnel location and out of the combine cab while attaching the drop pan).
4. Each combine was allowed to reach steady state (20 seconds) before the remote control was used to drop the pan.
5. Once the combine operator moved far enough away, field-test personnel approached the test area to retrieve the drop pan.
6. The discharge width of the straw and chaff was measured with a stake and tape measure and recorded.

For each combine, three test repetitions were completed.

3.2.4 Sample Collection and Loss Calculation

After each repetition, the canola was carefully separated from the straw and chaff using fans and sieves. For larger sample sizes, this was completed in multiple steps. The canola samples from each repetition were stored in labelled containers to be measured and weighed upon completion of all repetitions. The samples were weighed using a calibrated scale, and the data recorded on the in-field survey sheet. The following equation was used to calculate canola combine loss:

$$\boldsymbol{Loss}\left(\frac{bu}{ac}\right) = \frac{\boldsymbol{Collected\ Weight}\ (g)}{\boldsymbol{Catch\ Area}\ (ft^2)} * \frac{\boldsymbol{Discharge\ Width}(ft)}{\boldsymbol{Cut\ Width}(ft)} * \frac{1}{\boldsymbol{Canola\ Density}\left(\frac{lb}{bu}\right)} * \frac{43{,}560\ (\frac{ft^2}{ac})}{453.6\ (\frac{g}{lb})}$$

Where:

Collected Weight (g): Weight of canola collected during loss test.

Catch Area (ft^2): Area of drop pan used for testing.

Discharge width (ft): Width of dropped or spread chaff and straw. Measured in field.

Cut Width (ft): Obtained from producer; swather width or straight-cut header width.
Canola Density: 50 lb/bu.

This method used only the weight of the collected canola sample to determine losses; however, it is important to note that there are other suitable methods that use volume and seed count. **Appendix B** includes PAMI's final report from the 2019 on-farm survey. Within the report, Appendix A includes the Combine Seed Loss Guide, which discusses these other methods (Canola Council of Canada and PAMI, 2017).

3.3 Data Analysis

The data collected during the tests were statistically analyzed using analysis of variance (ANOVA) in R software. Statistical analysis helps to determine whether differences observed in the data are due to the measured variables or due to random variability. A statistically significant result means that the difference exhibited is highly likely to be due to the treatment itself. The loss data was tested for normality (**Figure 3**). For most of the variables considered, an ANOVA was completed to determine the effect of each variable on the observed losses. If a P-value of less than 0.05 was observed, then the null hypothesis is rejected with 95% confidence. The P-value is a calculated probability and can be used to conclude whether there is a statistically significant difference between treatments. A P-value of less than 0.05 means there is a 95% confidence level with the results. For all statistical analysis, a 95% confidence level was used.

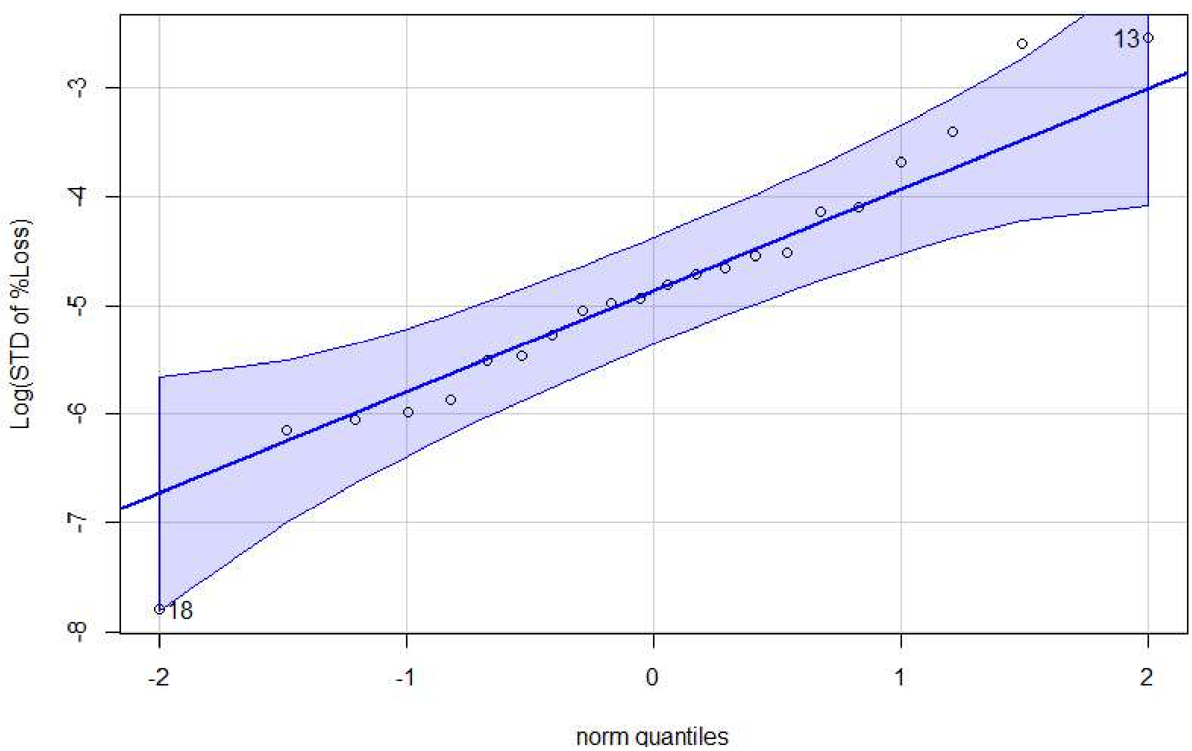

Figure 3. Test for normality of data (STD % yield loss) for the combines tests.

The objective of the project was to compare the variability in losses throughout a day. As such, the standard deviation from the three tests throughout the day for each combine was calculated to represent the variability in changing conditions throughout the day. This standard deviation was then used for the ANOVA to compare between combines for different parameters. It should be noted that most of the data collected for this project – particularly the combine settings – was obtained from producers and not measured by PAMI field-test personnel; therefore, the accuracy of this data is dependent on the calibration methods used by each producer.

4. RESULTS AND DISCUSSION

This section discusses the results obtained from the combine loss testing.

4.1 Data Summary

This project collected combine loss data from 22 combines owned by 13 different canola producers across Saskatchewan and Manitoba.

The following points describe the breakdown of tests completed on the combines:

- Combine manufacturers: 4; combine models: 14.
- Swathed loss tests: 8; straight-cut loss tests: 14 .
- Auto-adjusting capabilities: 11; manual adjusting: 11.

Table 2 provides an overview of the data that was collected for all 22 combines tested. This table provides a high-level overview of the farming operations that are represented within this project.

Table 2. General data summary of 22 test combines.

Variable	Minimum	Maximum
Seeding Date	24-May-22	8-Jun-22
Canola Seed Rate, lb/ac (kg/ha)	3.8 (4.3)	5.2 (5.8)
Row Spacing, in (cm)	9.0 (22.9)	12.0 (30.5)
Spray or Swath Date	18-Aug-22	16-Sep-22
Cut Width, ft (m)	32.0 (9.8)	49.0 (12.8)
Harvest Date	9-Sep-22	10-Oct-22
Yield, bu/ac (MT/ha)	20.0 (1.4)	65.0 (4.4)
Moisture Content, %	5	11
Calculated Loss, bu/ac (kg/ha)	0.1 (6.7)	10.6 (712.9)
Percent of Total Yield Lost, %	0.2	29.4

The losses experienced by the 22 combines with dropped straw ranged from 0.1 bu/ac (6.7 kg/ha) up to 10.6 bu/ac (712.9 kg/ha), giving a range of 0.1% to 10.6% of total yield loss due to combine losses. It should be noted that the loss values represent the average losses for each combine over three repetitions at a particular time of day. Note: there were a few measurement points that were extremely high; however, the goal was to collect real data. These points were tested for outliers but were not deemed to be.

Table 3. Ambient conditions during testing.

Variable	Minimum	Maximum
Relative Humidity, %	20	80
Air Temperature, °C	6	27

It should be noted that the combines were not specifically optimized for the various field conditions and harvest types. Combines were tested at the settings determined by each individual producer.

4.2 Data Analysis Results

The data collected during the tests were statistically analyzed using ANOVA in R software.

4.2.1 Environmental Conditions

An objective of this project was to assess the effect of environmental variability within a harvest day on the variability of combine losses as a percentage of yield. The standard deviation from the three tests throughout the day for each combine was calculated to represent the variability in changing conditions throughout the day. This standard deviation was then used for the ANOVA to compare between combines.

The effect of varying relative humidity on combine loss variability throughout the day did not appear significant across all combines tested.

The number of days into testing (i.e., early September vs early October) also did not appear to be significant. In an effort to identify an observable affect on results as the weather changed throughout the harvest season, this variable was brought in to normalize the daily mean temperature (average of all temperature data through the day rather than variability between the three test times) and daily mean relative humidity values.

The temperature standard deviation from the three tests was reviewed (in an attempt to represent the changing conditions as the day progressed) and did not appear to be significant. However, daily mean temperature was the only variable tested that appeared to be significant ($P<0.05$). As daily mean temperature increased, yield loss variation increased. **Figure 4** illustrates the standard deviation as a percentage of loss (SD % loss) for each combine test compared to daily mean temperature; auto and manual combine types are differentiated.

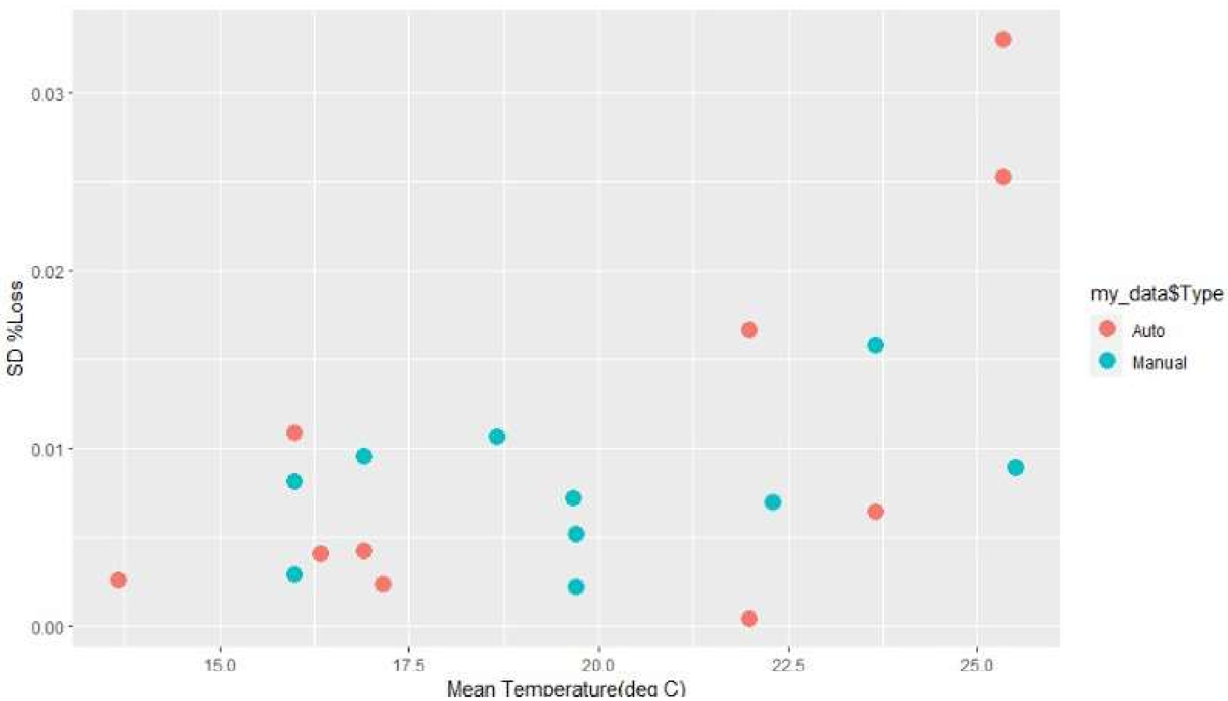

Figure 4. Standard deviation of % loss across three test points in a day relative to mean daily temperature for each combine split between manual and auto adjusting combine types.

There also was not a significant difference (P=0.56) between swathed and straight cut operations which is sometimes a process impacted by environmental conditions.

4.2.2 Equipment Operating Conditions

The study in 2019 found that operating conditions such as ground speed and grain feed rate had an impact on losses. These parameters represent easy-to-adjust factors impacting the loaded threshing capacity during operation.

Ground speed (mph) during the three tests throughout the day did not appear to be significant. This variable was attempted initially to represent whether a combine operator may be overloading the threshing area. The average grain feed rate (bu/hr) during the three tests throughout the day also did not appear to be significant.

It should be noted that fleet effect is possible, as multiple combines were tested at some of the sites. Operators typically communicate to make adjustments to ground speed even if they are not regularly checking losses on all combines.

4.2.3 Auto-Adjusting Capabilities

The other objective of the project was to assess the potential auto-adjusting capabilities of new combine models to respond to changing environmental conditions in order to reduce losses. The standard deviation of the average losses across the three tests was once again used to represent variation throughout the day. However, when comparing auto- vs manual-adjusting combine types across the data set, there did not appear to be any significant difference (P=0.80) with respect to average yield loss (as a percentage of total yield).

While there is no significant difference between auto-adjusting and manual-adjusting capabilities for the mean variability in percentage of yield loss for a single combine, there does appear to be a large variability in the observed variation as illustrated in the box and whisker graph in **Figure 5,** where the mean is indicated by the dark horizontal line, the height of the box spans the standard deviation, and the whiskers indicate the minimum and maximum values. While the manual adjust mean variation is slightly higher (not significantly) than the auto adjusting types tested, the range of potential variation is much smaller. This indicates that while auto-adjusting capabilities may be able to adjust to changing conditions as well as manual adjusting types, they cannot be blindly relied upon (i.e., a “set it and forget it” mindset should not be employed).

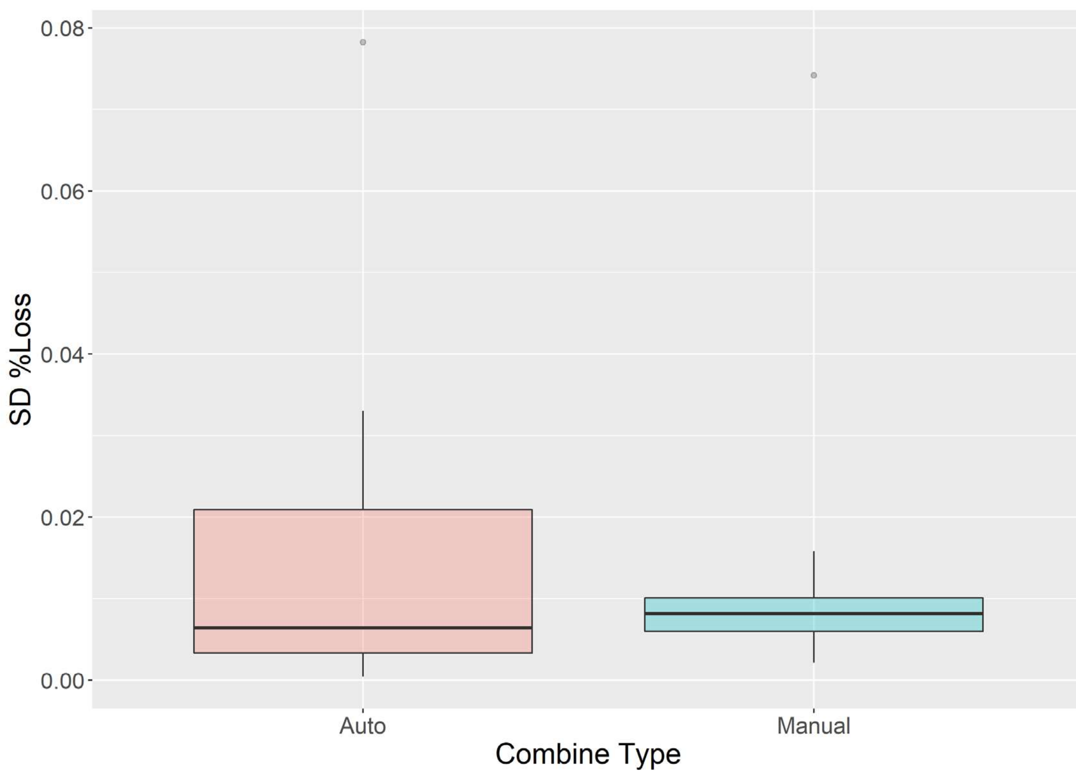

Figure 5. Box and whisker graph for standard deviation of % yield loss for auto and manual adjusting combine types.

5. CONCLUSIONS AND RECOMMENDATIONS

The goal of this project was to continue the survey style work of a study completed by PAMI in 2019, by further investigating the effect of changing environmental conditions throughout a harvest day and the capabilities available for adjusting to these changes.

The data collected and analyzed in this study found that mean daily temperature had a significant effect ($P<0.05$) on harvest yield loss while variation of temperature and humidity throughout the day (represented by standard deviation) did not appear to have a significant effect on the variability of percentage yield loss throughout the day.

Further, for the 22 combines tested, of which half had auto-adjusting capabilities, the auto-adjusting combines had slightly lower variation in yield loss compared to the manual adjusting capabilities, but this was not a significant difference, statistically. More importantly though, it was observed that the range of variation for the manual adjusting combine types was much lower than the auto-adjusting types. This indicates that auto-adjusting combine types still need calibration and monitoring to ensure that they are operating properly to respond to changing conditions and losses. The method of data collection is not sufficient for further analyzing the details of what conditions may have caused the large range in variation for the auto-adjusting types.

There is not a standard set of combine settings that can be attributed to specific losses. Each combine, operating in particular conditions for a specific crop must be optimized for the given environment. Auto-adjusting capabilities in new combines have the potential to effectively respond to changing environmental conditions, but they cannot just be set and forgotten. They should be calibrated regularly, and losses should be manually checked occasionally to ensure the machine is operating suitably. As with all harvest scenarios, you cannot make informed management decisions if you do not know what is happening. It is important to regularly measure losses to ensure adjustments are made to properly optimize harvest yield by reducing combine losses. While it may allow more frequent adjustment to changing conditions, auto-adjust features do not negate the requirement to measure. Further, it can be said that any method to check for losses is better than not checking at all.

5.1.1 Recommendations for Further Research

The next recommended phase for this research would be to complete a more controlled, side-by-side analysis of the research questions in this project. That is, it would be valuable to compare manual adjusting, auto adjusting, and no adjusting (as a control) in the same field on the same day to compare variation in losses for the same ambient conditions.

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APPENDIX A

FINAL REPORT: IN-FIELD SURVEY OF COMBINE GRAIN LOSS IN CANOLA ACROSS WESTERN CANADA

Project No. R19038P
Date: January 10, 2020
Humboldt, Saskatchewan

Final Report

On-Farm Survey of Combine Grain Loss in Canola Across Western Canada

For:
Canola Agronomic Research Program
Winnipeg, Manitoba

Innovative Solutions
for Agriculture and Beyond

R19038P
January 10, 2020
Humboldt, Saskatchewan

Final Report

On-Farm Survey of Combine Grain Loss in Canola Across Western Canada

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Acknowledgements

The Prairie Agricultural Machinery Institute (PAMI) acknowledges funding for this project from the Canola Council of Canada (CCC), Saskatchewan Canola Development Commission (SaskCanola), and Manitoba Canola Growers Association, through the Canola Agronomic Research Program (CARP). PAMI also acknowledges Bushel Plus and Schergain for providing both funding support and materials for this project. PAMI also acknowledges the many canola producers throughout Alberta, Saskatchewan, and Manitoba who volunteered to participate in this project. In-kind funds were also provided by PAMI to support the research and development of topics that are important to producers.

Table of Contents

1. Executive Summary

Canola is an essential crop in the Canadian Prairies, and canola losses are an unfortunate part of harvest that must be managed by producers. Canola losses can be categorized as either environmental losses, header losses, or combine losses. Environmental losses occur prior to cutting or gathering; header losses occur during swathing, picking up swaths, or when straight cutting; and combine losses occur during harvesting and refer to grain lost (discarded with the chaff and straw) from the separation and cleaning systems. The Prairie Agricultural Machinery Institute (PAMI), with support from Canola Council of Canada (CCC), Saskatchewan Canola Development Commission (SaskCanola), Manitoba Canola Growers Association and drop pan manufacturers, Bushel Plus and Schergain, set out to collect data on canola combine losses across Western Canada. The target audience for this report is the Canola Council of Canada (CCC), but it is recommended that the information be further disseminated to producers.

The objective of this project was to obtain a deeper understanding of the source of combine losses in canola by determining which parameters and variables are most likely to have an effect. A secondary goal was to continue to provide awareness to the seriousness of combine losses and to educate producers on methods for measuring their loss. Losses will always exist; however, the goal is to optimize the process and reduce loss.

The canola harvest season for this project stretched from August 22, 2019, through to October 18, 2019. PAMI visited 31 different producers across Alberta, Saskatchewan, and Manitoba and measured canola combine losses from 50 combines. Six different combine manufacturers were represented during testing with a total of 40 different combine models.

To ensure PAMI could obtain a true representation of canola combine losses being experienced by producers across the Prairies, producers were encouraged to operate at their normal operating conditions during testing. PAMI ensured strict biosecurity procedures were followed to prevent the transfer of crop contaminants, such as weed seeds, insects, and pathogens.

Drop pans were used (provided by Bushel Plus and Schergain) to measure the canola loss from the combines. To ensure an accurate representation of producer losses was obtained, each combine loss test was repeated three times for each combine.

Following the completion of the harvest season, the collected data was analyzed. Of the 50 combines tested, 44 used the method of dropped straw for loss testing, while 6 used the method of spread straw. Due to the reduced loss measurement accuracy of the six

combines with spread straw, the results from these tests were not included in the data analysis. An average combine loss of 1.3 bu/ac (72.9 kg/ha) was determined for the 44 combines tested with dropped straw during this project. This represented an average of 2.8% of total yield for this group of producers. Results from loss test repetitions ranged from 0.2 bu/ac (11.2 kg/ha) to 4.1 bu/ac (229.8 kg/ha), which translates into a 0.4% to 10.7% total loss of producer yield.

Statistical analysis of the data determined that ambient temperature, relative humidity, weather conditions, harvest method (swathed/straight-cut), canola variety (shatter resistant/non-shatter resistant), and ground speed all had a significant impact on the combine losses observed by the producers in this study. The results showed that canola combine losses were significantly lower (P-value = 0.001) during tests completed at ambient temperature's above 73.4˚F (23.0˚C), and at relative humidity levels of less than 45% (P-value = 0.04). It was observed that during this project, the tests completed on days with minimal cloud cover had significantly lower combine losses (P-value = 0.00003). It was also observed that the tests completed on swathed canola had significantly lower combine losses compared to tests conducted on straight-cut canola (P-value = 0.04). Non-shatter resistant canola varieties tested during this project also showed significantly lower combine losses when compared to the shatter resistant varieties (P-value = 0.01). Ground speeds less than 4.3 mph (6.9 km/h) were also attributed to lower losses (P-value = 0.0005); however, there were minimal data points available in the higher range. While these results were determined during this study, additional testing is required to fully understand the individual effects of each variable on loss.

Overall, it was noted that weather conditions are a key factor influencing combine losses, and that combines should be set based on these conditions. It is important for producers to reassess their combine losses as conditions change throughout the day and harvest season.

The goal of this project was to gain a better understanding of combine losses in the Prairies. In this regard, the project was a success, as the collected data shows the wide range of conditions experienced by producers and the observed impact of these conditions on combine losses. Throughout this project, methods of measuring combine losses were shared with producers. Information was dispersed to not only the producers who participated but also the producers who had volunteered but were unable to participate. In total, combine loss information was disseminated to over 130 producers. This project was one of the first real-world research projects aimed at studying in-field combine losses, and its success should encourage further research in this area.

It should be noted that the majority of data collected during this project was obtained directly from producers; therefore, the accuracy and consistency of this data greatly relied on the calibration methods used by each producer. This should be taken into account when considering the results from this project.

2. Introduction and Background

Canola production is an essential part of Canada's economy. A study commissioned by the Canola Council of Canada revealed that Canadian-grown canola contributes $26.7 billion to the Canadian economy, along with 250,000 jobs (Canola Council of Canada, 2016). Approximately 43,000 farms grow canola in Canada, the majority of which are located in Alberta, Saskatchewan, and Manitoba (Canola Council of Canada, 2016). **Table 1** lists the major canola producing provinces and the total 2018 and 2019 harvested area for each. **Figure 1** illustrates the density of canola production throughout Canada.

Table 1. Harvested areas of canola, by province.

Province	2018 Harvested Area of Canola[a]	2019 Harvested Area of Canola[a]
Saskatchewan	12,244,000 ac (4,955,000 ha)	11,377,300 ac (4,604,200 ha)
Alberta	6,679,200 ac (2,703,000 ha)	5,820,800 ac (2,355,600 ha)
Manitoba	3,379,100 ac (1,367,500 ha)	3,208,600 ac (1,298,500 ha)

[a] (Statistics Canada, 2018)

Figure 1. Canola Growing Region Map. Image Source: https://www.canolacouncil.org/media/image-gallery/canola-growing-region-map/)

With such a large fraction of arable land being dedicated to growing canola on an annual basis, it is paramount that technical resources are made available to producers so that they can make management decisions that increase production efficiency and decrease losses. However, there is currently insufficient research results regarding yield losses during canola production to guide management practices. Research is essential to enhancing the understanding of factors affecting harvest losses and determining methods to aid in alleviating some of the challenges faced by producers. Total canola harvest losses can be divided into three main types: environmental loss, header loss, and combine loss. Environmental losses occur prior to cutting or gathering. Header losses occur during swathing, picking up swaths, or when straight cutting. Combine losses occur during combining and refers to grain that has passed through the combine and is discarded with the chaff and straw. A regional study conducted by Gulden et al. in Western Canada revealed that for the fields and producers tested, the average total harvest loss was 5.79% (Gulden, Shirtliffe, & Thomas, 2003). For the purposes of this project, only combine losses will be considered and investigated, with the goal being to determine how much canola loss is attributed to combine loss.

The main objective of this project was to obtain a deeper understanding of the cause of canola combine losses by determining which parameters and variables are most likely to have an effect. The results from this project will help to educate and inform producers about the factors most likely to contribute to increased combine loss levels. The second underlying objective was to provide producers with more information on how to measure their combine losses through hands-on, in-field demonstrations. The target audience for this report is the Canola Council of Canada (CCC), but it is recommended that the information be further disseminated to producers.

3. Procedure and Methods

This project can be separated into three distinct phases: project planning and preparation, field testing, and data analysis and reporting. The tasks and methodology completed for each of these phases are explained in the following sections.

3.1 Project Planning and Preparation

The initial scope of this project required the voluntary participation of 100 producers from across Alberta (AB), Saskatchewan (SK), and Manitoba (MB). PAMI attended events to promote the project and utilized social media platforms, such as Twitter and Facebook, to broadcast project information to the public. PAMI also relied on additional support from the Canola Council of Canada and SaskCanola to promote the project and source participants. In total, 131 canola producers registered to participate.

An online survey was used to obtain preliminary information from producers. This survey requested information such as farm location, contact information, combine type, canola variety, canola acres, and total acres and was used to ensure producers met the requirements for the research project. **Figure 2** shows the approximate location of the 131 producers who signed up for this project.

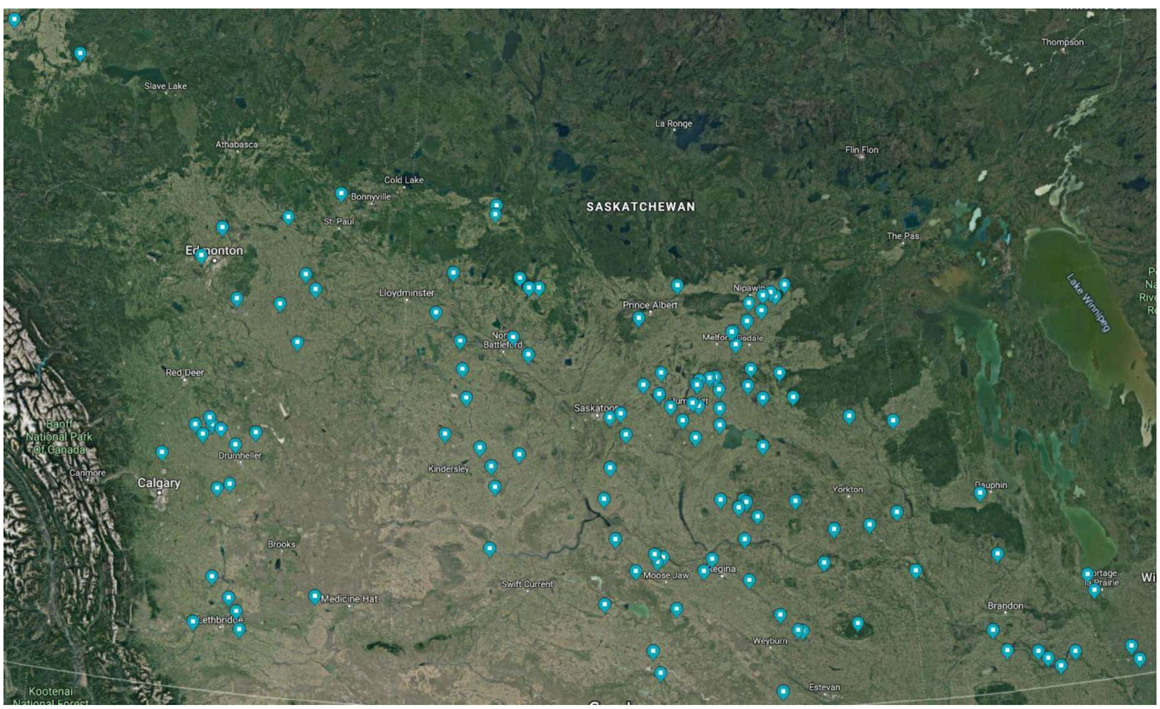

Figure 2. Location of producer volunteers. (Image source: https://www.google.ca/maps/@0,-0.0021887,17z/data=!3m1!4b1!4m3!11m2!2srOTviQv04E_vMDD8Y59CbmONpiLSnA!3e3)

Table 2 shows the provincial breakdown for these producers. The goal was to ensure that the breakdown of tests in each province was representative of the total canola acre breakdown in Western Canada.

Table 2: Provincial breakdown of volunteer producers.

Province	Total Producers	Percent of Total (%)
Alberta	28	21
Saskatchewan	89	68
Manitoba	14	11

The project scope called for loss measurements to be conducted at 100 farm operations; however, due to the challenging harvesting conditions experienced across the Canadian Prairies in 2019, a total of 50 combines were tested, from a total of 31 different canola producers. These 31 producers were chosen based on harvest timing, weather conditions, and the ability to accommodate testing during such a challenging harvest season. The harvest windows for many canola producers were far from average, which led to many challenges when trying to schedule field visits, and unfortunately, due to these challenges, PAMI was not able to make multiple trips to the same location or visit every single producer who signed up for the project. However, even with the undesirable circumstances, the research team feels that enough data was collected to ensure that the analysis was statistically relevant.

3.2 Field Testing

Field testing was conducted between August 22 and October 18, 2019, throughout the three prairie provinces. As outlined in the project proposal, it was important that the collected data represented a cross section of canola producers in the Canadian Prairies. This meant covering all three provinces (AB, SK, and MB), testing as many different brands and types of combines as possible, and testing in both straight-cut and swathed canola fields.

The field-testing phase involved three key areas: biosecurity and safety, loss measurement testing, and data collection. Each of these key points are described in the following sections.

3.2.1 Biosecurity and Safety Measures

Biosecurity and safety were both extremely important aspects of field testing. A biosecurity protocol was developed using the Canola Council of Canada field entry policy (Canola Council of Canada) and adapted for the specifics of this project. Safety was incorporated into the project through the use of safety meetings that were held before every field test.

To avoid bio-contamination between test fields, it was important to take the appropriate steps to prevent transfer of crop contaminants, such as weed seeds, insects, and pathogens. Key points were identified for the biosecurity protocol, and included only entering fields on foot, using boot covers, and spraying down equipment with disinfectant. The Canola Council of Canada’s Field Entry Policy was followed (Canola Council of Canada).

Safety is essential for any project work; field projects are no exception and often require more attention due to extensive work with ever-changing groups of producers and project volunteers. Field-work safety meetings were completed with every producer prior to conducting in-field loss measurement testing. The safety meeting included discussions on machinery and the hazards associated with working around moving combines, hazards associated with using disinfectant, as well as sound levels, dust conditions, and working alone.

All of the above information was shared with the producer prior to commencing field testing. Each producer was asked to sign the data collection sheet to acknowledge that the biosecurity protocol, safety form, and testing protocol had been reviewed with them.

3.2.2 Equipment

Drop pans are the primary tool used to measure combine losses. The pans are dropped to the ground from the rear of the combine, below the machine’s separation and cleaning system, and collect any refuse material exiting the machine (chaff, seed, etc.). There are a few commercially available systems that producers can purchase to measure and manage their own losses. This project used pans supplied by Bushel Plus and Schergain (**Figure 3**). The two styles of pans differ slightly, but both comply with the methodology for collecting accurate combine loss data. Pans were alternated between fields.

The Bushel Plus drop pan comprised a cover that was directly attached to the combine and a drop pan that is secured to the cover with magnets. This drop pan has interior dimensions of 10.0 in (25.4 cm) by 59.3 in (150.6 cm), with a catch area of 4.11 ft^2 (0.38 m^2). The Schergain drop pan attaches directly to the combine. This drop pan has interior dimensions of 11.5 in (29.2 cm) by 66.0 in (167.6 cm), with a catch area of 5.27 ft^2 (0.49 m^2). Both drop pans are equipped with remote controls that allow the drop pan to be released at the optimum time during combine loss testing.

Figure 3. Bushel Plus drop pan (left; image source: http://bushelplus.ca/bushel-plus-harvest-loss-system/) Schergain drop pan (right; image source: https://www.schergain.ca/pricing/).

Both commercial drop pan sets include measuring systems for weighing and/or measuring volume; however, for the purpose of this project, the canola samples were collected from the pans and weighed with calibrated scales; these weights were then entered into the loss equation shown in **Section 3.2.4.**

The combines tested throughout the duration of this project were provided by all of the producers who volunteered to participate. Six different manufacturers were represented: Case IH, Claas, Fendt, John Deere, New Holland, and Massey Ferguson. For the purpose of this study, the combine losses between combine manufacturers were not compared.

3.2.3 Combine Loss Testing

Extensive communication occurred between PAMI and the producers prior to any field testing; this provided PAMI with the best opportunity of successfully visiting as many of the producers during their canola combining window. With ongoing changes to harvest schedule due to weather, this constant line of communication was essential to the success of this project. Once producers had communicated an estimated timeframe for their canola harvesting, they were added to the schedule. As their estimated timeframe approached, emails and calls were exchanged to confirm the timing. If weather and schedule lined up, the producers received a call from the PAMI team the day prior to testing. During this call, location and an approximate test time were confirmed.

An in-field survey was completed with the participating producers. This survey included questions related to

- weather conditions (relative humidity, ambient air temperature, wind speed),
- crop information (seeding date, seeding rate, canola variety),
- harvest method (swathing, straight-cut),
- combine information (make, model, year, type, hours),
- harvest information (yield, discharge width, canola moisture content), and
- combine settings (fan speed, rotor/cylinder speed, sieve opening, ground speed).

When this information was collected, PAMI field-test personnel observed the following test procedure:

1. Take photo of combine to be tested.
2. Ask producer to disengage the chopper and spreader, if feasibly possible.
3. Work with the producer to safely attach a drop pan to their combine. Drop pan should be attached to either the back axle or belly of the combine, ideally in a location where canola cannot be prematurely collected. (Always ensure that the combine operator is aware of your location and out of the combine cab while you are attaching the drop pan.)
4. Allow combine operator to reach steady state (20 seconds) before using the remote control to drop the pan.

5. Once the combine operator has moved far enough away, approach the test area and retrieve the drop pan.
6. Measure and record the discharge width of the straw and chaff.

For each combine, three test repetitions were completed.

3.2.4 Sample Collection and Loss Calculation

After each repetition, the canola was carefully separated from the straw and chaff using fans and sieves. For larger sample sizes, this was completed in multiple steps. The canola samples from each repetition were stored in labelled containers to be measured and weighed upon completion of all repetitions. The samples were weighed using a calibrated scale, and the data recorded on the in-field survey sheet. The following equation was used to calculate canola combine loss:

$$\textbf{Loss}\left(\frac{bu}{ac}\right) = \frac{\textbf{Collected Weight}\ (g)}{\textbf{Catch Area}\ (ft^2)} * \frac{\textbf{Discharge Width}(ft)}{\textbf{Cut Width}(ft)} * \frac{1}{\textbf{Canola Density}\left(\frac{lb}{bu}\right)} * \frac{43{,}560\ (\frac{ft^2}{ac})}{453.6\ (\frac{g}{lb})}$$

Where:

Collected Weight (g): Weight of canola collected during loss test.
Catch Area (ft^2): Area of drop pan used for testing.
Discharge width (ft): Width of dropped or spread chaff and straw. Measured in field.
Cut Width (ft): Obtained from producer; swather width or straight-cut header width.
Canola Density: 50 lb/bu.

This method used only the weight of the collected canola sample to determine losses; however, it is important to note that there are other suitable methods that use volume and seed count. **Appendix A** includes the Combine Seed Loss Guide, which discusses these other methods (Canola Council and PAMI, 2017).

3.3 Data Analysis

The data analysis for this project was conducted using Minitab 18 Statistical Software. Statistical analysis helps to determine whether differences observed in the data are due to the measured variables or due to random variability. A statistically significant result means that the difference exhibited is highly likely to be due to the treatment itself. The loss data was tested for normality; if the data set was determined to not follow a normal distribution, a Box Cox transformation was completed before completing the data analysis. For most of the variables considered, an analyses of variance (ANOVA) was completed to determine the effect of each variable on the observed losses. If a P-value of less than 0.05 was observed, then the null hypothesis is rejected with a 95% confidence. The P-value is a calculated probability and can be used to conclude whether there is a statistically significant difference between treatments. A P-value of less than 0.05 means there is a 95% confidence level with the results. If necessary, a Tukey means separation was conducted to determine where the significant difference existed. For all statistical analysis, a 95% confidence level was used.

It should be noted that the majority of the data collected for this project – particularly the combine settings – was obtained from producers and not measured by PAMI field-test personnel; therefore, the accuracy of this data is dependent on the calibration methods used by each producer. Not every producer was able to provide a complete data set, so the number of data points (n) in each data set may vary between variables. For each analysis, the number of data points, will be included to show how many of the test repetitions fall into each sample group.

The discharge method for each test was chosen by the producer. If the chopper and spreader feature could be easily disengaged, the producer was encouraged to drop the straw; however, if the chopper and spreader was an aftermarket addition or could not be easily disengaged, the test was completed while spreading the straw. The disadvantage of spreading during loss testing relates to the unpredictability of the distribution of grain throughout the discharged material. When dropping the straw, the majority of the losses will be found within the dropped discharge width. When the discharged material is spread, the drop pan collects only a fraction of the total material discharged, and unless the canola is evenly distributed throughout the discharge width, the collected sample may not be truly representative of the entire density of lost grain. During this project, 44 of the combine tests were completed with dropped material and 6 were completed with spread material. For the data analysis, only the 44 dropped material combine tests were analyzed. Each of these 44 combine tests involved 3 repetitions, for a total of 132 data points.

A field project of this size (covering a large geographical area) required two field-testers. To ensure that this variable did not impact the results, an ANOVA was completed to confirm that there was no significant difference between measured losses collected by either field-tester before continuing with further analysis.

There are numerous variables that can impact the losses experienced when combining canola. For the purpose of this analysis, the variables were split into three groups: environmental variables, harvest and crop variables, and equipment variables. The sections below describe the variables that were included in these groupings and discuss how these variables were included in the data analysis.

3.3.1 Environmental Variables

Environmental variables include any weather or environmental conditions, as well as the time of day the test was conducted. The following environmental variables were investigated to determine their potential impact on combine losses:

- Harvest timing (morning, afternoon, evening)
- Ambient temperature
- Relative humidity
- Weather conditions (sunny, partially cloudy, cloudy)
- Wind speed and wind direction

Harvesting times were separated into three categories: morning, afternoon, and evening. Morning tests were categorized to be any time before 12:00 p.m., afternoon tests fell between 12:00 p.m. and 5:00 p.m., and evening tests were completed after 5:00 p.m.

Ambient temperature was recorded using a calibrated monitor, and the values were categorized as cool or warm. Cool was classified as any temperature below 73.4°F (23.0°C) and warm was classified as any temperature greater than or equal to 73.4°F (23.0°C).

The relative humidity was also determined using a calibrated monitor, and the values were categorized into two groups (low, high). The low relative humidity group was defined as any value less than 45%, and high was defined as any value greater than or equal to 45%.

The field-testers made note of the weather conditions prior to each test. Weather conditions were identified as either sunny, partially cloudy, or cloudy. The data was separated into these three groups prior to analyzing.

Wind was described by two categories: speed and direction. For speed, field-testers recorded the actual speed using the closest Environment Canada weather station. For the direction, the wind was categorized as either a cross wind, tail wind, head wind, quarterly tail wind, or quarterly head wind, based on the direction of travel of the combine during testing.

3.3.2 Harvest and Crop Variables

Harvest and crop conditions relate to decisions the producer made regarding variety, harvest type, and harvest timing. The following harvest and crop variables were investigated to determine their potential impact on combines losses:

- Harvest practice: straight-cut or swathed
- Grain moisture content
- Variety: shatter-resistant or non-shatter resistant

Producers determined whether to straight-cut or swath their canola based on the variety of canola seeded and the weather conditions experienced during harvest. Many of the registered producers had initially planned to straight-cut their canola; however, due to weather conditions, they made the decision to swath instead. These decisions by the participating producers caused disparity between the total number of straight-cut tests compared to the total number of swathed tests.

The moisture content of the grain was provided by the producer. It should be noted that each producer may have had a different method for determining their canola moisture content at time of harvest. As such, the values obtained from each producer were grouped into dry, tough, and damp. Dry was considered to be any value less than 10.1%, tough was defined as 10.1% to 12.5%, and damp was any value greater than 12.5% (Canadian Grain Commission, 2016).

A dozen different varieties of canola were tested during this project. For the purpose of this analysis, the varieties were separated into two groups depending on their shatter resistance (shatter resistant, non-shatter resistant). **Table 3** shows the groupings.

Table 3. Canola varieties tested

Shatter Resistant Canola Varieties	Non-Shatter Resistant Canola Varieties
BASF InVigor L255PC[a]	BASF InVigor L252[a]
BASF InVigor L233P[a]	Pioneer P501L[b]
BASF InVigor L258HPC[a]	Pioneer 45H33[b]
Pioneer 45M35[b]	Brett Young 6074 RR[e]
Nexera 2024CL[c]	Cibus Falco 68K[f]
DEKALB TRUFLEX DKTF 92 SC[d]	Bunge HyHear 3[g]

[a] (BASF, 2019) [b] (Pioneer, 2019) [c] (Brevant Seeds, 2019) [d] (DEKALB, 2019) [e] (Brett Young, 2019) [f] (Falco Seed, 2019) [g] (Duncan, et al., 2017)

3.3.3 Equipment Variables

The goal of this project was to observe and collect data from producers during tests that represented their normal operating conditions. The following equipment variables were investigated to determine their potential impact on combine losses:

- Combine ground speed
- Grain feed rate
- Fan speed
- Rotor/cylinder speed
- Concave clearance
- Upper sieve opening
- Lower sieve opening
- Combine age
- Separator hours

Within the data set, all of the above variables were separated into groups for analysis. The ranges used for each of these categories are displayed in the **Table 4**.

Table 4. Equipment variable ranges.

Variable	Low Range	Middle Range	High Range
Ground Speed, mph (km/h)	< 4.3 (6.9)	-	≥ 4.3 (6.9)
Grain Feed Rate, bu/hr (MT/hr)	< 350.0 (7.9)	-	≥ 350.0 (7.9)
Fan Speed, rpm (hz)	< 725 (12)	-	≥ 725 (12)
Rotor/Cylinder Speed, rpm (hz)	< 660 (11)	-	≥ 660 (11)
Concave Clearance, in (mm)	< 0.87 (22.10)	-	≥ 0.87 (22.10)
Upper Sieve Opening, in (mm)	< 0.47 (11.94)	-	≥ 0.47 (11.94)
Lower Sieve Opening, in (mm)	< 0.20 (5.08)	-	≥ 0.20 (5.08)
Combine Age	< 2006	2006 - 2014	≥ 2015
Separator Hours, hr	< 1,000	1,000 – 1,999	≥ 2,000

As best as possible, the same combine settings were maintained for all three repetitions for each combine. It should be noted that the combine manufacturer and type (conventional, rotary, or hybrid) was not taken into account when investigating these settings.

The ground speed and grain feed rate groups were found based on the value at which a significant difference was observed. The grain feed rate was calculated using the following equation.

$$Grain\ Feed\ Rate\ \left(\frac{bu}{hr}\right) = Yield\ \left(\frac{bu}{ac}\right) *\ Ground\ Speed\ (mph) * Cut\ Width\ (ft) * \frac{5{,}280\ (\frac{ft}{mile})}{43{,}560\ (\frac{ft^2}{ac})}$$

For fan speed, rotor/cylinder speed, concave clearance, upper sieve opening, and lower sieve opening, the average observed value was used to set the ranges for data analysis. The ranges for combine age and separator hours were determined based on the number of samples in each grouping, this sought to obtain an even split between the three groups.

4. Results and Discussion

This section will discuss the results obtained from the combine loss testing.

4.1 Data Summary

This project collected combine loss data from 50 combines owned by 31 different canola producers, located over three provinces. **Figure 4** shows the 31 test locations.

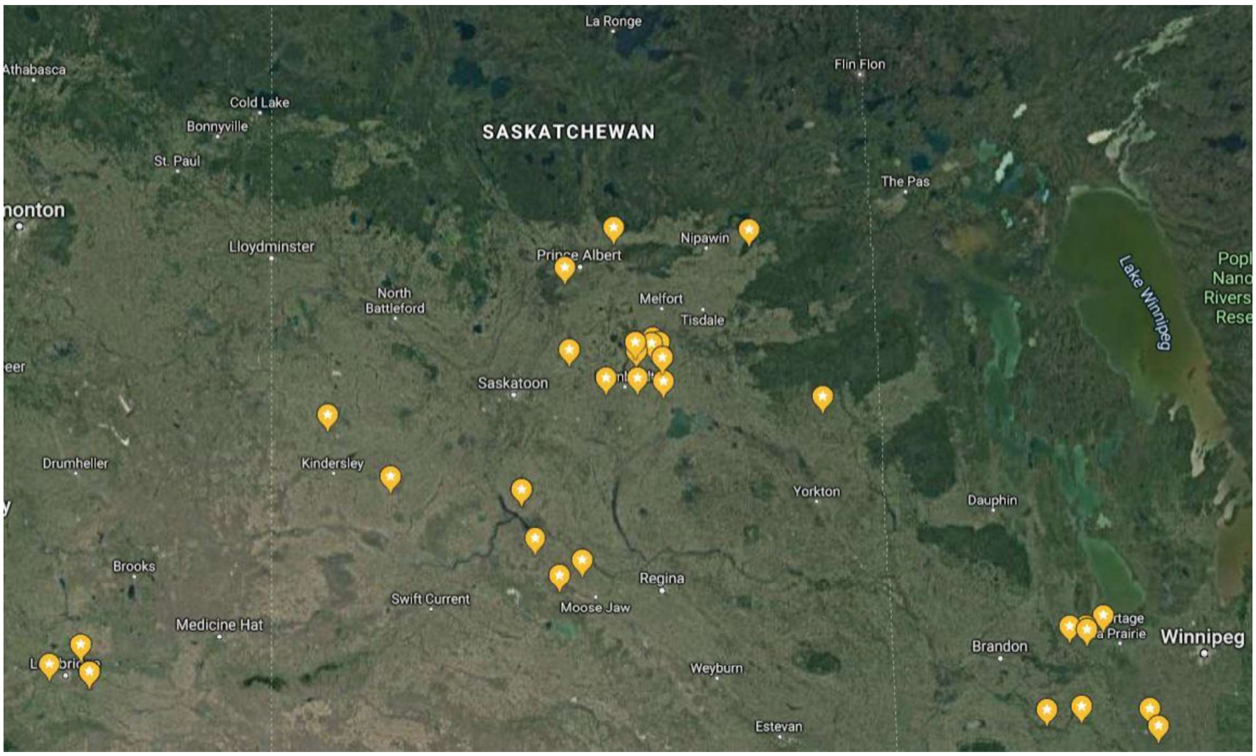

Figure 4. The 31 field test locations. (Image source: https://www.google.ca/maps/@51.171016,-110.1587888,6z/data=!3m1!4b1!4m2!11m1!3e4)

Although 50 combines were tested, only 44 combines from 29 producers were tested with dropped straw. As explained in **Section 3.3**, since the results obtained from combines with spread straw may not be truly representative of actual losses, only combines that dropped straw were used for the data analysis. From this point on, all results will be based on the 44 combine tests that were completed with dropped straw samples.

The following points describe the breakdown of tests completed on the 44 dropped straw combines:

- Saskatchewan: 30; Manitoba: 9; Alberta: 5
- Combine manufacturers: 6; combine models: 35
- Conventional: 2; rotary: 39; hybrid: 3
- Canola seed companies: 7
- Canola varieties: 12; shatter resistant: 6, non-shatter resistant: 6

- Swathed loss tests: 34; straight-cut loss tests: 10
- Dryland loss tests: 39; irrigated land loss tests: 5
- Bushel Plus drop pan loss tests: 21; Schergain drop pan loss tests: 23

Table 5 provides an overview of the data that was collected for all 44 combines tested. This table provides a high-level overview of the farming operations that are represented within this project.

Table 5. General data summary of 44 dropped straw test combines.

Variable	Minimum	Maximum	Average
Total Seeded Area, ac (ha)	600 (243)	60,000 (24,281)	7,702 (3,117)
Seeded Canola Area, ac (ha)	180 (73)	14,000 (5,666)	2,617 (1,059)
Seeding Date	24-Apr-19	27-May-19	12-May-19
Canola Seed Rate, lb/ac (kg/ha)	2.5 (2.8)	5.0 (5.6)	4.5 (5.0)
Row Spacing, in (cm)	7.0 (17.8)	15.0 (38.1)	10.3 (26.2)
Swathing Date	9-Aug-19	26-Sep-19	31-Aug-19
Swather Width, ft (m)	24.5 (7.5)	40.0 (12.2)	32.6 (9.9)
Spray Date	19-Aug-19	16-Sep-19	2-Sep-19
Straight-Cut Header Width, ft (m)	30.0 (9.1)	40.0 (12.2)	36.4 (11.1)
Harvest Date	22-Aug-19	18-Oct-19	24-Sep-19
Yield, bu/ac (MT/ha)	30.0 (1.7)	90.0 (5.0)	48.0 (2.7)
Calculated Loss, bu/ac (kg/ha)	0.2 (11.2)	4.1 (229.8)	1.3 (72.9)
Percent of Total Yield Lost, %	0.4	10.7	2.8

The losses experienced by the 44 combines with dropped straw ranged from 0.2 bu/ac (11.2 kg/ha) up to 4.1 bu/ac (229.8 kg/ha), giving a range of 0.4% to 10.7% of total yield loss due to combine losses. Overall, the average losses experienced were 1.3 bu/ac (72.9 kg/ha), which represented an average of 2.8% of total yield for this group of producers. **Figure 5** shows a histogram for calculated combine losses for all of the 44 dropped straw combines tested. More than half of the combines tested experienced average losses of 1 bu/ac (56 kg/ha) or less over the three field repetitions. It should be noted that the figure below takes into account the average losses for each combine over three repetitions.

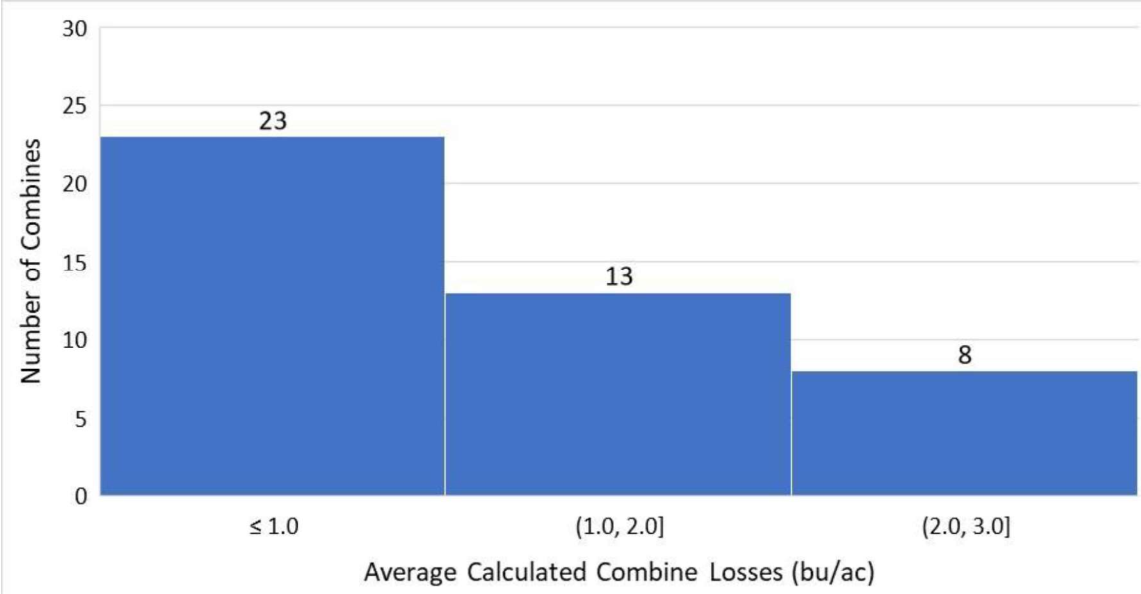

Figure 5. Histogram of average calculated combine losses.

4.2 Data Analysis Results

This section summarizes the results and conclusions for each of the three variable groupings: environmental, harvest and crop, and equipment. As explained in **Section 3.3**, since the results obtained from combines with spread straw may not be truly representative of actual losses, only combines with dropped straw tests were used for the data analysis

It should be noted that the combines were not optimized for the various field conditions and harvest types. Combines were tested at the settings determined by each individual producer.

4.2.1 Environmental Variables

The impact of harvest timing was investigated. The results showed that the chosen time of day to combine canola did not have a direct impact on the losses experienced, since as the harvest season progresses, the optimal time of day for harvesting changes. For example, the conditions experienced at 10:00 a.m. in late August can differ greatly from the average conditions experienced at the same time in late October. This leads to the next analysis which investigated the environmental conditions in more depth.

Throughout the testing season, ambient temperatures ranged from 33.8˚F (1.0˚C) up to 84.0˚F (29.0˚C). Data analysis revealed that combine losses were significantly lower during tests conducted at warmer ambient temperatures (P-value = 0.001). The average losses observed for tests (n=96) completed at temperatures less than 73.4˚F (23.0˚C), were found to be 1.4 bu/ac (78.5 kg/ha), while the average losses for the warmer temperatures (n=36) were found to be 0.8 bu/ac (44.8 kg/ha).

Relative humidity ranged from 20% to 71% for all of loss tests completed. Data analysis revealed that losses were significantly lower during tests conducted at relativity humidity levels less than 45% (P-value = 0.04). The average losses for tests completed at relative humidity levels less than 45% (n=108) were 1.2 bu/ac (67.3 kg/ha), while the average losses for the tests conducted at higher relative humidity levels (n=24) were found to be 1.6 bu/ac (89.7 kg/ha).

Weather conditions were noted by PAMI at the time of testing. The Tukey test revealed that losses were significantly different between cloudy and sunny weather conditions as well as cloudy and partially cloudy weather conditions (P-value = 0.00003). The average losses experienced during the tests completed during cloudy weather conditions (n=39) were 1.7 bu/ac (95.3 kg/ha). The average losses experienced during partially cloudy weather conditions (n=60) were 1.1 bu/ac (61.6 kg/ha). Finally, the average losses experienced during sunny weather conditions (n=33) were 1.0 bu/ac (56.0 kg/ha). While some of these loss differences may not seem large on a practical scale, they still show that weather conditions need to be monitored and settings optimized as the conditions change.

The wind speed during testing varied between 1.9 and 21.1 mph (3.0 to 34.0 km/h) and wind direction changed with each field. The data analysis revealed, that during these tests, wind speed and direction did not have a significant impact on the losses experienced. More testing is required to fully understand this variable and how it impacts losses.

Overall, the temperature, relative humidity, and weather conditions were found to have a significant impact on the losses experienced during testing. These three variables are closely connected to one another. During testing, the cloudy day average temperature was 53.4˚F (11.9˚C) with an average relative humidity of 46.5%. The partially cloudy day average temperature was 61.7˚F (16.5˚C) with an average relative humidity of 34.4%. The sunny day average temperature was 72.5˚F (22.5˚C) with an average relative humidity of 37.5%. Based on the combine set-ups as tested, these results revealed that losses are greatly impacted by the continually changing environmental conditions experienced during harvest.

4.2.2 Harvest and Crop Variables

The harvest and crop variables included the variety of canola, the moisture content at time of harvest, and the harvest type (swathed or straight-cut).

For the 44 combines that used the dropped straw method, seven different canola seed companies were represented, with a total of 12 different varieties (**Table 3**). Within these varieties, six were marketed as shatter-resistant. For the purpose of this project, data analysis was conducted on the shatter resistant and non-shatter resistant variety groupings. The data analysis revealed that the combine losses experienced with the shatter resistant varieties were significantly higher than the non-shatter resistant varieties (P-value = 0.01). The shatter resistant varieties (n=87) were found to have average losses of 1.3 bu/ac (72.9 kg/ac), while the non-shatter resistant varieties (n=45) were found to have average losses of 1.1 bu/ac (61.6 kg/ha). Due to the harvest conditions experienced in fall 2019, not all shatter resistant varieties were straight-cut.

Canola seed moisture content varied between 6% and 17% for all of the tests conducted. The moisture content values obtained from each producer were grouped based on the Canadian Grain Commission ranges for dry, tough, and damp, as described in **Section 3.3.2**. Based on these groupings, no significant differences for losses were observed between the three ranges.

Harvest type was defined as either swathed or straight-cut, and was determined solely by the producer's preferred or necessitated practices. As mentioned in previous sections, due to the challenges faced during the 2019 harvest season, many of the producers who had planned to straight-cut their canola chose to swath. This led to 34 producers swathing and 10 producers straight-cutting. The data analysis revealed that the swathed canola tests had significantly lower losses that the straight-cut canola tests (P-value =0.04). The average losses experienced for the swathed tests (n=102) were 1.2 bu/ac (67.3 kg/ha), while the average losses for the straight-cut tests (n=30) were 1.5 bu/ac (84.1 kg/ha). It is important to note that the relative percentage of total losses attributed to combine losses compared to either environmental or header losses may differ substantially between harvest practices; however, this was out of scope for this project.

Although this data shows that the canola variety had a significant impact on losses, there are many other variables in the background that may have also affected the results. For example, the length of time that producers allowed their canola to dry down may vary, and the length of time between spraying desiccant and combining may vary. These variables could easily have impacted the results. Further testing is required to fully understand how these variables impact combine losses.

4.2.3 Equipment Variables

Prior to and during field testing, many combine settings were obtained from the producers. Of the variables collected, the following were investigated for their impact on losses: ground speed, fan speed, rotor/cylinder speed, concave clearance, upper sieve opening, lower sieve opening, and combine age. In addition, the grain feed rate was also investigated.

Combine ground speed ranged from 2.0 to 5.0 mph (3.2 to 8.0 km/h) for all of the completed tests. The data analysis revealed that the loss tests conducted at a ground speed of greater than or equal to 4.3 mph (6.9 km/h) had significantly higher losses compared the tests conducted at ground speeds less than 4.3 mph (6.9 km/h; P-value =

0.0005). The average losses experienced in the lower speed group (n=123) were 1.2 bu/ac (67.3 kg/ha), while the average losses experienced for the higher speed group (n=9) were 2.2 bu/ac (123.3 kg/ha). It should be noted that only three combine tests, with nine total repetitions, were completed at ground speeds greater than or equal to 4.3 mph (6.9 km/h), additional testing is required to fully understand the most efficient ground speed to manage losses and efficiency.

Grain feed rate takes into account ground speed, cutting width, and crop yield and provides producers with an indication of the total volume they are processing with their combines. During this project, the grain feed rate ranged from 265.0 to 1,170.0 bu/hr (6.0 to 26.5 MT/hr). The only detectable significant difference (P-value = 0.0007) occurred with grain feed rates above and below 350.0 bu/hr (7.9 MT/hr). The average losses experienced by combines operating at grain feed rates of less than 350 bu/hr (7.9 MT/hr; n=6) were 0.5 bu/ac (28.0 kg/ha) and the average losses for combines operating at a grain feed rate of greater than 350 bu/hr (7.9 MT/hr; n=123) were 1.3 bu/ac (72.9 kg/ac). The large sample inequality between the two groups should be noted when taking this data into consideration. The two combines, with a total of six test repetitions, included in the low grain feed rate grouping experienced 35 bu/ac (2.0 MT/ha) yield, and were operating at 2.2 mph (3.5 km/h) and 2.5 mph (4.0 km/h). There is a balance between efficiency and losses that must be managed. Additional testing is required to fully understand this variable.

The combine settings investigated during this project included fan speed, rotor/cylinder speed, concave clearance, upper sieve opening, and lower sieve opening. **Table 6** shows the minimum, maximum, and average values observed for each of these variables.

Table 6. Observed combine settings.

Variable	Minimum	Maximum	Average
Fan speed, RPM (Hz)	500 (8)	1,000 (17)	725 (12)
Rotor/Cylinder Speed, RPM (Hz)	440 (7)	1,100 (18)	660 (11)
Concave Clearance, in (mm)	0.20 (5.08)	2.24 (56.90)	0.87 (22.10)
Upper Sieve Opening, in (mm)	0.24 (6.10)	0.71 (18.03)	0.47 (11.94)
Lower Sieve Opening, in (mm)	0.06 (1.52)	0.51 (12.95)	0.20 (5.08)

No significant differences were observed between any of the combine settings. While on an individual basis, these settings can have a very drastic impact on the losses a producer experiences, in a wide data set, covering a large range of harvest conditions, it is logical that no one fan speed or concave setting can be attributed to losses. The most optimized settings will inevitably differ depending on weather conditions, crop conditions, and combine type. In future studies, it is suggested that the recommended manufacturer settings be compared to the combine settings used by producers.

The combine age was defined by the year of manufacture, and this project included combines manufactured between 1993 and 2019. For this analysis, the combines were separated into three age groups. 1993 to 2005 (n=33), 2006 to 2014 (n=57), and 2015 to 2019 (n=42). Based on these groupings, the older combines had significantly lower losses compared to both other ages groups (P-value = 0.0001). The older combine grouping had average losses of 0.8 bu/ac (44.8 kg/ha), the middle age grouping had average losses of 1.5 bu/ac (84.1 kg/ha), and the newer age grouping had average losses of 1.3 bu/ac (72.9 kg/ha). These results highlight the importance of optimizing a combine for the conditions no matter the age of the equipment. It also implies that operator familiarity with a piece of equipment may be important; for example, a producer who has been using the same combine for many years is more in tune with how to adjust that particular combine in different conditions to minimize losses.

Of the 44 combines used during this analysis, 33 of those operators were able to provide the equipment separator hours. Three groups were created to investigate this variable: less than 1,000 hours (n=27), 1,000 to 1,999 hours (n=36), greater than or equal to 2,000 hours (n=36). No significant differences were observed between these groups in regards to combine losses.

Overall, the results obtained by analyzing the equipment variables revealed that setting and optimizing a combine for the conditions and crop are essential and have the biggest impact on losses.

5. Conclusions and Recommendations

Losses are an inevitable and unfortunate element to every producer's harvest. Understanding the different impacts on losses can help producers make more informed decisions about the equipment they use and the practices they follow. This project focused on one of the three loss types: combine losses. These are the losses attributed to grain that is discharged from the back of the combine. The objective of this project was to gain a better understanding of these losses and how much they contribute to the total loss experienced by producers.

An average combine loss of 1.3 bu/ac (72.9 kg/ha) was determined for the producers during this project, which represented an average of 2.8% of total yield for this group of producers. Collectively, the producers who volunteered for this project seeded 70,400 ac (28,490 ha) of canola in 2019. Using the average combine loss determined and assuming a canola price of $9.50/bu ($418/MT), a total monetary loss of approximately $870,000 was experienced by the group of participating producers. On average, the producers participating in this study experienced losses of $12.35/ac ($30.52/ha).

The data analysis completed during this project revealed that ambient temperature, relative humidity, and general weather conditions had a significant impact on losses experienced by producers. For the tests completed, it was found that ambient temperatures below 73.4˚F (23.0˚C), relative humidity above 45%, and cloudy weather all caused significantly higher combine losses. These values will differ with each set of data; however, the general trend of lower temperatures and higher relative humidity causing increased losses should be noted by producers. Environmental and weather conditions should be carefully monitored when harvesting, and combines should be set according to these conditions.

For the tests completed in this project, it was found that harvest method (straight-cut or swathed) had a significant impact on combine losses. The data from this study showed that the swathed canola had significantly lower combine losses when compared to straight-cut. There are many other variables that could have impacted this result, such as harvest timing, drying time, and canola variety. The data from this study also showed that shatter resistant canola had significantly higher losses when compared to non-shatter resistant varieties. It was also found within this project, that canola moisture content did not have a significant impact on combine losses.

This project revealed that there is not a standard set of combine settings that can be attributed to their losses. Each combine, operating in particular conditions for a specific crop must be optimized for the given environment. This study revealed that increased ground speed can have a negative impact on combine losses; however, more testing is required to fully understand this. During this project, a wide range of different combine ages were investigated. Through data analysis, the data collected during this project revealed that a new combine does not necessarily mean reduced combine losses. A well-set older combine can experience lower losses than a newer poorly-set combine. An analysis on the separator hours revealed no significant difference between the different use groups. In general, the data analyzed during this section all hinted towards the importance of setting a combine for the conditions at hand, no matter the age or type.

This project highlighted the importance of optimizing your combine for current weather conditions and using loss measurement as a means of verifying combine settings. Combine loss measurement can be completed using equipment supplied by companies such as Bushel Plus and Schergain, but if producers do not have access to this equipment, any pan or tray can be used to obtain a rough estimate of combine losses. Any method is better than not checking.

Following the completion of this project, PAMI has three recommendations for future work. It is recommended that this report be condensed into a concise document that can be easily distributed to producers, providing a summary of the methods and results obtained. Secondly, it is recommended that more research be conducted in the area of combine loss. Future projects should build on the results from this project and focus on specific variables identified as having the potential to impact combine losses. Producers should be asked which variables they would like to see investigated in more depth. A narrowed scope with controlled parameters could provide more visibility on certain variables, further enhancing our understanding of which variables truly impact combine losses. The final recommendation includes further research on the other two types of harvest losses: environmental losses and header losses. Investigating all loss types would provide a complete picture of the losses experienced by producers, thereby allowing them make educated decisions on how to most effectively manage their farming operation.

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Appendix A

Combine Seed Loss Guide

A method for determining seed loss from your combine based on weight, volume, or seed count with choppers and spreaders disengaged.

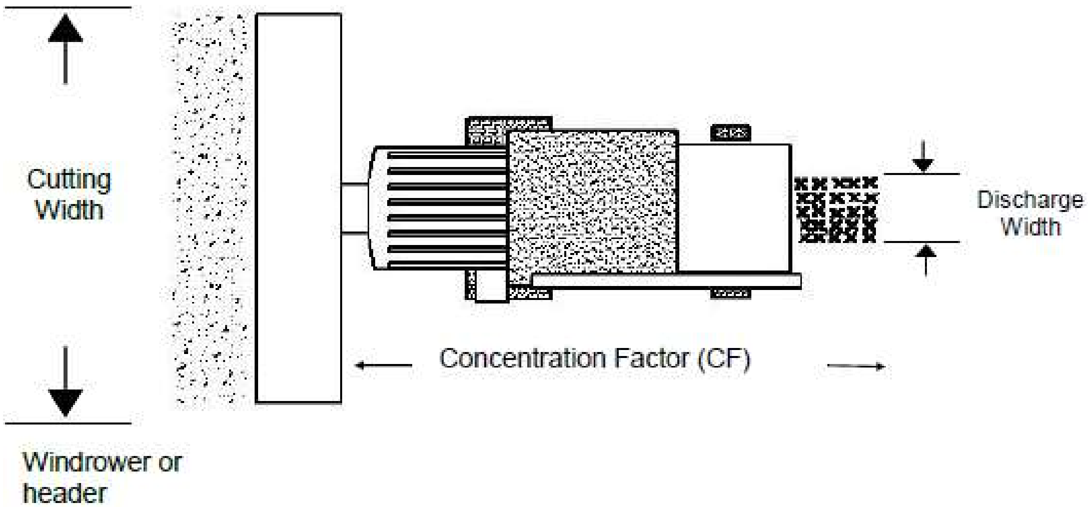

Table 1

STEP 1
Find your CF—in this table

Common Concentration Factors					
	Discharge Width (ft)				CF
	3	4	5	6	(X)
Cutting Width (ft)	12	16	20	24	4
	15	20	25	30	5
	18	24	30	36	6
	21	28	35	42	7
	24	32	40	48	8
	27	36	45	54	9
	30	40	50	60	10

STEP 2
Collect a Sample from discharge of known area

Be Careful
Be Safe

Continue steps on next page

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STEP 3 Remove chaff from sample

Tips:

- Use round hole sieve
- Blow out (leaf blower and 5 gallon pail)

STEP 4 Determine weight (g), volume (ml), or seed count measurement.

STEP 5 Calculate loss in pan per sq ft of pan first. Collection pan can be any size; however, pan width equal to width of sieves is recommend (divide results by ft^2 of collection pan).

STEP 6 Select **Table 2, 3, 4,** or **5** to find loss on a per acre basis

Table 2 — **Weighing Method - All Crops**

(0.010413 grams/ft² over each ft² in an acre = 1 lb/ac)

	Concentration Factor (CF)								Loss
CF	**1**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**lb/ac**
Loss Collected Behind Combine in 1 square foot (Grams/ft²)	0.1	0.4	0.5	0.6	0.7	0.8	0.9	1.0	**10**
	0.3	1.0	1.3	1.6	1.8	2.1	2.3	2.6	**25**
	0.5	2.1	2.6	3.1	3.6	4.2	4.7	5.2	**50**
	0.6	2.5	3.1	3.7	4.4	5.0	5.6	6.2	**60**
	0.8	3.1	3.9	4.7	5.5	6.2	7.0	7.8	**75**
	1.0	4.2	5.2	6.2	7.3	8.3	9.4	10.4	**100**
	1.3	5.2	6.5	7.8	9.1	10.4	11.7	13.0	**125**
	1.6	6.2	7.8	9.4	10.9	12.5	14.1	15.6	**150**
	1.8	7.3	9.1	10.9	12.8	14.6	16.4	18.2	**175**
	2.1	8.3	10.4	12.5	14.6	16.7	18.7	20.8	**200**

To find the value in this chart when using collection pans greater than 1 sq ft, divide the volume or weight measured by the square footage of the pan first.

Table 3 — **Volume Measurement Method - All Crops**

(0.8348875 ml/ft² over each ft² in an acre = 1 bu/ac)

	Concentration Factor (CF)								Loss
CF	**1**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**bu/ac**
Loss Collected Behind Combine in 1 ft² in Millilitres (ml/ft²)	0.2	0.8	1.0	1.3	1.5	1.7	1.9	2.1	**0.25**
	0.4	1.7	2.1	2.5	2.9	3.3	3.8	4.2	**0.5**
	0.6	2.5	3.1	3.8	4.4	5.0	5.6	6.3	**0.75**
	0.8	3.3	4.2	5.0	5.8	6.7	7.5	8.3	**1.0**
	1.0	4.2	5.2	6.3	7.3	8.3	9.4	10.4	**1.25**
	1.3	5.0	6.3	7.5	8.8	10.0	11.3	12.5	**1.5**
	1.5	5.8	7.3	8.8	10.2	11.7	13.1	14.6	**1.75**
	1.7	6.7	8.3	10.0	11.7	13.4	15.0	16.7	**2.0**
	2.1	8.3	10.4	12.5	14.6	16.7	18.8	20.9	**2.5**
	2.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0	**3.0**
	2.9	11.7	14.6	17.5	20.5	23.4	26.3	29.2	**3.5**
	3.3	13.4	16.7	20.0	23.4	26.7	30.1	33.4	**4.0**
	3.8	15.0	18.8	22.5	26.3	30.1	33.8	37.6	**4.5**
	4.2	16.7	20.9	25.0	29.2	33.4	37.6	41.7	**5.0**

To find the value in this chart when using collection pans greater than 1 sq ft, divide the volume or weight measured by the square footage of the pan first.

Table 4 Seed Count Method - Wheat

(20 kernel/ft² over each ft² in an acre = 1 bu/ac)

	Concentration Factor (CF)								Loss
CF	1	4	5	6	7	8	9	10	bu/ac
Loss Collected Behind Combine in 1 ft² in # of Kernels (#/ft²)	5	20	25	30	35	40	45	50	0.25
	10	40	50	60	70	80	90	100	0.5
	15	60	75	90	105	120	135	150	0.75
	20	80	100	120	140	160	180	200	1.0
	25	100	125	150	175	200	225	250	1.25
	30	120	150	180	210	240	270	300	1.5
	35	140	175	210	245	280	315	350	1.75
	40	160	200	240	280	320	360	400	2.0
	50	200	250	300	350	400	450	500	2.5
	60	240	300	360	420	480	540	600	3.0
	70	280	350	420	490	560	630	700	3.5
	80	320	400	480	560	640	720	800	4.0
	90	360	450	540	630	720	810	900	4.5
	100	400	500	600	700	800	900	1000	5.0

To find the value in this chart when using collection pans greater than 1 sq ft, divide the seed count by the square footage of the pan first.

Table 5 Seed Count Method - Barley

(14 kernel/ft² over each ft² in an acre =1 bu/ac)

	Concentration Factor (CF)								Loss
CF	1	4	5	6	7	8	9	10	bu/ac
Loss Collected Behind Combine in 1 ft² in # of Kernels (#/ft²)	4	14	18	21	25	28	32	35	0.25
	7	28	35	42	49	56	63	70	0.5
	11	42	53	63	74	84	95	105	0.75
	14	56	70	84	98	112	126	140	1.0
	18	70	88	105	123	140	158	175	1.25
	21	84	105	126	147	168	189	210	1.5
	25	98	123	147	172	196	221	245	1.75
	28	112	140	168	196	224	252	280	2.0
	35	140	175	210	245	280	315	350	2.5
	42	168	210	252	294	336	378	420	3.0
	49	196	245	294	343	392	441	490	3.5
	56	224	280	336	392	448	504	560	4.0
	63	252	315	378	441	504	567	630	4.5
	70	280	350	420	490	560	630	700	5.0

To find the value in this chart when using collection pans greater than 1 sq ft, divide the seed count by the square footage of the pan first.

Table 6 Number of seeds per square foot to equal 1 bu/acre loss if distributed evenly behind full combine cut width

Crop	Seeds/sq ft to equal1 bu/acre loss	Crop	Seeds/sq ft to equal1 bu/acre loss
Barley	14	Sorghum	20
Corn	2	Soybean	4
Durum	16	Sunflower	3
Oat	10	Wheat	20
Pea	3		

Seed count method is not recommended for canola or flax due to small seed size

Function	Problem	Adjustment (make only one at a time)
Under-Threshing	straw - seed left in heads or pods	increase threshing speed, decrease concave clearance, add concave blanks, slow down
	cleaner - unthreshed heads	increase threshing speed, decrease concave clearance, add concave blanks, slow down
	returns - unthreshed heads	increase threshing speed, decrease concave clearance, add concave blanks, slow down
	graintank - part heads, no small kernels	increase threshing speed, decrease concave clearance, add concave blanks, slow down
Over-Threshing	straw - broken up excessively	drive faster, decrease threshing speed, increase concave clearance
	cleaner - high chaff load, cracked grain	drive faster, decrease threshing speed, increase concave clearance
	grain tank - cracked grain	decrease threshing speed, increase concave clearance
Separating	straw - grain loss	increase threshing speed, decrease concave clearance, use wider spaced wire concaves, reduce vane angle, slow down
	straw - excessive chaff	decrease threshing speed, increase concave clearance, use narrow wire space concaves, increase vane angle
Cleaning	What fan speed?	feed combine slowly - increase fan speed until start blowing a few seeds over chaffer sieve
	chaff - seed (threshed)	increase chaffer sieve opening, even out chaff/grain loading, decrease chaffer opening, decrease cleaning sieve opening
	grain - light trash	increase fan speed, decrease chaffer opening, decrease cleaning sieve opening
	return - clean grain	open sieve, open chaffer, decrease fan speed

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APPENDIX B

IN-FIELD SURVEY FORM

CARP Grain Loss In-Field Survey (R21013P)

General Information		
Name:	Date:	Time:
Field Location:	Wind speed & Direction (km/h):	Relative Humidity (%):
Ambient Temp (°C):	Weather Description: (sun/cloud/wind)	Wind level (L/M/H): ☐1 ☐2 ☐3
Drop Pan Used: ☐ **Bushel Plus** (Catch Area = **4.17 ft^2**)		Total Combines in Operation:

Biosecurity Information		
Field Entry Consent? ☐ Yes ☐ No	**Personal Protective Clothing Used:** ☐ Boot covers ☐ Gloves/Hand Sanitizer ☐ Coveralls	*Mark as N/A if not applicable
	Sanitization Completed: ☐ Tools/Equipment ☐ Truck ☐ Boots	

Crop Information			
Seeding Date:	Seeding Rate (bu/ac):	Canola Variety:	Row Spacing (in):
☐ **Swathed**	Swathing date:		Swather (cut) Width (ft):
☐ **Straight-Cut**	Pre-Harvest treatment date & type:		Header (cut) Width (ft):

Test Information - Combine #1				
Make:	**Model:**	**Year:**	**Type:**	**Hours:**
Discharge Width (ft):	Cut Width (ft):	Concentration Factor:	Catch Area (ft^2):	Yield (bu/ac):
Canola Moisture Content (%):	Accelerated Pre-Sep (in): (Claas only)	Discharge (dropped, chopped/spread):		
Fan Speed (RPM):	Rotor/Cylinder Speed (RPM):	Concave Clearance (in):		
Pre Sieve Opening (in):	Upper Sieve Opening (in):	Lower Sieve Opening (in):		

TEST REPS	Ground Speed (mph)	Collected Volume (ml)	Collected Weight (g)	Calculated Loss (bu/ac)	Direction of Travel	Notes
Rep #1						
Rep #2						
Rep #3						

Comments:

$$Loss\left(\frac{bu}{ac}\right) = \frac{Collected\ Weight\ (g)}{Catch\ Area\ (ft^2)} * \frac{1}{Concentration\ Factor} * \frac{1}{Canola\ Density\left(\frac{lb}{bu}\right)} * \frac{43{,}560\ \left(\frac{ft^2}{ac}\right)}{453.6\ \left(\frac{g}{lb}\right)}$$

Assuming:

$$Canola\ Density = 50\ lb/bu$$

$$Concentration\ Factor\ (CF) = \frac{Cut\ Width(ft)}{Discharge\ Width(ft)}$$

$$Loss\ \left(\frac{bu}{ac}\right) = \frac{Collected\ Weight\ (g)}{Catch\ Area\ (ft^2)} * \frac{Discharge\ Width(ft)}{Cut\ Width(ft)} * 1.92\ \left(\frac{ft^2 * bu}{g * ac}\right)$$

I acknowledge that the PAMI representative on site reviewed the *Field Entry Biosecurity Protocol*, the *Test Procedure*, and the *Toolbox Safety Form* prior to commencing testing. I also grant PAMI permission to anonymously use any data collected during testing.

Cooperator Name: **Cooperator Signature:**

Test Information - **Combine #2**						
Make:	**Model:**		**Year:**		**Type:**	**Hours:**
Discharge Width (ft):	Cut Width (ft):		Concentration Factor:		Catch Area (ft^2):	Yield (bu/ac):
Canola Moisture Content (%):		Accelerated Pre-Sep (in): (Claas only)			Discharge (dropped, chopped/spread):	
Fan Speed (RPM):		Rotor/Cylinder Speed (RPM):			Concave Clearance (in):	
Pre Sieve Opening (in):		Upper Sieve Opening (in):			Lower Sieve Opening (in):	
TEST REPS	**Ground Speed (mph)**	**Collected Volume (ml)**	**Collected Weight (g)**	**Calculated Loss (bu/ac)**	**Direction of Travel**	**Notes**
Rep #1						
Rep #2						
Rep #3						
Comments:						

Test Information - **Combine #3**						
Make:	**Model:**		**Year:**		**Type:**	**Hours:**
Discharge Width (ft):	Cut Width (ft):		Concentration Factor:		Catch Area (ft^2):	Yield (bu/ac):
Canola Moisture Content (%):		Accelerated Pre-Sep (in): (Claas only)			Discharge (dropped, chopped/spread):	
Fan Speed (RPM):		Rotor/Cylinder Speed (RPM):			Concave Clearance (in):	
Pre Sieve Opening (in):		Upper Sieve Opening (in):			Lower Sieve Opening (in):	
TEST REPS	**Ground Speed (mph)**	**Collected Volume (ml)**	**Collected Weight (g)**	**Calculated Loss (bu/ac)**	**Direction of Travel**	**Notes**
Rep #1						
Rep #2						
Rep #3						
Comments:						

Test Information - **Combine #4**						
Make:	**Model:**		**Year:**		**Type:**	**Hours:**
Discharge Width (ft):	Cut Width (ft):		Concentration Factor:		Catch Area (ft^2):	Yield (bu/ac):
Canola Moisture Content (%):		Accelerated Pre-Sep (in): (Claas only)			Discharge (dropped, chopped/spread):	
Fan Speed (RPM):		Rotor/Cylinder Speed (RPM):			Concave Clearance (in):	
Pre Sieve Opening (in):		Upper Sieve Opening (in):			Lower Sieve Opening (in):	
TEST REPS	**Ground Speed (mph)**	**Collected Volume (ml)**	**Collected Weight (g)**	**Calculated Loss (bu/ac)**	**Direction of Travel**	**Notes**
Rep #1						
Rep #2						
Rep #3						
Comments:						

For further information with regards to this report, please contact:

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