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Final Report

Benchmark Testing in Canola using a John Deere X9 1100 with HD50R and a CLAAS Lexion 8800 with MacDon FD145

For:

John Deere Harvester Works
East Moline, Illinois

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1. Executive Summary

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John Deere Harvester Works (the Client) contracted Prairie Agricultural Machinery Institute (PAMI), to provide combine benchmark testing between John Deere's latest Class 10 combine (X9) and a Class 10 CLAAS Lexion 8800 series combine. The testing was conducted between October 1 and October 4, 2020, in canola in a test field near Marsden, Saskatchewan, Canada.

The benchmark testing in canola consisted of loss curve testing, fuel consumption testing, and header loss testing. All tests were conducted using a straight-cut method, in a pod shatter-resistant variety of canola (L345PC). The John Deere X9 combine was equipped with a John Deere HD50R Hinge Draper header, and a MacDon FD145 Flexdraper header was attached to the CLAAS 8800. Where appropriate, an analysis of variance (ANOVA) with a confidence level of 90% was used to determine if test results were significant.

Both combines were configured for harvesting canola as per manufacturer instructions (operator's manual). Loss curve testing was conducted first, and prior to testing, the settings of both combines were optimized for typical producer throughput at the target total loss rate on both the separator and the cleaning shoe. The optimization procedure included following manufacturer-recommended settings; then, through the use of the PAMI equipment and methods, settings were further optimized.

PAMI's combine test equipment was used to develop loss curves for each combine, these loss curves provide a complete picture of grain loss over the range of feed rates tested and allowed combine capacity to be determined. The test combines were compared using total feed rate, while also taking into account material other than grain (MOG) to grain ratios.

Combine performance is evaluated by the achievable capacity at a given total loss rate; in this report, combine capacity was compared at a total loss rate of 3.0% as per the ANSI/ASAE standard (S343.4 – Terminology for Combines and Grain Harvesting).

The loss curve results showed both combines had very similar total loss rates across the entire range of feed rates tested, where the loss curves nearly matched when plotted on the same graph. Combine capacities were therefore very similar; both the John Deere and CLAAS were able to reach between 62 and 63 tonnes/h (137,000 and 139,000 lb/h) at 3.0% total loss. Both combines were found to be cleaning-shoe limited at combine capacity. The canola crop condition was such that the stalks and stems were still green; however, the pods and grain were cured and dried. In this tougher threshing condition, both combines had approximately 1% loss on the separator over the entire range of feed rates, though cleaning shoe losses were dominant, as high chaff loads were still apparent.

Both combines were material-handling limited at the highest throughput tested. Due to green stems in the canola, there was a risk of plugging rotors/threshing cylinder at higher throughputs. Therefore, the highest achievable throughput was based on operator discretion (i.e., comfort level based on machine distress, noise, vibration, etc. from the threshing area) and may not represent the actual highest throughput possible in this condition. The John Deere distress level was found to occur at a higher throughput (89 tonnes/h) compared to the CLAAS (73 tonnes/h).

Fuel consumption testing was also conducted between the two combines to evaluate fuel consumption performance in canola.

Testing consisted of plumbing in auxiliary fuel tanks on both combines and measuring fuel usage by measuring the difference in fuel weight from the beginning and end of each test. Tests were conducted by harvesting a full header width for the entire test length of 683 m (2,240 ft). To ensure grain loss levels were similar between combines, the capacity at 3.0% total loss was targeted (known from loss curve testing conducted previously), which was approximately 25 tonnes/h (55,000 lb/h) grain feed rate or 62 tonnes/h (137,000 lb/h) total feed rate. Combine settings were also adjusted to the optimized settings found during loss curve testing, with the addition of setting the residue systems on each combine to achieve similar chop and distribution quality.

The specific fuel consumption results showed the John Deere X9 used 18% less fuel per tonne of grain harvested compared to the CLAAS 8800. In terms of fuel consumption rate with respect to time and area harvested the John Deere used 20% less fuel per hour and 16% less fuel per harvested area than the CLAAS 8800.

The purpose of header loss testing was to directly compare performance of the John Deere HD50R Hinge Draper and the MacDon FD145 Flexdraper header.

Header loss testing consisted of placing loss pans between rows in undisturbed crop, along the entire header width (except in areas of combine or header tires) as well as 76 cm (30 in) past each divider to collect grain loss. Prior to testing, each combine harvested multiple passes in the same direction as the tests were to be conducted in and header settings were adjusted to reduce header loss. It should be noted, the canola stand was leaning to the east and the tests were conducted in the same direction as the crop lean; therefore, more aggressive header settings were required to pull the plants back towards the header. Three repetitions were conducted per combine, where each combine harvested at a ground speed of 4 km/h (2.5 mph). Each test consisted of a run-in length of approximately 55 m (180 ft), in which the combine was able to obtain steady-state prior to reaching the loss pans. After the combine passed over the loss pans, the combine was stopped and allowed to clean out such that the neither the header cleanout nor the material discharging from the rear of the combine contaminated the loss pans.

The header loss results showed the total average header loss of the John Deere was 1.0% while the MacDon was 1.4%. The difference of 0.4% was found to be statistically significant. The results were further broken up into five main sections across the header, specifically the right divider, right draper belt, center, left draper belt, and left divider. In terms of loss variance across the sections, both combines showed higher loss rates at the dividers and center section than the draper belt zones. The header loss on the right divider and draper belt sections was found to be statistically significantly less on the John Deere header than the MacDon.

Combine configuration, setting, and operation was led by PAMI; however, John Deere representatives were present to assist with optimization of the John Deere combine. Experienced PAMI personnel were responsible for optimizing the CLAAS combine, as no manufacturer representatives were present at any point during optimization or testing.

Although best efforts were made to conduct tests under constant conditions, inconsistent crop, changing weather conditions, and other uncontrollable variables are inherent during combine testing. These factors need to be considered when drawing conclusions from the data collected.

2. Introduction

This testing was conducted by the Prairie Agricultural Machinery Institute (PAMI) working in collaboration with its associate.

John Deere Harvester Works (the Client) contracted Prairie Agricultural Machinery Institute (PAMI) to provide combine benchmark testing between its latest Class 10 combine, the X9 1100, and a CLAAS Lexion 8800 series combine.

Testing was conducted in a pod shatter-resistant variety of canola (BASF Invigor L345PC) using straight-cut headers. The John Deere X9 was outfitted with a John Deere HD50R Hinge Draper header and the CLAAS 8800 with a MacDon FD145 Flexdraper header.

The goal of this testing was to directly compare performance results from the two combines in typical harvesting conditions in canola in Western Canada. Data was collected and analyzed to calculate the following harvesting performance parameters:

- Combine capacity (loss testing)
- Fuel consumption
- Header loss

PAMI has forty-five years of experience testing harvesting equipment in various locations worldwide with a specialty in Western Canadian crops and conditions. PAMI has developed a specific procedure for benchmarking combines and has the specialized equipment, expertise, and third-party impartiality to provide accurate, meaningful data to the Client.

Although this project was funded by the Client, PAMI conducted the tests as an independent agency with full control of the testing and data. Combine configuration, setting, and operation, was led by PAMI; however, Client representatives were present to assist with optimization of John Deere combine performance. Experienced PAMI personnel were responsible for optimizing the CLAAS combine, as no manufacturer representatives were present at any point during optimization or testing. It is also important to note that for this project, the field testing was conducted in one field condition per crop; therefore, the test results may not represent performance in all crops or conditions.

3. Test Procedure

The following subsections detail the procedure used for the combine benchmarking tests conducted in canola between October 1 and October 4, 2020.

3.1 Equipment

The following equipment was used in combine benchmark testing for this project:

- The test combines used are described below and shown in (**Figure 1**).
  - John Deere X9 with 15.2 m (50 ft) John Deere HD50R Flex Draper Header
    - John Deere vertical knife dividers installed
    - Upper cross auger equipped
  - CLAAS LEXION 8800 with 13.7 m (45 ft) MacDon FD145 Flex Draper Header
    - Ziegler vertical knife dividers installed
    - Upper cross auger equipped
- PAMI combine test equipment
  - Processor
  - Collector
  - Tandem Grain Truck (with load cells)
  - Moisture Meter
  - Loss drop pans
  - Remote drop pans
  - Forage separator

Figure 1. John Deere X9 (left) and CLAAS Lexion 8800 (right) attached to collector during loss curve testing.

3.2 Combine Settings Optimization Procedure

Prior to optimizing settings, both combines were configured for harvesting canola as per the combine manufacturer’s recommendations (operator’s manual). The combines were then fully optimized for typical producer throughput at the target total loss rate of 3% using PAMI equipment and methods. As well, each combine was started and allowed to run for a period of time to clean internal surfaces of rust, excess paint, or anything else that may impede smooth operation.

The engine and threshing hours of each machine prior to testing were recorded and are shown in **Table 1**.

Table 1. Threshing hours of each machine prior to testing.

Combine	Engine hours	Threshing Hours
John Deere X9 1100	40	9
CLAAS LEXION 8800	61	6

The following paragraphs describe the procedure used to optimize combine settings prior to loss curve testing. Note, the same optimized combine settings were then used in both fuel consumption and header loss testing.

The procedure to optimize each combine began by using manufacturer-recommended settings as stated in the operator's manual. If settings were given as a range, the value that would result in the least amount of loss was initially selected (i.e., widest sieve opening and smallest concave gap).

Loss data was collected using PAMI's unique combine loss testing equipment (collector and processor) to quantify the grain loss associated with the test combine's separator and cleaning shoe. The grain tank sample quality (amount of material other than grain [MOG] and grain damage in sample) was also monitored to ensure each combine had a similar and acceptable sample. This was done by collecting several grain samples during the test runs and processing them for damage and MOG. If grain loss was found to be higher than acceptable on either the separator or cleaning shoe, settings were changed on each system accordingly. This included making changes to concave gap or rotor speed to reduce separation loss and changes to both the chaffer and bottom sieve openings as well as fan speed to reduce grain loss on the cleaning shoe. It's important to note, all automatic combine setting features were turned off during the optimization procedure and during testing.

The optimized combine settings used for testing in canola are found in Error! Reference source not found., and a full list of combine configurations are found in **Appendix A**.

Table 2. Combine settings in canola.

Combine Setting	John Deere X9	CLAAS LEXION 8800
Chaffer Sieve mm (in)	15 (19/32)	15 (19/32)
Lower Sieve mm (in)	5 (7/32)	5 (7/32)
Fan Speed (rpm)	700	1000
Rotor Speed (rpm)	750	780
Threshing Cylinder Speed (rpm)	-	430
Concave clearance mm (in)	22 (7/8)	21 (27/32)
Vane Position	Fixed	Fixed

Combine Setting	John Deere X9	CLAAS LEXION 8800
Separator Blank Out Plates	Installed	Closed All (4/4)
Threshing Blank Out Plates	Removed	-
Disawning Plates	-	Open
Concave Bar Position	-	Disengaged

3.3 Loss Curve

The purpose of this test was to directly compare the capacity performance of a John Deere X9 1100 to a CLAAS Lexion 8800. Loss curve testing was conducted using PAMI's unique combine test equipment including a collector, processor, and tandem grain truck equipped with scales. Testing was conducted in canola near Marsden, Saskatchewan, Canada.

3.3.1 Combine Loss Collection Procedure

PAMI's grain loss testing equipment consists of a collector and processor, which when used together, collect the discharged material from the rear of the combine over a set distance and separate the grain loss from the MOG. A typical collection point can be seen in **Figure 2** where the test combine has come to a stop, the collector hitch has extended and the processor is beginning to process the material from the collector belts.

Figure 2. Loss curve testing collection point.

The collector is towed behind the test combine and collects all material discharged from the rear of the combine. The combine harvests for at least 30 seconds to reach a steady state at a given feed rate. During this time, material from the combine's separator is conveyed on the top "straw belt", while material from the cleaning shoe is conveyed on the lower "chaff belt" of the collector. It should be noted that the choppers and spreaders are removed to facilitate the collection of straw and free grain.

When the test combine operator believes the combine has reached a steady state, the "start test" button on the collector controller is pressed and the test process begins. The collector travels a distance equivalent to one half rotation of its belts (9.0 m [29.5 ft]) before the belts stop

and the hitch extends away from the discharge area of the combine. The operator then stops the test combine and the material on each collection belt is weighed. The material on each belt consists of MOG and grain loss. These weights, the time it took for a collection, belt length, and belt speed-to-ground speed ratio are recorded on the loss spreadsheet along with known values of crop yield and header width.
Crop yield is calculated by weighing the harvested grain at each collection point. With the known header width, distance travelled, and grain weight, the yield is calculated for each collection point rather than an average over the field. The weight is taken by unloading the test combine into the tandem grain truck outfitted with load cells after each point.

Once the belt gross weights are recorded, the chaff belt is unloaded into the processor, which recleans and, as necessary, rethreshes the crop material from the belt. Through a pneumatic retrieval system, the free grain and previously unthreshed grain are delivered at separate instances to the cab of the processor. The grain loss is then weighed and recorded as free grain and as unthreshed grain loss. The reclean procedure is then repeated for the straw belt. Once both belts are empty, a tare weight is taken to get a net MOG (and grain loss) weight for the collection.

This process was repeated six to eight times at varying feed rates to create a grain loss curve. Note, the order in which the combines were tested was switched between test days to reduce the effect of changing crop condition on the results. The process to determine the target feed rates that would most effectively build a loss curve was similar for each combine. The first four collection points were used to fill in the majority of the curve by targeting feed rates of approximately 30, 45, 60, and 70 tonnes/h (66,000, 99,000, 132,000 and 154,000 lb/h). Another collection point was collected at the combine's approximate maximum throughput (100% engine load or other harvest limitations) to achieve a high loss/high throughput point. The remaining collection points targeted specific ground speeds to achieve better resolution in areas of the curve where the rate of grain loss was changing rapidly.

To maintain optimum processor performance, settings were adjusted to the specific crop and field conditions. To verify the performance once the processor was set for canola, a 1,000 g sample of free grain was allowed to run through the processor, and the retrieved grain was weighed. Multiple repetitions were conducted in each crop and resulted in a grain retrieval rate of approximately 93%.

Grain moisture samples were also collected throughout testing to obtain an average grain moisture content during each test day.

The above loss collection procedures were completed in reference to the ANSI/ASEA standard (S396.3 – Combine Capacity and Performance Test Procedure).

3.3.2 Loss Curve Creation

Data from the loss collection procedure is used to create loss curves, which allow the test combines to be compared head-to-head. Data from each collection point is plotted on a graph that compares grain loss to feed rate. Typically, six to nine points are collected to create a curve. The grain loss is presented as a percentage of grain yield to reduce the effect of a variable yield. The feed rate can be presented as either MOG, grain, or total feed rate dependent on the crop, conditions, and results.

Once the points are plotted for each test combine, a line of best fit is laid out, typically an exponential or second-order polynomial. From there, a loss limit is set at which the capacity of the combines can be compared. The limit is dependent on the grain being harvested, and in this case the canola loss limit will be compared at 3.0% total loss respectively, as per the ANSI/ASAE Standard S343.4 – Terminology for Combines and Grain Harvesting.

MOG-to-grain ratios, MOG yield versus grain yield, and yield variations through the field, are all metrics used to verify the quality of the data. Loss points that deviate significantly from the curve can be removed if they are deemed to be outliers. This can be due to machine malfunction, test equipment malfunction, significant crop condition changes, or a number of other reasons. If the points are removed, reasons for removal are provided.

3.4 Fuel Consumption

The objective of this testing was to directly compare the fuel consumption performance of a John Deere X9 combine to a CLAAS LEXION 8800 combine. All testing was conducted using test equipment from PAMI, including auxiliary fuel tanks, fuel plumbing systems and a grain truck equipped with load cells. Tests were conducted near Marsden, Saskatchewan, Canada, in canola.

3.4.1 Test Procedure

The test procedure included operating each combine at a throughput that resulted in a similar and acceptable grain loss level, this value was set at 3.0% total loss, which corresponded to a total throughput of approximately 62 tonnes/h (137,000 lb/h) or grain throughput of approximately 25 tonnes/h (55,000 lb/h) for both combines (known from loss curve test results presented in **Section 4.1.2**). A full header width was obtained over the full test distance through the use of combine GPS. To reduce any change in conditions between tests, the combines were tested side by side, in the same direction, with one immediately following the other. The fuel consumption test included the fuel used to thresh the grain (unloading of the grain and headland turning were not taken into account).

To determine fuel use, an auxiliary fuel supply tank was weighed before and after each test. To utilize the auxiliary tank for measuring fuel use during the test, a valve was plumbed into the fuel line between the main tank and the engine. This valve switched the fuel supply from either the main fuel tank or the auxiliary tank. Similarly, a selector valve was plumbed into the return fuel line to direct return flow to either the main or auxiliary tank.

Plastic fuel tanks were used as the auxiliary tanks (**Figure 3**) and were equipped with quick couplers for easy attachment to the fuel supply and return lines.

Figure 3. Marine auxiliary tank on John Deere X9 1100 combine.

Prior to testing, variables that could have a significant effect on fuel consumption between combines were noted and were set similarly across all the combines including chop quality, grain tank sample, grain loss, and grain damage.

Chopping quality was set similarly between both combines by adjusting the knife bank setting on the chopper. Crop residue samples were collected at this knife bank setting and processed through the forage separator to get chop quality results for each combine. It was determined that a fully engaged knife bank on both combines resulted in very similar chop quality and therefore this position was used during testing.

At the beginning of each test, the combine was positioned directly in front of the crop and a new GPS heading was created. The fuel line valves were then switched to the auxiliary tank. The combine thresher and header were engaged and the test start time was recorded using a stopwatch. The time spent idling before entering crop (time for operator to engaged header, thresher etc.) was also recorded, which was kept as consistent as possible between combines. This idle time was determined to be insignificant relative to the test length.

To ensure there was no residual grain or MOG in the combines, each combine exited the crop by approximately 3 m (10 ft) at the end of the run, while the separator remained engaged for ten seconds after the combine came to a complete stop. The operator then disengaged the separator, idled the engine down and switched the selector valves back to the combine tank. At this point, the fuel lines to the auxiliary tank were uncoupled and the fuel tank was weighed using a length of square tubing and a load cell. Once the fuel usage was determined at the end of each test, the harvested grain was unloaded into a tandem grain truck outfitted with weigh scales so the grain yield could be determined.

3.5 Header Loss

Header loss testing was completed in a shatter-resistant variety of canola (Bayer Invigor L345PC) in a field near Marsden, Saskatchewan, Canada, on October 3, 2020.

Due to availability, the test combines were equipped with headers of different widths, the CLAAS 8800 was outfitted with a MacDon FD145 with a width of 13.7 m (45 ft) and the John Deere X9 was outfitted with a John Deere HD50R with a width of 15.2 m (50 ft). Both headers were configured with vertical knife dividers, where the MacDon FD145 was equipped with Ziegler branded vertical knifes and the John Deere HD50R had John Deere vertical knifes.

3.5.1 Combine Header Optimization and Settings

Prior to testing, both combine headers were optimized to reduce grain loss while ensuring consistent crop feeding. This was accomplished by harvesting multiple passes with each combine in the same direction in which the actual header loss tests were to be conducted, while adjusting header settings and visually observing crop flow characteristics. It should be noted that the canola crop was leaning east to west and was harvested in the same direction; this gave the best chance to see header loss in the shatter-resistant variety.

Header cutter bar height was similarly set between combines at approximately 15 cm (6 in) and was maintained throughout testing by use of auto-header height control. This was the highest cut height where all pods were still being collected due to the lean in the crop stand. In general, reel settings were adjusted to the least aggressive setting (i.e., reel speed to match ground speed, reel fingers just in crop, etc.) and adjusted as needed to aid crop feeding. It should be noted that the reel on each combine was positioned slightly further forward and down to aid in pulling the canola plants that were leaning away from the header.

The optimized header settings for each header can be seen below in **Table 3**.

Table 3. Optimized header settings.

Header Setting	**MacDon FD145**	**JD HD50R**
Reel speed	2.8 mph	Setting 12
Reel fore/aft position[1]	Position 4 (19 in)	(15.5 in)
Reel finger pitch	Cam setting - 2	Cam setting - mid
Reel height	Fingers just in-crop	Fingers just in-crop

Header Setting	MacDon FD145	JD HD50R
Cross auger speed	Synced to draper speed	Synced to draper speed
Draper speed	Mid-high	Mid-high (70)
Header tilt	Centered	-
Feeder house tilt	Centered	Centered

[1]Indicates distance from center of reel to end of knife section

3.5.2 Header Grain Loss Test Procedure

Header grain loss testing was conducted with the test combines in one variety of canola (L345PC); three repetitions were conducted per combine.

To mark the beginning and end of the test area, alleyways, two header-widths wide, were harvested in a north and south direction. The alleyways were combined using GPS to keep the test area a consistent length of approximately 55 m (180 ft), where the test runs were harvested in the direction the canola was seeded (east to west). This allowed grain loss pans measuring 113 x 18 cm (44.4 x 7.1 in.) to be placed between the rows at the end of the test area (**Figure 4**).

Figure 4. Loss pans placed in between crop rows.

Prior to testing, the pan layout was determined for each header. Pans were placed along the front of the header, except where they would be in the path of the combine's tires and header gauge wheels. To ensure pan placement was constant through all test iterations, a rope was stretched across the pans and the location of each was marked. To further ensure the header would be centered over the pans, a new GPS heading was created for each test.

Once the loss pans were placed, the combine began harvesting at the start of the test area, targeting a ground speed of 4 km/h (2.5 mph) with auto-header height control and auto-steer engaged. The combine and header had sufficient time to achieve steady state prior to reaching the grain loss pans located at the end of the test area. Once the combine header had fully passed the grain loss pans, the combine was stopped and allowed to clean out (**Figure 5**). The combine was stopped in such a position that the grain loss pans would not be contaminated by the header cleanout or the material discharging from the rear of the combine. The combine was then reversed, and the loss material from each pan was bagged and labelled. This process was then repeated immediately with the second combine, leaving approximately 3 m (10 ft) of unharvested crop between test runs.

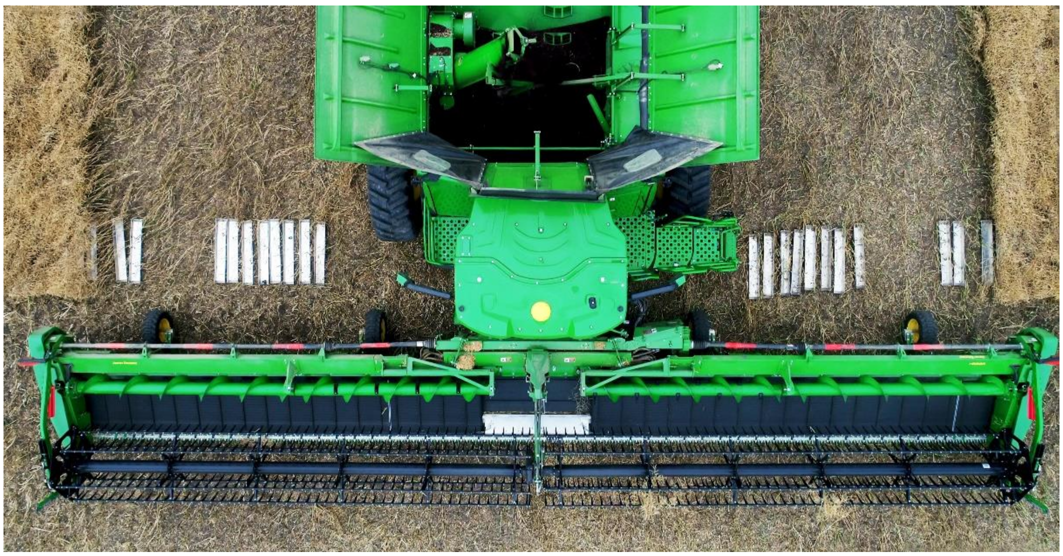

Figure 5. Combine stopped after passing grain loss pans.

The pan layout used for the MacDon and John Deere headers can be seen in **Figure 6** and **Figure 7**, respectively.

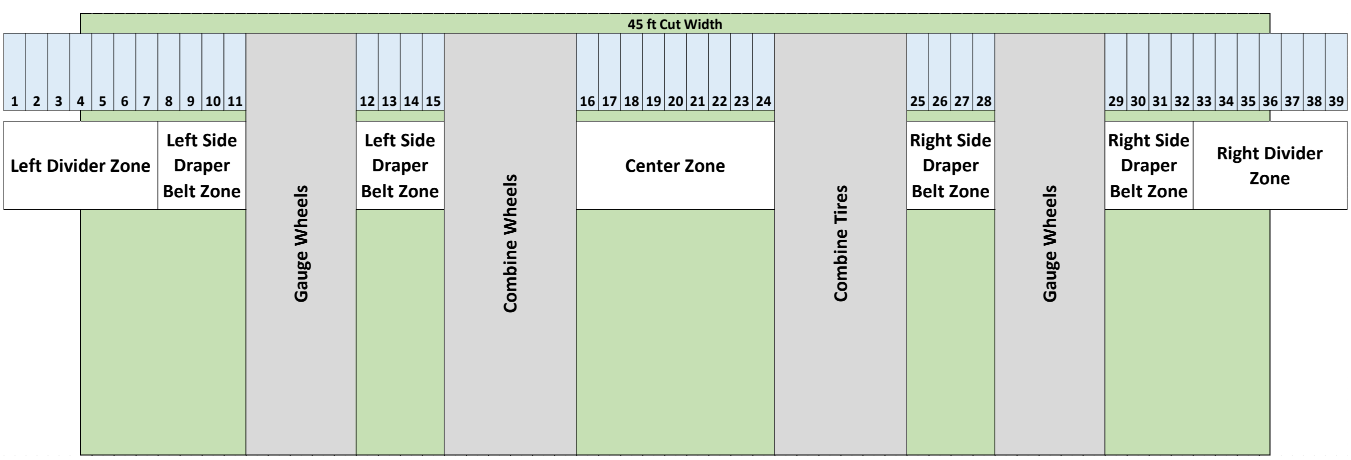

Figure 6. MacDon FD145 header loss pan layout.

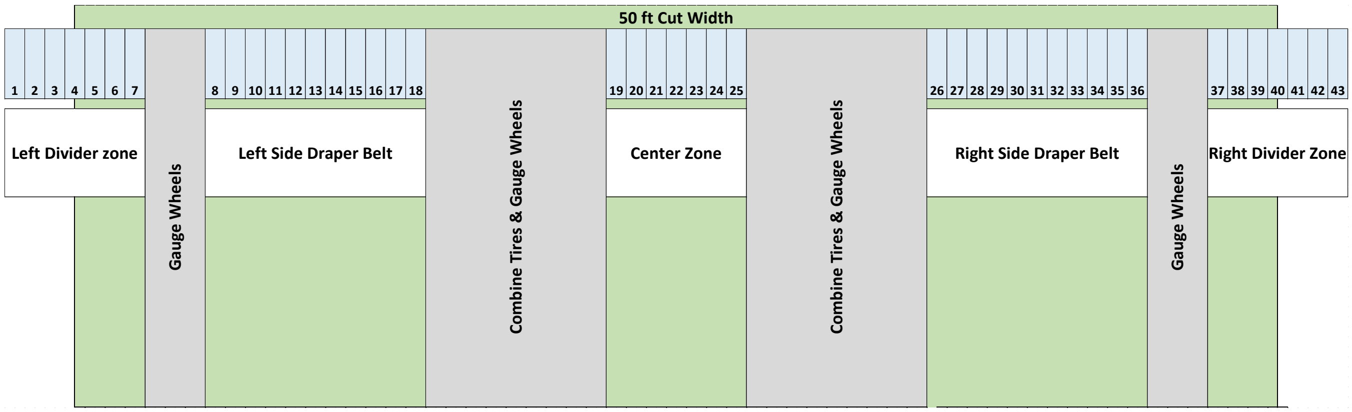

Figure 7. John Deere HD50R header loss pan layout.

As seen in **Figure 6** and **Figure 7,** the MacDon header had fewer loss pans (39 pans compared to the 43 used for the John Deere header) to account for the difference in header widths. Each header was broken down into five main zones: left divider, left side draper belt, center, right side draper belt, and right divider. Again, the number of pans within these zones varied between the headers as a result of implement width and combine/gauge wheel location.

3.6 Limitation of Results

In general, the combines were all tested in a similar crop/weather condition using the same testing procedures, such that testing could be conducted as fairly and in a controlled environment as possible. However, there are always uncontrollable variables and uncertainties to consider. These variables are further apparent with field testing where environmental conditions cannot be controlled.

In addition, the results across all tests were collected from one crop, over one day, in one condition; therefore, the results will not represent performance in all crops or all conditions.

3.6.1 Loss Curve Testing

Combine configuration, setting, and operation was led by PAMI; however, John Deere representatives were present to assist with optimization of the John Deere combine. Combine-experienced PAMI personnel were responsible for optimizing the CLAAS combine, as manufacturer representatives were not present at any point during testing.

3.6.1.1 Processor Loss

To ensure the processor was operating at optimum performance, settings were adjusted to the specific crop and field conditions. To verify the performance of the processor for canola, a 1,000 g sample of free grain was put through the processor and the retrieved grain was weighed. Multiple repetitions were conducted and resulted in a grain retrieval rate approximately 93%.

3.6.1.2 Collector Scales

As the collector was being used for field testing in an uncontrolled environment, there are several factors that can affect the scale readout, such as the slope of the terrain where the collector was sitting, wind, and belt positioning/tracking.

3.6.1.3 Approximation in Loss Curve Analysis

The methods used to analyse the loss curve data included using exponential or polynomial functions to approximate a best-fit curve. These functions are used to interpolate between loss points so multiple curves or combines can be compared at a specific grain loss or feed rate. As such, it is difficult to accurately predict values of loss along the curve, especially if the data points are variable and do not show a strong trend in the curve.

3.6.1.4 Field Variability

Comparing the combine's capacity at a percentage loss rather than absolute loss helps remove some uncertainty from field variability in the analysis. Despite this, variability in grain yield and/or MOG yield over short distances can still affect the results. Since yield is measured as an average over the distance the combine travels during the point, the short actual collection time where the loss is collected may not completely represent the average yield. Since it is difficult to keep a constant feed rate into the combine, due to crop yield changes, a constant speed is the best approximation.

3.6.2 Fuel Consumption Testing

The method used to test the fuel consumption of each combine was designed to reduce the chance of human error and provide the most accurate results. Therefore, fuel usage across all combines was determined by strictly measuring for harvesting only (i.e., threshing the grain) and not accounting for the fuel required to turn at headlands or unload grain. In doing so, the results obtained can be used as a comparison across combines; however, the values do not actually represent realistic values that a producer would see, as unloading and turning at headlands are inherently part of the harvesting operation.

Due to availability, the combine headers used during testing were not the same width (X9 was 10% wider) and although its effect on test results are considered minimal, it should be noted.

Combine configuration, setting, and operation was led by PAMI; however, John Deere representatives were present to assist with optimization of the John Deere combine; experienced PAMI personnel were responsible for optimizing both the CLAAS combine, as no manufacturer representatives were present at any point during optimization or testing.

3.6.3 Header Loss Testing

Because header widths were not equal between combines, and taking into account the variance of the combine/gauge wheel positions, drop pan layouts were determined to individually accommodate each combine. This variance in drop-pan layout could have contributed to higher or lower loss points for the combines.

Loss pans were placed into the crop as carefully as possible by sliding them in from the end facing downward and then turning them over. Although care was taken while positioning the pans, this procedure caused unavoidable contact with the canola stalks, which in this case was worsened by crop lean. This may have caused some grain loss prior to testing; however, this loss, although important to note, was very small and found to be insignificant compared to the header loss from the tests.

4. Testing and Results

Testing in canola took place in a field approximately 2 km (1.3 miles) north east of Marsden, Saskatchewan (**Figure 8**), between October 1 and 3, 2020.

Figure 8. Canola test field shown, approximately 2 km (1.3 miles) north east of Marsden, Saskatchewan.

Some crop and field characteristics that are common among all tests are discussed below.

The test field consisted of one quarter of canola, seeded east or west and totaling 160 seeded acres of very flat, uniform land. The canola was a shatter-resistant Invigor variety (L345PC) that was seeded on May 8, 2020.

Overall, harvest conditions were favorable during all tests. The canola plants had a general lean to the east, so a lower cut height was required to ensure all pods were collected. It should also be noted that at the time of harvesting, the canola stalks/stems were still very green even though the grain and pods were very dry. The green stems created a tougher threshing condition, while the dry pods caused high chaff loads. The crop was desiccated prior to harvesting by applying 2.5L/ha (1 Qt/acre) of 360g/L glyphosate using a helicopter on September 10, 2020.

4.1 Loss Curve Testing

The objective of this testing was to directly compare the performance of the combines, by creating loss curves for each, allowing for measurement of their capacities at a given loss rate. Testing was conducted in canola using combine test equipment (collector and processor) from PAMI.

4.1.1 Crops, Conditions, and Test Location

Loss testing took place on the west side of the test field (**Figure 9**) on October 1, 2020. All tests were conducted running south to north, perpendicular to the crop lean which was found to be the best direction for crop feeding.

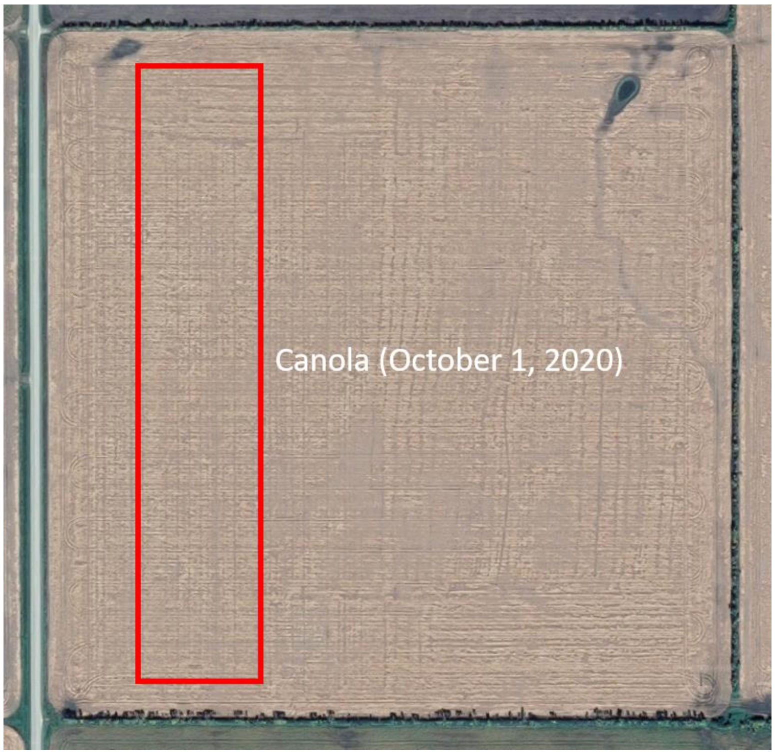

Figure 9. Satellite image showing approximate loss curve testing location within the overall test field.

To reduce the effect of changing crop conditions as much as possible, all testing was conducted between 3:30 p.m. and 6:30 p.m. Weather conditions during loss curve testing were mostly overcast, so crop conditions were relatively stable.

A summary of the weather conditions during loss curve testing is shown in **Table 4** (obtained from the airport weather station in Lloydminster, Alberta); the full weather data set can be found in **Appendix B**).

Table 4. Weather conditions during loss curve testing on October 1, 2020.

Test Day	Time	Temp		RH %	Wind			Condition
		°C	°F		(km/h)	(mph)	Direction	
1-Oct-20	3:30 PM	11	52	53	26	16	NNE	Overcast
	4:00 PM	11	52	51	17	11	NNE	Overcast
	5:00 PM	11	52	53	17	11	NNE	Overcast
	6:30 PM	10	50	57	13	8	NNE	Partly Cloudy

The average grain yield over all tests in the L345PC canola variety was 4.09 tonne/ha (72.9 bu/acre) and the moisture content averaged 7.5%.

4.1.2 Loss Test Results

The John Deere X9 was evaluated first followed by the CLAAS 8800. Loss testing resulted in one loss curve per combine, with each curve consisting of six collection points.

The capacity of each combine was evaluated at 3.0% total grain loss for canola (obtained from ANSI/ASAE S343.4 – Terminology for Combines and Grain Harvesting). The full set of raw data from both days of loss testing can be found in **Appendix C**.

In addition, the combines were compared using total machine loss with respect to total feed rate, as well as a breakdown of separator and cleaning shoe performance. It should be noted that for the purposes of this report, the total machine loss consisted of the separator and cleaning losses but does not include external losses such as header loss. The separator and cleaning shoe loss are discussed in terms of total feed rate.

The total grain loss for each test combine (as a percentage of total grain loss) is plotted in **Figure 10**.

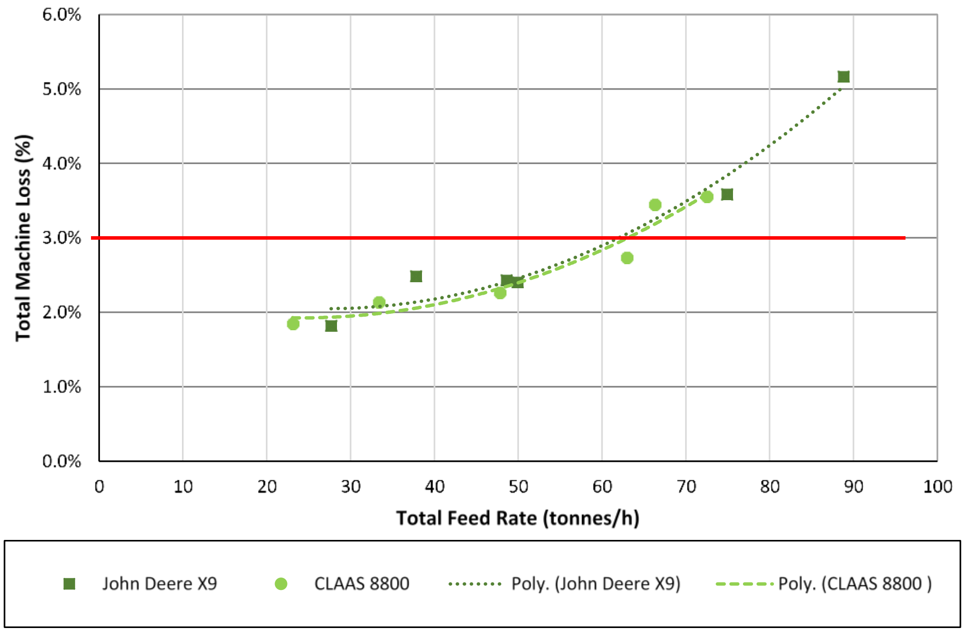

Figure 10. Total machine loss curves in canola.

The total machine loss curves as seen in **Figure 10** are very similar in shape, almost positioned directly on top one another. Both combines achieved approximately 2.0% loss at the lowest feed rate in the conditions tested and steadily increased with increased throughput. Combine capacity at the total machine loss threshold of 3.0% was found to be between 62 and 63 tonnes/h (137,000 and 139,000 lb/h) for both the John Deere and CLAAS.

It should be noted, both combines were material-handling limited at the highest throughput tested; there was a risk of plugging rotors/threshing cylinder at higher throughputs due to green stems in the canola. Therefore, the highest achievable throughput was based on operator discretion (i.e., comfort level based on machine distress, noise, vibration, etc. from the threshing area) and may not represent the actual highest throughput possible in this condition. As seen from the curves, the John Deere distress level was found to be at a higher throughput at 89 tonnes/h compared to the CLAAS at 73 tonnes/h.

The rotor loss on each combine was very similar as well, each combine had a very flat curve where losses remained slightly above 1.0% over the entire range of feed rates tested (**Figure 11)**. The tougher threshing conditions of the canola (shatter-resistant variety with very green stems) are reflected in the separator loss curves where losses did not dip below 1.0% even at low feed rates.

Adjusting threshing settings more aggressively to reduce loss on the rotor was limited due to increased seed damage as well as adversely effecting cleaning shoe loss with higher chaff loads.

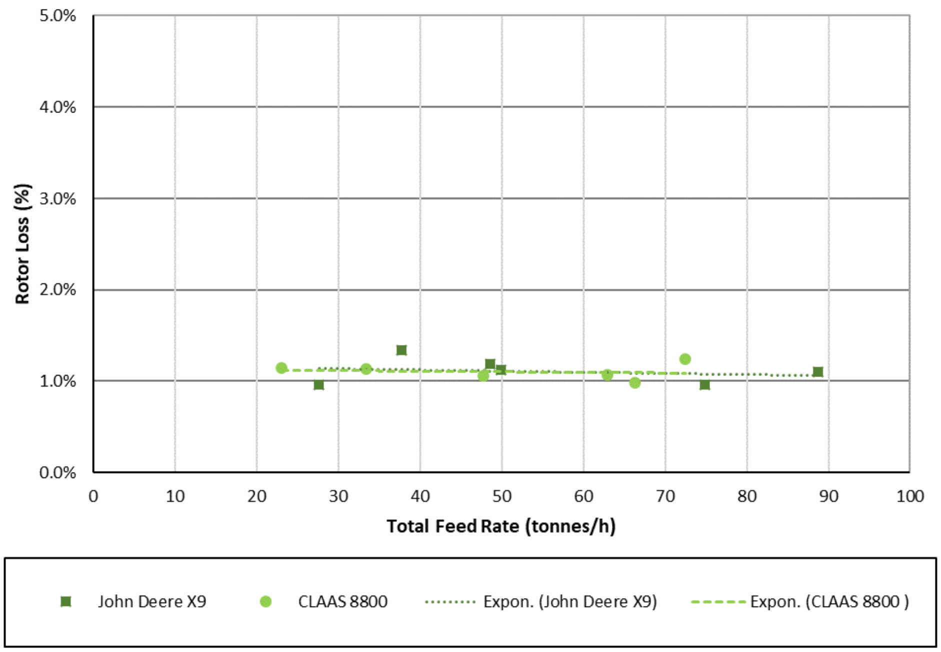

Figure 11. Separator loss curves in canola.

The cleaning shoe loss curves were again very similar, where losses increased steadily as feed rates increased on both combines (**Figure 12**). The cleaning shoe system can be seen to be the dominant loss system in canola, where losses on the shoe were almost always higher than the rotor. This might indicate a high chaff load on the cleaning shoe, which was reduced as much as possible by installing separator covers on the John Deere and engaging the rotor flaps on the CLAAS.

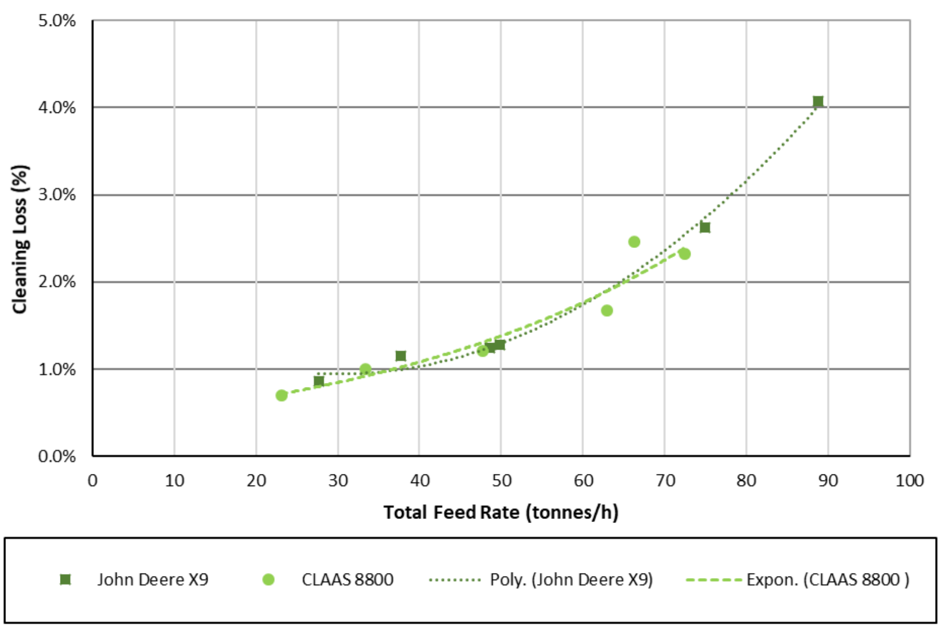

Figure 12. Cleaning loss curves canola.

Even though the test field appeared very uniform and flat, there was some variability in the MOG-to-grain ratios as well as the grain yield. The MOG-to-grain ratios in canola ranged from 1.33 to 1.52 for the John Deere and 1.24 to 1.56 on the CLAAS combine. These ratios fell within the acceptable range of 1.0 to 3.0 for canola according to the ANSI/ASAE Standard S343.4. Grain yields ranged from 3.78 tonnes/ha (67.5 bu/ac) to 4.97 tonnes/ha (88.8 bu/ac) over all tests.

4.2 Fuel Consumption

The purpose of this testing was to directly compare fuel consumption performance of the John Deere X9 1100 to the CLAAS 8800 in canola. All testing was conducted using test equipment from PAMI, including auxiliary fuel tanks, fuel plumbing systems, and a grain truck equipped with load cells.

4.2.1 Crops, Conditions, and Test Location

Fuel consumption testing took place near the center of the test field (**Figure 13**) on October 4, 2020. All tests were conducted south to north, perpendicular to the crop lean which was found to be the best direction for crop feeding.

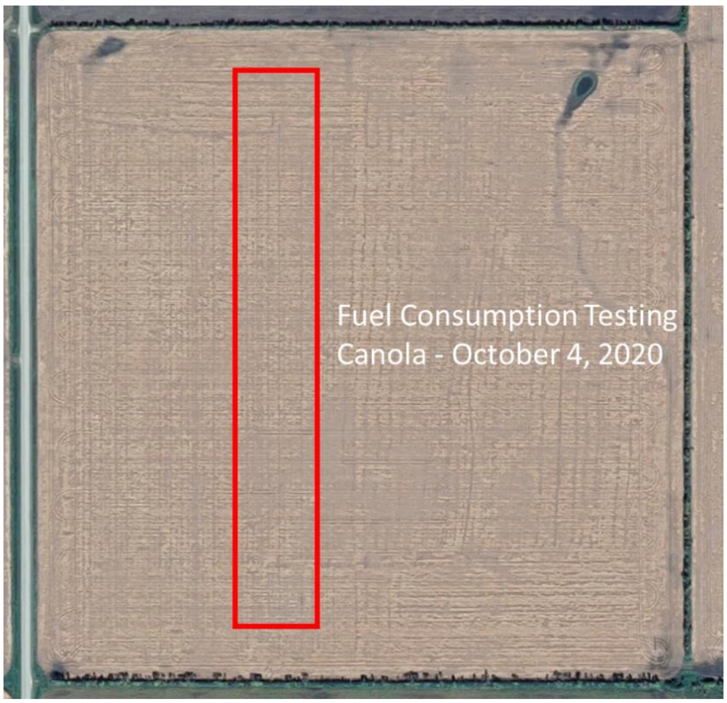

Figure 13. Approximate location of fuel consumption testing within the overall test field.

All testing was conducted between 11:00 a.m. and 2:00 p.m. to reduce the effect of changing crop condition as much as possible. Weather conditions during testing were mainly warm and partly cloudy.

A summary of the weather conditions during fuel consumption testing is shown in **Table 4** (obtained from the airport weather station in Lloydminster, Alberta); the full weather data set can be found in **Appendix B**).

Table 5. Weather conditions during fuel consumption testing on October 4, 2020.

Test Day	Time	Temp		RH %	Wind			Condition
		°C	°F		(km/h)	(mph)	Direction	
4-Oct-20	11:00 AM	18	64	53	18	11	NNE	Partly Cloudy
	12:00 PM	18	64	55	18	11	NNE	Partly Cloudy
	1:00 PM	18	64	52	18	11	NNE	Partly Cloudy
	2:00 PM	18	64	55	22	13	NNE	Partly Cloudy

The average grain yield over all fuel tests in the L345PC canola variety was 3.87 tonnes/ha (69 bu/ac) and the average grain moisture content was 8.2%.

4.2.2 Fuel Consumption Results

The fuel consumption results were recorded using two main metrics: specific fuel consumption, fuel consumption rate (with respect to time and area harvested) as well as secondary metrics of throughput and field capacity.

The fuel consumption data is presented in this section using tables and graphs; the raw data is available in **Appendix D**. Where appropriate, an analysis of variance (ANOVA) was used to determine if the differences found in the data were significant. For all statistical analyses, a 90% confidence level was used; indicating a P-value < 0.1 is significant. In addition, a Grubb's outlier test was performed on the data collected to determine if any outliers existed; none were found.

The average specific fuel consumption results in **Figure 14** show that the John Deere and CLAAS used 3.27 and 3.98 L/t (1.96 and 2.38 US gal/100 bu), respectively. These results were found to be statistically significant where the John Deere used 18% less fuel per unit of grain harvested than the CLAAS.

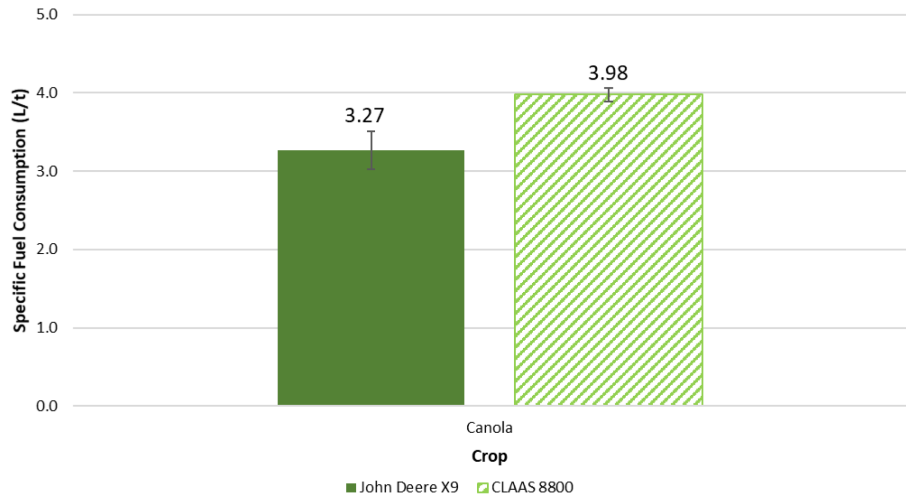

Figure 14. Average specific fuel consumption results.

The fuel consumption rate with respect to time was also graphed for each combine as seen in **Figure 15**. The results show the John Deere and CLAAS used 80.7 and 100.5 L/h (21.3 and 26.6 US gal/h), respectively. The difference in the fuel consumption rate was again found to be significantly different between combines, where the John Deere used 20% less fuel per hour than the CLAAS.

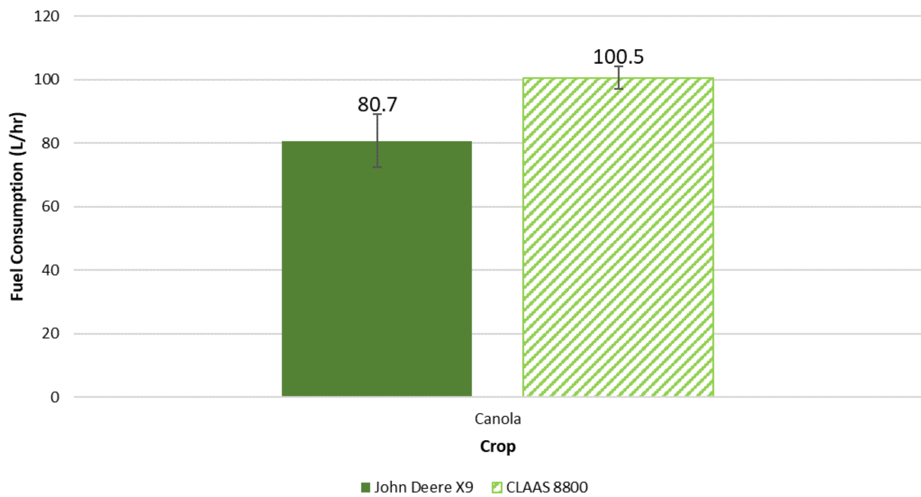

Figure 15. Average fuel consumption rates in liters per hour.

Finally, the fuel consumption rate with respect to harvested area was also graphed for each combine, and is presented in **Figure 16**. The results show the John Deere and CLAAS used 12.8 and 15.2 L/ha (1.4 and 1.6 US gal/ac), respectively. The difference in fuel consumption rates were again found to be significant, where the John Deere used 16% less fuel per area harvested.

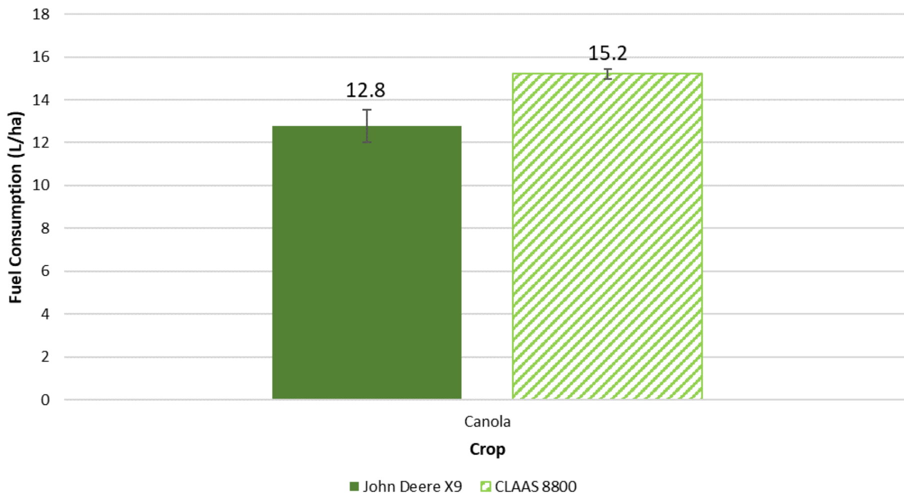

Figure 16. Average fuel consumption rate in liters per hectare.

The actual grain throughput and field capacity results for each combine are shown in **Table 6**. The grain throughput for both combines was targeted at 25 tonnes/h (55,000 lb/h), which corresponded to a total machine loss rate of 3.0% (presented in **Section 4.1.2**). As seen from the results, the average grain throughput and corresponding field capacity was very close to target for both combines.

Table 6. Grain throughput and field capacity results.

	Grain Throughput		**Field Capacity**	
	t/h	bu/h	ha/h	ac/h
John Deere X9	24.7	1,090	6.3	15.6
CLAAS 8800	25.3	1,116	6.6	16.3

A summary of the fuel consumption results discussed in the above section was tabulated and is presented in **Table 7**.

Table 7. Fuel consumption results summary.

Average Fuel Use in Canola										
	Specific Fuel Consumption		**Fuel Consumption Rate**				**Grain Throughput**		**Field Capacity**	
	L/t	**US gal/100 bu**	**L/h**	**US gal/h**	**L/ha**	**US gal/ac**	**t/h**	**bu/h**	**ha/h**	**ac/h**
John Deere X9	3.27	1.96	80.7	21.3	12.8	1.4	24.7	1,090.4	6.3	15.6
CLAAS 8800	3.98	2.38	100.5	26.6	15.2	1.6	25.3	1,115.6	6.6	16.3
Combine A compared to Combine B	82%[1]		80%[1]		84%[1]		-		-	
P-Value	0.069		0.016		0.048		-		-	

[1] Statistically significant at a 90% confidence level

4.3 Header Loss

The objective of this testing was to directly compare the performance of John Deere's HD50R straight-cut header to the MacDon FD145 straight-cut header in canola using grain loss pans placed under each header.

4.3.1 Crops, Conditions, and Test Location

Header loss testing was conducted on the south side of the test field in a uniform and flat area (**Figure 17**). To reduce the effect of changing crop conditions as much as possible, testing was conducted between 2:00 p.m. and 6:00 p.m. Weather conditions during header loss curve testing were sunny and dry.

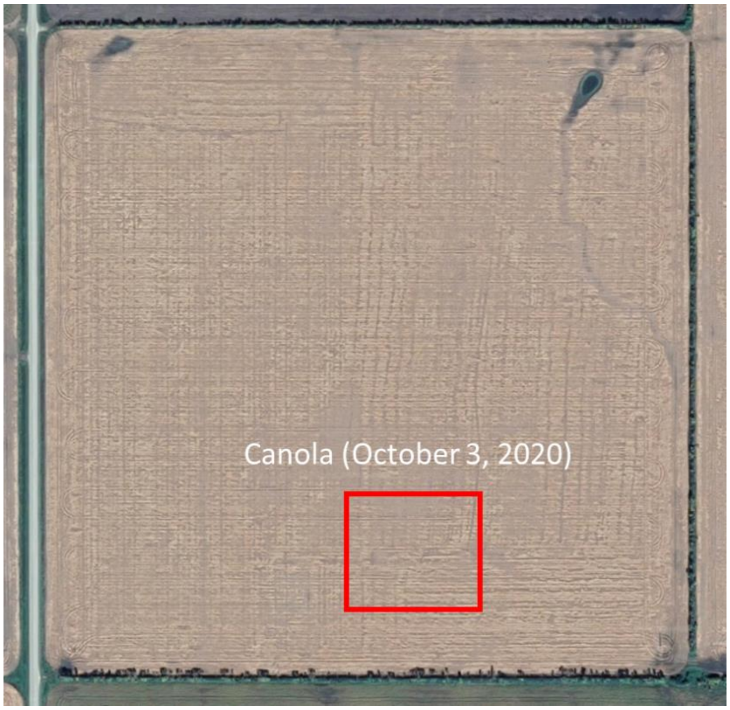

Figure 17. Approximate location of header loss testing within the overall test field.

A summary of the weather conditions during header loss testing is detailed as follows (obtained from the airport weather station in Lloydminster, Alberta); the full weather data set can be found in **Appendix B**).

Table 8. Weather conditions during header loss testing.

Test Day	Time	Temp		RH %	Wind			Condition
		°C	°F		(km/h)	(mph)	Direction	
3-Oct-20	2:00 PM	17	63	43	11	7	NNE	Sunny
	3:00 PM	17	63	42	17	11	NNE	Sunny
	4:00 PM	17	63	42	15	9	NNE	Sunny
	5:00 PM	16	61	47	13	8	NNE	Sunny
	6:00 PM	12	54	55	13	8	NNE	Sunny

All testing was conducted in the direction the crop was seeded (west to east), and in the direction of crop lean. Both combines were driven in the same direction, side by side, within the same location of the field. The average grain yield in the L345PC canola variety was 3.75 tonnes/ha (68.4 bu/ac) and the average grain moisture content was 7.4%.

4.3.2 Header Grain Loss Results

Header grain loss testing resulted in three repetitions of data per combine header, the following section graphically compares this loss data and uses statistics to determine if the observed differences between combine headers are significant. Header loss raw data can be found in **Appendix E**.

The statistical method used to determine if the data sets were significantly different from one another was an analysis of variance (ANOVA) test, which was conducted at a 90% confidence level. Therefore, the statistical P-values calculated indicate a significant difference when the P-value < 0.1.

The header grain loss was plotted as a percentage of total loss and graphed across the header width for each header. A picture of each header was superimposed over the graph to aid in presenting the data as shown in **Figure 18** and **Figure 19**.

The horizontal axis represents loss pan position with respect to the header, where blank positions are areas where no pans were located due to combine tires or gauge wheels. Note that these gaps are not to scale within the figures; and because of this, the header picture does not align perfectly with actual loss pan locations and should only be used as an approximate visual reference.

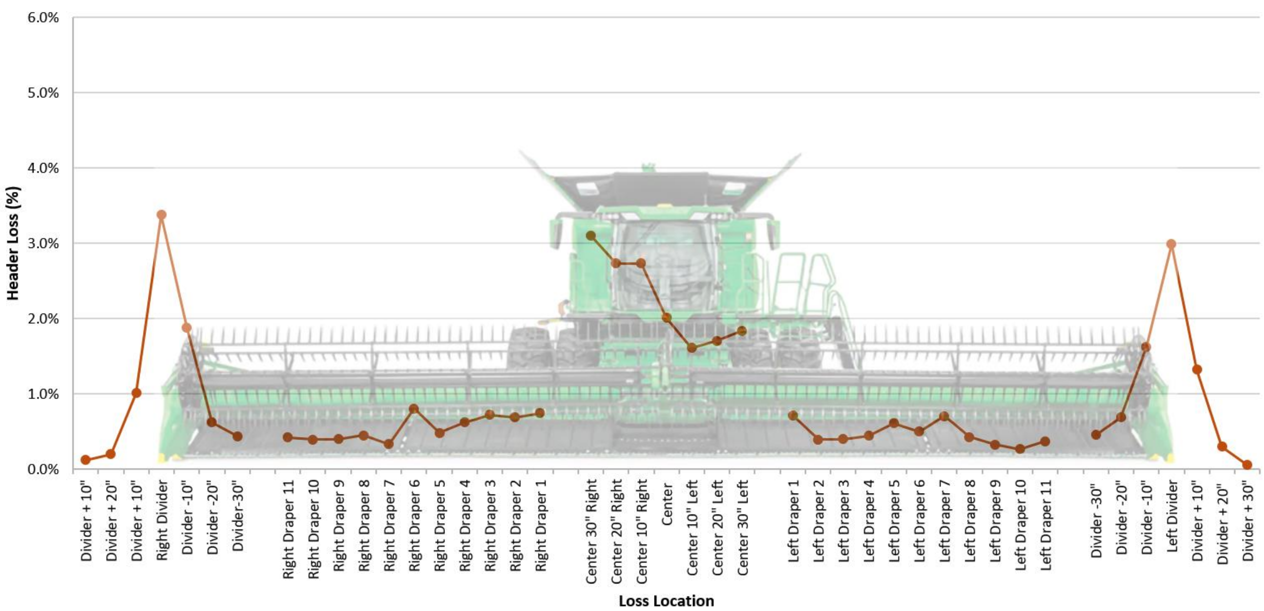

Figure 18. John Deere HD50R header loss graph.

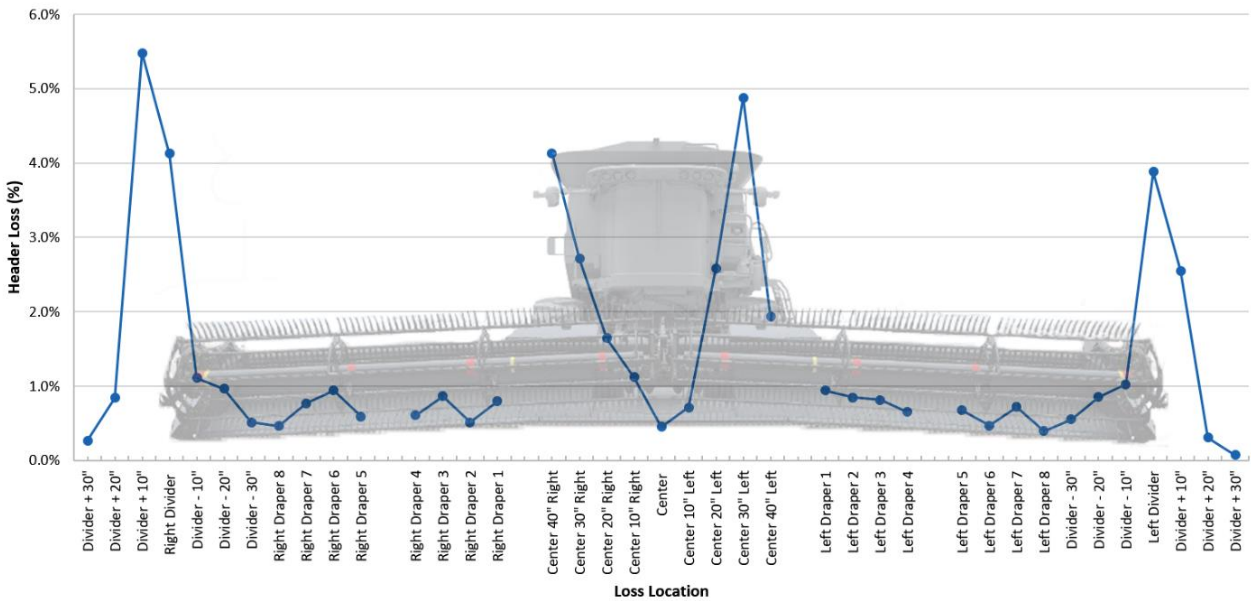

Figure 19. MacDon FD145 header loss graph.

As can be seen in **Figure 18** and **Figure 19**, header grain loss levels were higher at the dividers and center sections and lower on the intermediate sections for both headers. The loss profile at the dividers generally showed maximum loss in the pan directly below the divider with a quick reduction in loss when moving laterally to the inside or outside of the divider. The John Deere reached a maximum loss of approximately 3.5% directly below the right divider while the MacDon reached a maximum of approximately 5.5% 10 inches to the outside of the right divider. The intermediate sections cover an area of the header that was very uniform in terms of crop flow and showed a relatively consistent loss level, with lower loss variability compared to the center or divider sections. The center section of the MacDon header showed more variability, with higher loss levels on the outside pans where the draper belts transition to the center belt and lower loss levels in the center. The John Deere header showed less variability on the center section and also showed lower loss near the middle of the header and higher levels near the transition of the draper to the center belt (especially on the right side).

To further show the relative performance between the two headers, **Figure 20** presents the data points from both headers graphed together for an easy and quick comparison.

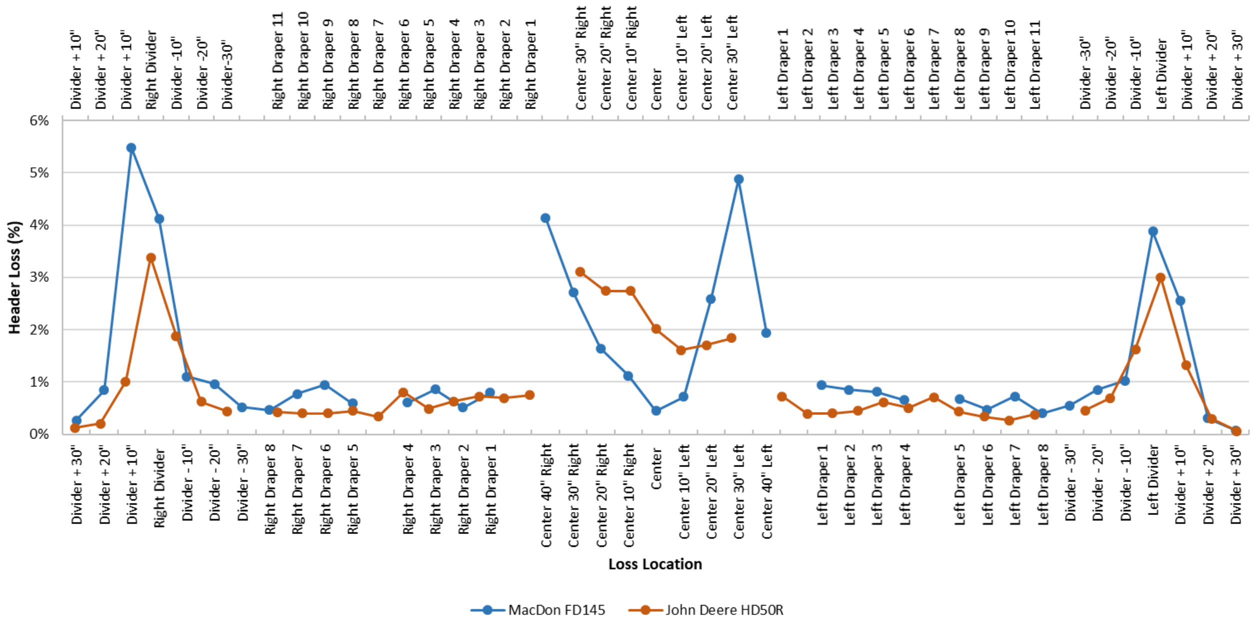

Figure 20. Percentage of grain loss across both headers.

Finally, the grain loss across the five sections was averaged for each header and is displayed in **Figure 21**.

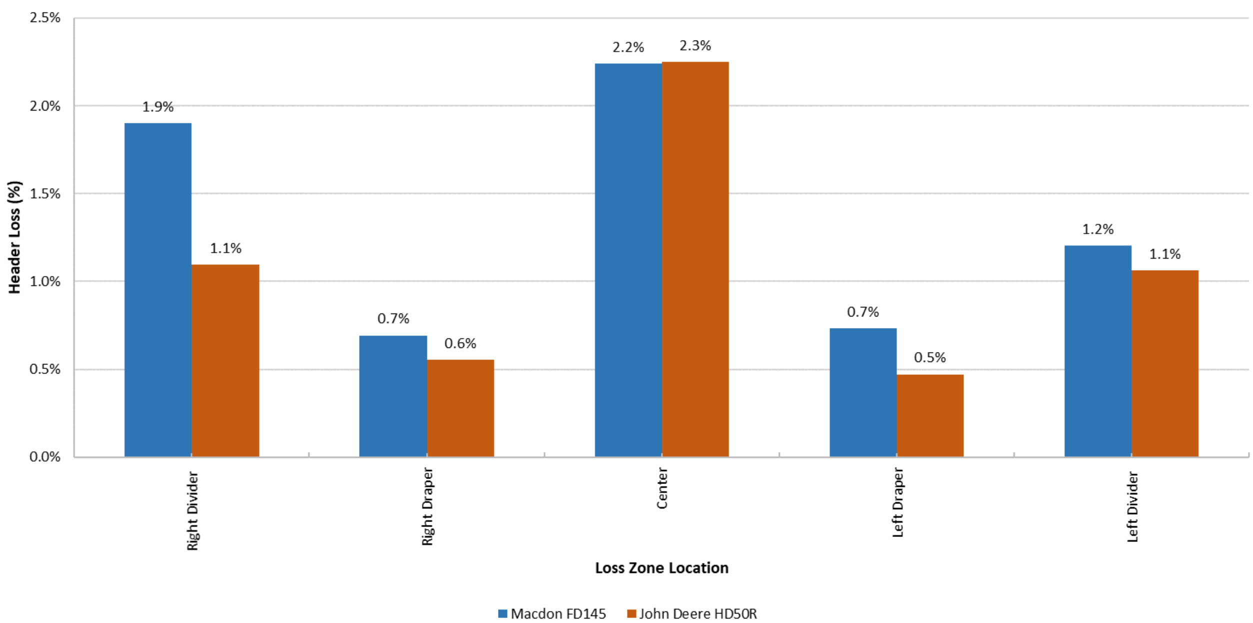

Figure 21. Average grain loss across each header section.

The average grain loss over the right and left dividers on the MacDon was found to be 1.9% and 1.2%, respectively, while the John Deere was found to be 1.1% at both dividers. Of note, a Grubbs Test was used to determine the presence of any outliers during the results analysis.

This test found that the left divider pan (one pan 10 in. to the inside of the divider) used for the MacDon header had a high loss point of approximately 10% during the third test repetition (the previous two had resulted in an approximate 1% loss for each repetition). Accordingly, this result was considered an outlier and removed from consideration in the final results analysis. The difference in loss values was found to be statistically different on the right-hand divider but not on the left-hand divider. The intermediate sections resulted in an average loss of 0.7% on the MacDon, while the John Deere resulted in 0.6% on the right intermediate zone and 0.5% on the left intermediate zone. Although these differences were found to be significantly different statistically, practically the differences are quite small. Finally, the total header loss averaged over each header was found to be 1.4% for the MacDon and 1.0% for the John Deere, again this difference was found to be significantly different.

A summary of the grain loss across header sections, and how these compare between the two headers as well as the corresponding statistical P-value, is shown in **Table 9**.

Table 9. Summary of header grain loss per section.

	Header Grain Loss (%)					
	Right Divider	**Right Draper**	**Center**	**Left Draper**	**Left Divider**	**Total Header**
John Deere HD50R	1.1	0.6	2.3	0.5	1.1	1.0
MacDon FD145	1.9	0.7	2.2	0.7	1.2*	1.4
Difference between John Deere and MacDon	0.8[1]	0.1[1]	(0.1)	0.2[1]	0.1	0.4[1]
P-Value	0.065	0.002	0.404	0.005	0.745	0.025

* Grubbs Test determined “divider -10”” location in the third repetition of this test to be an outlier, as it registered a significantly higher percentage of loss than the previous two repetitions.

[1] Statistically significant at a 90% confidence level

5. Conclusions

Based on the combine benchmark test results in canola some conclusions can be made regarding relative combine performance between the John Deere X9 1100 and CLAAS 8800. These conclusions are discussed in the following sections.

5.1 Loss Curve Testing

Conclusions from loss curve testing in canola showed performance to be very similar between combines, where combine capacity at 3.0% total loss was found to be approximately 62 to 63 tonnes/h (137,000 to 139,000 lb/h) for both the John Deere and CLAAS 8800 in canola.

It should be noted, crop conditions at the time of testing resulted in a tougher than normal threshing conditions, where the canola stalks and stems were still very green but the pods and grain were dry. This was reflected in relatively constant separator losses of approximately 1.0% over the entire range of feed rates on both combines.

The cleaning shoe performance was also very similar between combines, where losses increased steadily with feed rate and were found to be the dominant form of losses on both machines. At the loss limit of 3.0% both the John Deere and CLAAS 8800 were cleaning shoe limited in the crop conditions tested.

It should be noted that both combines were material-handling limited at the highest throughput tested, as there was a risk of plugging rotors/threshing cylinder at higher throughputs due to the green canola stems. As such, the highest achievable throughput was based on operator discretion (i.e., comfort level based on machine distress, noise, vibration, etc. from the threshing area) and may not represent the highest throughput possible in this condition. The John Deere distress level was found to occur at a higher throughput of 89 tonnes/h compared to the CLAAS at 73 tonnes/h.

5.2 Fuel Consumption

Overall, in the conditions tested, the John Deere X9 showed an advantage in fuel consumption compared to the CLAAS 8800 in canola.

In terms of specific fuel consumption, the results showed the John Deere used 18% less fuel per unit of grain harvested than the CLAAS. Likewise, when comparing fuel consumption rates between combines the John Deere used 20% less fuel per hour and 16% less fuel per harvested area compared to the CLAAS.

Grain throughput and field capacity were limited by grain loss on both combines; 3.0% total grain loss was taken as the maximum acceptable limit which corresponded to approximately 25 tonnes/h (55,000 lb/h) grain throughput for both the John Deere and CLAAS.

5.3 Header Loss

Data was acquired throughout the afternoon of October, 3, 2020, to compare the performance of the John Deere HD50R header and the MacDon FD145 straight-cut headers in canola by way of grain loss pans placed under the headers.

As previously stated, both headers were optimized prior to testing to reduce grain loss while ensuring crop feeding remained consistent. Data analyzed after testing determined that total losses were found to be 1.0% and 1.4% for the John Deere HD50R and MacDon FD145 headers, respectively. Results of the ANOVA test determined that the difference of 0.4% was statistically significant.

Loss from the right-hand divider and draper belt areas were also considered significantly different, with the John Deere header showing less loss than the MacDon header. It should be noted, that although header loss was found to be statistically different on the draper belt sections, the difference was very small (0.1% on the right draper and 0.2% on the left draper) and when considered practically, they are very similar.

When analyzing the data from the left-hand divider, no statistical differences were found between the two headers.

Losses were also found outside of the dividers, which was likely due to the density of the canola stand. Losses were measured 10, 20, and 30 in., from the divider. It was found that loss was less significant at 30 in. than at 10 in.

Both headers seemed to experience the majority of loss on both dividers and at the center. More loss was also noticed on the outside of the center section, where the draper belt feeds to the header opening. According to the data, more loss occurred where the draper belts end.

Appendix A

Combine Configurations

Table A-1. Combine configurations.

	CLAAS Lexion 8800	**John Deere X9 1100**
Engine hours	61	40
Separator hours	6	9
Header type	Flex draper	Hinged draper
Header make	MacDon	John Deere
Header model	FD145	HD50R
Feeder drum position	Up	NA
Feeder jackshaft speed	Adjustable (high)	Fixed (490rpm)
Feeder chain speed	Adjustable (high)	Fast (26 tooth)
Feeder face plate position	Center pos.	0
Stone protection type	Standard	Standard
Feed accelerator/DSP speed	Synchronous to the threshing drum	Fast
Feed accelerator type	APS -Drum accelerate pre separation	Serrated wear strips
Rotor type	Std. series rotor	Std. dual rotor
Rasp bars	10 rasp bars (thresh cylinder)	30 grain threshing elements
Concave type	Standard (small grain)	Small wire
Concave bar	Disengaged	N/A
Concave covers (de-awning plates)	Open	None installed
Separator grate type	Fingerbar	Fingerbar
Separator Grate Covers	All covers closed (4/4)	2 sets installed
Separator Vanes	Fixed	Fixed
Chaffer type	Small grain - TM 6	General purpose
Sieve type	Small grain - TM 6	General purpose
Presieve type	N/A	Fixed
Tailings system concave position	N/A (conventional handling of returns)	Small grains
Spreader speed	Max	Fixed
Residue deflectors	Max width	50% width
Returns speed	Fixed	Fixed
Elevator speed	Fixed	Fixed

	CLAAS Lexion 8800	John Deere X9 1100
Chopper type	Special cut (premium line)	Premium
Chopper speed	High	High
Chopper knife bank position	Fully engaged	Fully engaged
Spreader type	Power spreader	Standard, Powercast Tailboard
Grain tank covers	Powered covers	Powered covers
Powered rear axle	No	No
Drive tires	Duals 580/85R42	Duals 650/85 R38
Steering tires	710/65R30	VF750/65R26
Rated power [hp = metric hp]	610 hp	603 hp
Max power [hp = metric hp]	653 hp	690 hp

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Appendix B

Weather Data

The weather conditions including the temperature, relative humidity, wind speed, wind direction, and general weather condition for each test day were collected and tabulated (**Table B-1**). The weather data was collected from the nearest weather station to the test field; in this case, Lloydminster, Saskatchewan, approximately 63 km (39 miles) away. Therefore, the weather data will not be an exact summary of the weather conditions at the test field, but provides a good approximation.

Table B-1. Weather conditions during loss curve test days.

Test	Test Day	Time	Temp		RH %	Wind			Condition
			°C	°F		(km/h)	(mph)	Direction	
Loss Testing	1-Oct-20	3:30 PM	11	52	53	26	16	NNE	Overcast
		4:00 PM	11	52	51	17	11	NNE	Overcast
		5:00 PM	11	52	53	17	11	NNE	Overcast
		6:30 PM	10	50	57	13	8	NNE	Partly Cloudy
Header Loss	3-Oct-20	2:00 PM	17	63	43	11		NNE	Sunny
		3:00 PM	17	63	42	17		NNE	Sunny
		4:00 PM	17	63	42	15		NNE	Sunny
		5:00 PM	16	61	47	13		NNE	Sunny
		6:00 PM	12	54	55	13		NNE	Sunny
Fuel Consumption	4-Oct-20	11:00 AM	18	64	53	18	11	NNE	Partly Cloudy
		12:00 PM	18	64	55	18	11	NNE	Partly Cloudy
		1:00 PM	18	64	52	18	11	NNE	Partly Cloudy
		2:00 PM	18	64	55	22	13	NNE	Partly Cloudy

Appendix C

Loss Curve Raw Data

Crop: Canola

October 1, 2020 Marsden, Saskatchewan

Curve 1 – CLAAS 8800

Curve 2 – John Deere X9 1100

								Yield Calculation					Gross Weight		Tare Weight		Rotor Loss		Cleaning Loss	
Time of Day	**Curve**	**Run**	**Cut Width (ft)**	**Ground Speed**	**Test Dist.**	**Rotor Belt Ratio**	**Clean Belt Ratio**	**Dist.**	**Tare**	**Gross**	**Yield**	**Time**	**Rotor**	**Clean**	**Rotor**	**Clean**	**Free Grain**	**Un-threshed**	**Free Grain**	**Un-threshed**
-	-	-		(km/h)	(m)	-	-	(m)	(kg)	(kg)	(t/ha)	(s)	(kg)	(kg)	(kg)	(kg)	(g)	(g)	(g)	(g)
3:23	1	1	15.2	3.3	9.0	1.19667	1.19667	76	2,163	2603	3.9	9.84	55.3	28.3	-4.2	7.1	494	138	506	162
3:31	1	2	15.2	2.6	9.0	1.19667	1.19667	78	2,593	3,041	3.9	12.38	57.1	28.9	-2.2	10	548	161	482	128
3:51	1	3	15.2	4.7	9.0	1.19667	1.19667	101	3,338	3,958	4.2	6.88	68.6	32.9	3.7	9.9	438	112	1,252	254
4:00	1	4	15.2	1.6	9.0	1.19667	1.19667	43	3,981	4,301	5.0	20.71	67.4	32.7	-5.9	13.8	510	149	419	166
4:11	1	5	15.2	5.9	9.0	1.19667	1.19667	96	4,292	4,840	3.9	5.53	65.7	30.1	1.9	8.9	492	105	1,897	308
4:23	1	6	15.2	3.2	9.0	1.19667	1.19667	63	4,855	5,250	4.2	10.21	67.7	31	3	10.7	508	142	585	156
17:13	2	7	13.7	3.6	9.0	1.19667	1.19667	86	0	436	3.8	9.02	59.5	29	5.2	9.2	400	93	411	153
17:20	2	8	13.7	2.6	9.0	1.19667	1.19667	83	434	857	3.8	12.43	54	29.2	2.5	11.4	422	110	324	145
17:36	2	9	13.7	5.5	9.0	1.19667	1.19667	78	1,160	1,552	3.8	5.94	64.9	26	4.7	11.8	483	98	874	214
17:47	2	10	13.7	4.8	9.0	1.19667	1.19667	165	1,580	2,462	4.0	6.78	62	23.8	5.8	9.6	433	94	654	172
17:55	2	11	13.7	1.7	9.0	1.19667	1.19667	58	2,462	2,811	4.5	19.27	55.6	27.3	0.3	13.2	505	129	268	119
18:08	2	12	13.7	4.8	9.0	1.19667	1.19667	115	2,812	3,437	4.1	6.69	61.5	29	5.3	10.9	422	78	985	262

Appendix D

Fuel Consumption Testing Raw Data

		JD X9 1100	CLAAS 8800	JD X9 1100	CLAAS 8800	Average JD X9 1100	Average CLAAS 8800	JD compared to CLAAS	P-Value
Test Data	**Date**	3-Oct-20	3-Oct-20	3-Oct-20	3-Oct-20				
	Time of Day	11:48	11:16	12:55	2:00				
	Test Duration (min)	10.05	8.50	9.85	8.67				
	Time Idle at Start (min)	0.17	0.17	0.17	0.17				
	Actual Test Duration (min)	9.88	8.33	9.68	8.50				
	Test Distance (m)	683	683	683	683				
	Test Area (m2)	10409	9368	10409	9368				
	Test Area (acres)	2.57	2.31	2.57	2.31				
	Grain Weight (kg)	4043	3682	4089	3484				
	Yield (tonnes)	4.04	3.68	4.09	3.48				
	Yield (bu)	178	162	180	154				
	Starting Fuel Weight (lb)	142.9	130.5	117.5	99.6				
	Ending Fuel Weight (lb)	117.5	104.5	94.1	73.4				
	Fuel used (lb)	25.4	26.0	23.4	26.2				
	Fuel used (US gal)	3.65	3.75	3.37	3.78				
	Fuel used (L)	13.8	14.2	12.7	14.3				
Results	**Specific Fuel Consumption (L/t)**	3.42	3.85	3.12	4.11	3.3	4.0	82%	
	Specific Fuel Consumption (US gal/100 bu)	2.050	2.310	1.870	2.460	2.0	2.4	82%	0.069
	Fuel Rate (L/h)	83.9	102.1	78.9	101.0	81.4	101.6	80%	
	Fuel Rate (US gal/h)	22.2	27.0	20.9	26.7	21.6	26.9	80%	0.016
	Fuel Rate (L/ha)	13.3	15.1	12.2	15.3	12.8	15.2	84%	
	Fuel Rate (US gal/acre)	1.42	1.62	1.31	1.63	1.4	1.6	84%	0.048
	Field Capacity (ha/h)	6.3	6.7	6.5	6.6	6.4	6.7	96%	
	Field Capacity (acre/h)	15.61	16.67	15.94	16.34	15.8	16.5	96%	0.084
	Throughput (t/h)	24.5	26.5	25.3	24.6	24.9	25.6	97%	
	Throughput (bu/h)	1,082	1,169	1,117	1,084	1,099.5	1,126.5	98%	0.604

NOTES:
1. Two reps were completed on each combine on September 19, 2020 and one rep completed on October 2, 2020.
2. Test area on JD was generally larger due to the header size difference.
3. Analysis of Variance (ANOVA) was performed using Minitab v18.1, P-value < 0.1 signifies statistically significant with a confidence level of 90%
4. Due to significant figures and the effects of round and conversions, values reported in the body of the report may not exactly match this table.
5. * indicates a bad weigh value on the grain weight, therefore these two values were taken as average yield (based on the previous rep)

Constants			Conversions	
Canola	50	lb/bu	2.2046	lb/kg
Diesel	6.943	lb/gal US	0.3048	ft/m
CLAAS cut width	45	ft	4046.86	acre/m²
JD cut width	50	ft	3.78541	L/gal US

Appendix E

Header Loss Raw Data

		John Deere HD50R		MacDon FD145	
		Header Grain Loss			
Rep	**Sample**	**(g)**	**(%)**	**(g)**	**(%)**
1	1	0.07	0.1%	0.25	0.3%
1	2	0.07	0.1%	1.18	1.6%
1	3	0.52	0.7%	6.40	8.8%
1	4	2.04	2.7%	3.10	4.2%
1	5	1.39	1.8%	0.67	0.9%
1	6	0.41	0.5%	0.99	1.4%
1	7	0.14	0.2%	0.72	1.0%
1	8	0.15	0.2%	0.63	0.9%
1	9	0.10	0.1%	0.62	0.8%
1	10	0.24	0.3%	0.92	1.3%
1	11	0.30	0.4%	0.29	0.4%
1	12	0.11	0.1%	0.38	0.5%
1	13	0.25	0.3%	0.60	0.8%
1	14	0.22	0.3%	0.40	0.5%
1	15	0.26	0.3%	0.63	0.9%
1	16	0.41	0.5%	2.11	2.9%
1	17	0.38	0.5%	1.25	1.7%
1	18	0.34	0.4%	0.76	1.0%
1	19	0.97	1.3%	0.84	1.1%
1	20	0.98	1.3%	0.27	0.4%
1	21	0.76	1.0%	0.37	0.5%
1	22	0.71	0.9%	3.19	4.4%
1	23	0.81	1.1%	2.15	2.9%
1	24	1.07	1.4%	0.54	0.7%
1	25	0.53	0.7%	0.40	0.5%
1	26	0.37	0.5%	0.66	0.9%
1	27	0.19	0.2%	0.38	0.5%
1	28	0.22	0.3%	0.36	0.5%
1	29	0.22	0.3%	0.35	0.5%
1	30	0.59	0.8%	0.25	0.3%
1	31	0.22	0.3%	0.37	0.5%
1	32	0.88	1.2%	0.34	0.5%
1	33	0.35	0.5%	0.31	0.4%
1	34	0.27	0.4%	0.30	0.4%
1	35	0.20	0.3%	0.67	0.9%
1	36	0.27	0.3%	2.64	3.6%
1	37	0.67	0.9%	2.13	2.9%
1	38	0.56	0.7%	0.23	0.3%
1	39	1.23	1.6%	0.01	0.0%
1	40	2.10	2.8%	-	-
1	41	1.78	2.3%	-	-

		John Deere HD50R		MacDon FD145	
		Header Grain Loss			
1	42	0.41	0.5%	-	-
1	43	0.01	0.0%	-	-
2	1	0.025	0.0%	0.18	0.2%
2	2	0.02	0.0%	0.1	0.1%
2	3	0.91	1.2%	0.47	0.6%
2	4	2.65	3.5%	2.63	3.6%
2	5	1.13	1.5%	1.2375	1.7%
2	6	0.45	0.6%	0.36	0.5%
2	7	0.15	0.2%	0.07	0.1%
2	8	0.5	0.7%	0.12	0.2%
2	9	0.47	0.6%	0.47	0.6%
2	10	0.42	0.6%	0.75	1.0%
2	11	0.32	0.4%	0.26	0.4%
2	12	0.37	0.5%	0.56	0.8%
2	13	1.28	1.7%	0.29	0.4%
2	14	0.48	0.6%	0.28	0.4%
2	15	0.85	1.1%	0.52	0.7%
2	16	0.752	1.0%	3.04	4.2%
2	17	0.81	1.1%	2.83	3.9%
2	18	0.81	1.1%	1.985	2.7%
2	19	1.58	2.1%	0.92	1.3%
2	20	0.7	0.9%	0.255	0.3%
2	21	1.14	1.5%	0.318	0.4%
2	22	0.85	1.1%	1.21	1.7%
2	23	0.89	1.2%	6.97	9.5%
2	24	0.795	1.0%	2.99	4.1%
2	25	1.12	1.5%	0.78	1.1%
2	26	0.425	0.6%	0.34	0.5%
2	27	0.52	0.7%	0.87	1.2%
2	28	0.5	0.7%	0.51	0.7%
2	29	0.29	0.4%	0.49	0.7%
2	30	0.54	0.7%	0.33	0.5%
2	31	0.48	0.6%	0.23	0.3%
2	32	0.44	0.6%	0.25	0.3%
2	33	0.43	0.6%	0.4	0.5%
2	34	0.31	0.4%	0.36	0.5%
2	35	0.26	0.3%	0.83	1.1%
2	36	0.38	0.5%	3.99	5.5%
2	37	0.17	0.2%	2.99	4.1%
2	38	0.6	0.8%	0.21	0.3%
2	39	0.88	1.2%	0.11	0.2%
2	40	1.14	1.5%	-	-
2	41	1.03	1.4%	-	-
2	42	0.2	0.3%	-	-
2	43	0.06	0.1%	-	-
3	1	0.20	0.3%	0.16	0.2%

		John Deere HD50R		MacDon FD145	
		Header Grain Loss			
3	2	0.37	0.5%	0.56	0.8%
3	3	0.88	1.2%	5.14	7.0%
3	4	3.03	4.0%	3.31	4.5%
3	5	1.77	2.3%	0.52	0.7%
3	6	0.56	0.7%	0.77	1.0%
3	7	0.72	0.9%	0.34	0.5%
3	8	Missing	Missing	0.26	0.4%
3	9	0.34	0.4%	0.60	0.8%
3	10	0.26	0.3%	0.40	0.5%
3	11	0.41	0.5%	0.74	1.0%
3	12	0.29	0.4%	0.40	0.5%
3	13	0.31	0.4%	1.00	1.4%
3	14	0.41	0.5%	0.44	0.6%
3	15	0.32	0.4%	0.60	0.8%
3	16	0.49	0.6%	3.90	5.3%
3	17	0.39	0.5%	1.87	2.6%
3	18	0.55	0.7%	0.86	1.2%
3	19	4.54	6.0%	0.70	1.0%
3	20	4.57	6.0%	0.46	0.6%
3	21	4.35	5.7%	0.88	1.2%
3	22	3.03	4.0%	1.27	1.7%
3	23	1.98	2.6%	1.58	2.2%
3	24	2.03	2.7%	0.71	1.0%
3	25	2.55	3.4%	0.88	1.2%
3	26	0.85	1.1%	0.86	1.2%
3	27	0.19	0.2%	0.54	0.7%
3	28	0.20	0.3%	0.56	0.8%
3	29	0.51	0.7%	0.64	0.9%
3	30	0.27	0.4%	0.45	0.6%
3	31	0.45	0.6%	0.98	1.3%
3	32	0.29	0.4%	0.28	0.4%
3	33	0.20	0.3%	0.50	0.7%
3	34	0.18	0.2%	1.21	1.6%
3	35	0.15	0.2%	7.32*	10.0%
3	36	0.21	0.3%	1.88	2.6%
3	37	0.20	0.3%	0.47	0.6%
3	38	0.42	0.6%	0.23	0.3%
3	39	1.61	2.1%	0.04	0.1%
3	40	3.59	4.7%	-	-
3	41	0.21	0.3%	-	-
3	42	0.08	0.1%	-	-
3	43	0.06	0.1%	-	-

* Grubb's Outlier Test indicated loss point was an outlier; therefore, point was removed from analysis.

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