Project No. A0514
April 18, 2017
Humboldt, Saskatchewan

Final Report

Research Report

Canola Direct-Cut Harvest System Development – Year 3 of 3

For:
Agricultural Development Fund (ADF)
Saskatchewan Canola Development Commission (SaskCanola)
Western Grains Research Foundation (WGRF)

PAMI
Innovative Solutions for Agriculture and Beyond

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Canola Direct-Cut Harvest System Development – Year 3 of 3

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1. Executive Summary

The results from the third year of testing generally validated the results from the first two years of testing. Primary considerations when looking to reduce the risk of straight cutting canola include choosing flat, uniform fields for even maturity, utilizing shatter-resistant varieties, seeding early and/or expecting later harvest dates for natural ripening, and considering the use of an extendable knife or draper header to minimize harvesting losses.

This report highlights the field tests and data acquired in 2016 (Year 3) in addition to summarizing key findings from all three years of trial data. The interim reports from Year 1 and Year 2 contain a detailed account of the 2014 and 2015 harvests.

The test protocol involved harvesting strips in a randomized split-block design of a shatter resistant and typical hybrid variety at Swift Current, Saskatchewan (dry prairie), and Indian Head, Saskatchewan (thin black zone). The harvest treatments included three straight-cut header types (rigid auger, extendable knife auger, and draper) and a swathed treatment, as well as a comparison of different divider types. Data collected included header loss, yield, and multiple seed quality parameters. Observations were documented for header ground following cutting and feeding performance in addition to general combine performance. Environmental losses between the swathing date and harvest date were collected using trays placed between the rows in multiple locations in the main plots.

The Swift Current site in 2016 was not ideal for straight cutting, but did show valuable insight into best management practices to minimize losses in adverse conditions. Delayed crop maturity resulted in the crop being subjected to late-season rain and snow events, pushing most of the harvest into November. In addition to harvest being late, the crop was severely lodged, and the typical hybrid variety suffered substantial environmental loss. The crop stature (lodged close to the ground) negated the ability to perform header loss testing, but the yield trial was completed along with observations of header performance.

The Indian Head site in 2016 was a good candidate for straight cutting. The crop was upright and uniformly mature. This site had mature seeds, but plant stems were still green, with the shatter-resistant variety having slightly later maturity than the typical variety. A wind prior to harvest caused significant shelling in the typical variety, with considerably lower losses in the shatter resistant variety. The combine power consumption was high with the green stems requiring increased power for processing and chopping.

The Humboldt site in 2016 embodied an ideal straight cut combining scenario. A different shatter resistant variety was used at this site, which was managed by a cooperating producer. Favorable weather throughout the growing season resulted in even and quick maturity on a level, well-drained field. The standing canola was harvested on September 14 and 15, at the same time the producer was harvesting the swathed portion of the field. Seeds for the standing canola were dry, and stems were cured and dry, resulting in low power usage compared to other sites.

Data from 2016 has continued to show the trend of higher harvested yield in the shatter resistant variety over the typical variety in all straight cut treatments. Weather events triggered large environmental losses, with over 5 bushels (bu) of loss at both sites in the typical variety, and less than 2 bushels per acre (bu/ac) in the shatter resistant one. Overall, harvested yield was highest in the swathed treatment for both varieties at Indian Head and in the typical variety at Swift Current. The extended knife header resulted in the highest yield in the shatter resistant canola at Swift Current.

Green seed percentage was an issue at Swift Current, with the severity in all treatments causing quality issues. Only the swathed shatter-resistant treatment at Indian Head had substantial green seeds at a value less than 1%. Thousand kernel weight (TKW) was significantly higher in the typical variety at Swift Current and similar between varieties at Indian Head. Oil content at Swift Current was slightly more in the straight-cut treatments while the swathed treatment had a higher content at Indian Head.

In all 6 site-years of testing, the extendable knife header has averaged the least header loss, followed by the draper, and then the rigid header. The lower loss with the extendable knife is especially noticeable at the centre of the header, where presumably seeds thrown by the reel and rotating auger fingers were retained. Divider type plays a key role in losses at the ends of the header. The divider type with the lowest loss exhibited varied results that were dependant on crop conditions experienced during the site-year. Overall, the rotary knife divider averaged higher losses than either the fixed or vertical knife.

Over all trial years, there was no definitive harvest system that had the highest yield, or the most desirable crop qualities, across all conditions encountered. There were instances where the swathed treatments performed better, and others where an advantage was seen with straight cutting. This indicates that overall crop management, in addition to environmental conditions, will largely determine the potential benefit of straight cutting canola for an individual operation.

The conclusions and recommendations in this report should be taken together with the overall context of the report, coupled with the corresponding site-years, environmental conditions, and test procedures.

2. Introduction

Within the scope of a collaborative research project funded by multiple agencies coordinated by the Prairie Agricultural Machinery Institute (PAMI), field-scale plots were established at two main sites near Indian Head and Swift Current, Saskatchewan, for the 2014, 2015, and 2016 crop years. A smaller-scale, third site with a focus on test procedure refinement, divider type effect on header loss, and header optimization was added for the 2015 and 2016 harvests and located near Humboldt, Saskatchewan.

The first objective of the project was to compare and evaluate the performance of three commercially available combine header types as part of a direct-cut canola harvest system using the conventional swathed-based harvest approach as the benchmarking standard. The parameters that were focused on are listed below.

- Harvested yield
- Header loss
- Combine loss
- Environmental shatter loss
- Seed Quality
  - moisture content
  - green seed
  - oil content
  - seed size

The second objective was to compare and evaluate the performance impact of settings and modifications to critical loss-influencing components. Areas studied are listed below.

- Header operating parameters
  - reel speed, height, fore and aft position
  - draper or auger speed
  - auger finger timing
- Crop Dividers
  - Shape, width
  - active and passive types
- Knife fore and aft position

Two test sites of approximately 50 acres each located at Indian Head, Saskatchewan, and Swift Current, Saskatchewan, were configured in a randomized split-block design with four header treatments and two crop varieties. Each site was managed by a local partner: IHARF managed the Indian Head site and Wheatland Conservation managed the Swift Current site. Mark Stumborg provided harvest system consultation and Lawrence Townley-Smith provided statistical analysis support.

Project co-ordination was performed by PAMI (Humboldt, Saskatchewan). PAMI prepared, transported, operated, and coordinated the harvesting and test activities. PAMI also supplied measuring equipment for in-field yield checks, environmental and header loss trays, scales and equipment for in-field yield, and combine loss measurements.

The data in this report is presented primarily in imperial units, which are commonly used by Western Canadian producers when stating yield, loss, speed, and measurement.

3. Methodology

This section deals with the research approach, experimental design, test sites, equipment, and test procedures.

3.1 Field Sites

As in 2015, three field sites were established in 2016, at Humboldt, Swift Current, and Indian Head, Saskatchewan, as shown in **Figure 1**. Plots at Swift Current and Indian Head were managed by the local cooperating partner. At Humboldt, the cooperating producer was responsible for all field activities except harvesting. Site activities included seeding, fertilizing, spraying, swathing, and placement of the environmental loss catch trays. **Table 1** details the seeding, swathing, and harvest dates for each site for all three crop years.

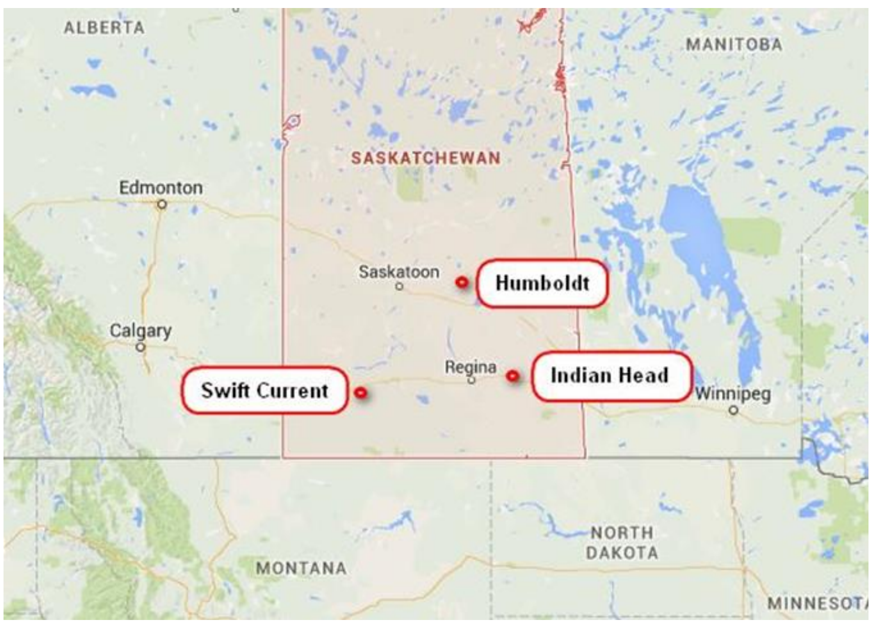


Figure 1. Field site locations.

Table 1. Crop activity dates with days after seeding.

Location	Year	Seeding	Environment Loss Tray Placement		Swathing		Harvest	
Swift Current	2014	25-29 May	27-Aug	92	27-Aug	92	24-26 Sep	121
	2015	25-May	1-Sep	99	25-Sep	123	21-Oct	150
	2016	6-Jun	30-Sep	116	30-Sep	116	27 Oct, 4,5 Nov	143, 151
Indian Head	2014	22-May	6-Sep	107	6-Sep	107	9-11 Oct	141
	2015	15-May	26-Aug	103	26-Aug	103	29-Sep	137
	2016	17-May	31-Aug	106	30-Aug	105	29 Sep-Oct 1	136
Humboldt	2015	27-May	N/A	-	3-Sep	99	22-Sep	118
	2016	20-21 May		-	28-Aug	100	14-15 Sep	117

Also at Swift Current in 2016 was the application of a desiccant on September 28, in an effort to reduce the amount of time before harvest.

3.1.1 Humboldt Site

The Humboldt site was managed by the cooperating producer and the location was north of Humboldt as outlined in red in **Figure 2**.

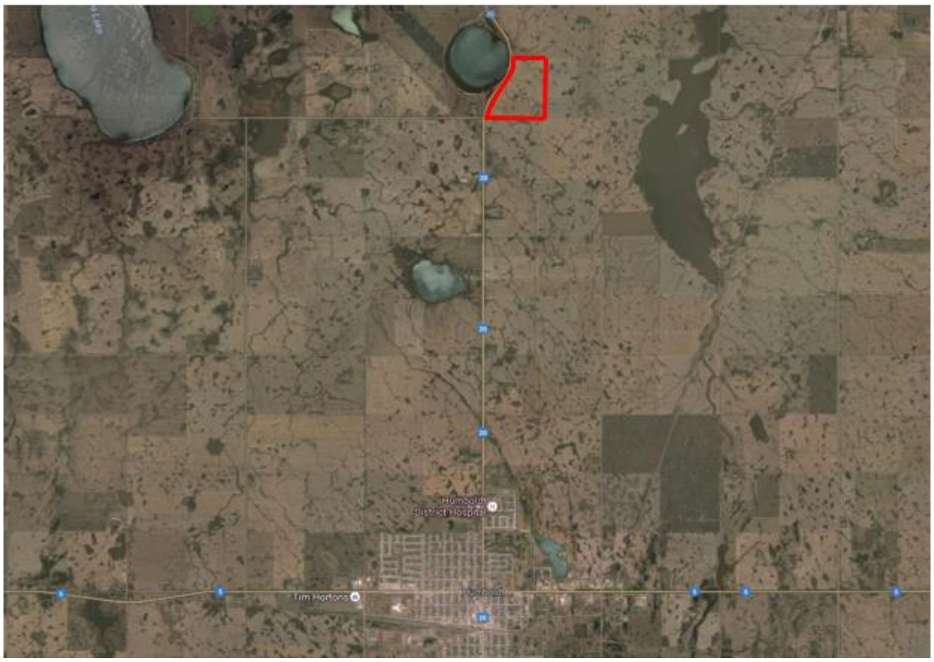


Figure 2. Humboldt field location.

3.1.2 Swift Current Site

Trials at the Swift Current site were managed by the Wheatland Conservation Area (WCA). The 2016 test plots were located south of Swift Current, as illustrated in **Figure 3**.

Figure 3. Swift Current field location.

3.1.3 Indian Head Site

The Indian Head Agricultural Research Foundation (IHARF) and Agriculture and Agri-Food Canada jointly managed the Indian Head site. The 2016 test plots were located east of Indian Head, as outlined in red in **Figure 4**.

Figure 4. Indian Head field location.

3.2 Randomized Split-Block Plot Design

Both the Swift Current and Indian Head sites were designed as a randomized split-block site with four header treatments as the main trial and two crop varieties as the split plot, as shown in **Figure 5**. Each of these sites included four repetitions for the yield trials. For 2015 and 2016, both sites also included separate blocks of each crop variety to perform header loss testing. In 2014, these header loss tests were done in conjunction with the yield trials.

The Humboldt site was used for test procedure refinement, divider type comparison, general header settings, and observations of straight cutting, and was not a randomized nonreplicated plot design.

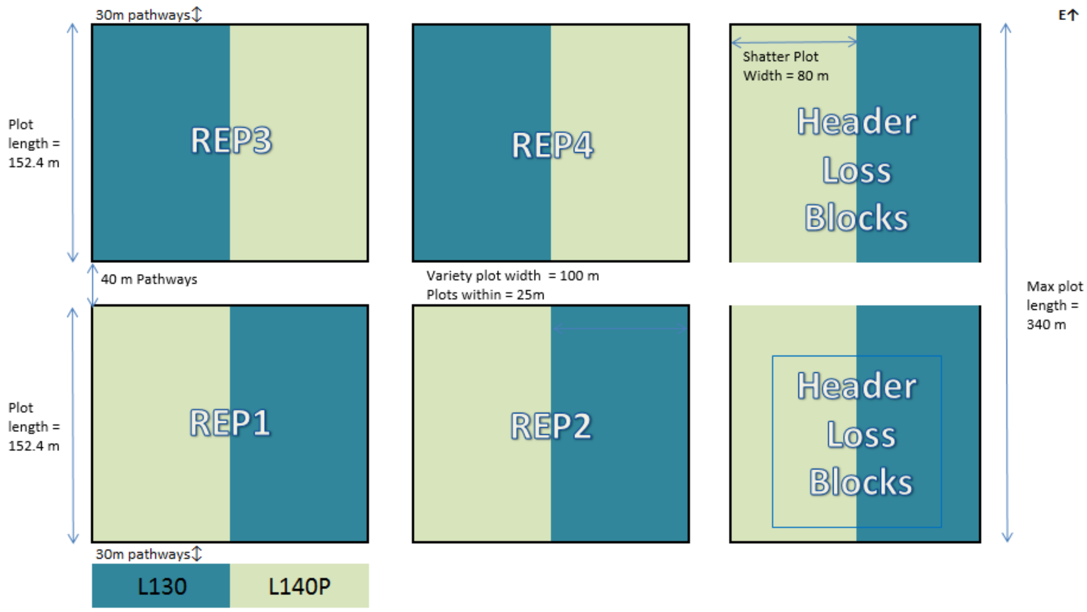


Figure 5. Split-block plot, with separate header loss blocks.

3.3 Varieties

Two canola varieties were used for the test plots at the Swift Current and Indian Head sites. Varieties were targeted to represent a 'typical' variety commonly grown in Saskatchewan and a variety with documented shatter-resistant traits. InVigor L130 represented the typical variety and InVigor L140P represented a variety with "Pod Shatter Reduction". Both varieties were supplied by Bayer Crop Science and are available across Western Canada.

At the Humboldt site in 2016, all trials were completed using Dekalb 75-65 RR, a variety with "strong pod integrity'. This variety is also commonly grown in Western Canada.

3.4 Harvest Equipment

As in previous years, a late model New Holland combine was used for trials at all locations. In 2016, a new CR9.90 Elevation combine was used at all three sites. The combine was configured for canola based on the manufacturer's recommended settings and then optimized for each site's conditions. Combine loss drop pans were used to aid in the adjustments (**Figure 6**), and the combine settings were not adjusted further during or between the different treatments in a repetition to maintain consistency.

Figure 6. Combine drop pan.

Three headers were used for the straight-cut treatments. The first two configurations were accomplished using the same header, a New Holland 35 ft Varifeed 760CG. This is a relatively new product offering to North America but is a common extendable knife cutter bar header used in Europe to harvest standing rapeseed. It is a rigid auger platform with full-width retractable fingers, a sloped top beam and seed deflector, steel auger floor, steel tine reel, active vertical-knife or passive fixed crop dividers, and a cutter bar that can be hydraulically positioned between 18 and 42 in. ahead of the auger.

The cutter bar fore and aft position of the New Holland Varifeed header was adjusted to represent two separate header types: an extended knife as shown in **Figure 7**, which is commonly used in Europe, and a rigid auger header as shown in **Figure 8** with the cutter bar retracted approximately 18 in. ahead of the auger.

Figure 7. Extended cutter bar header with cutter bar 42 in. ahead of auger.

Figure 8. Rigid auger header with cutter bar 18 in. ahead of auger.

The third straight cut header configuration used was a Honey Bee 36 ft draper header shown in **Figure 9**, which represented a common rigid draper header used in North America. It was configured with a leaf-spring header flotation system, outer gauge wheels, side delivery belts, full-width rear cross auger, center feed belt with feed auger, plastic reel tines, active rotary knife dividers, and a fixed cutting bar.

Figure 9. Rigid draper header with rotary dividers.

The fourth header used in the project was a New Holland 790CP-15 belt pickup (**Figure 10**). The pickup represents a common configuration used in Western Canada for canola windrows. It features a rigid frame, picking belt with plastic picking teeth, a ribbed transfer belt, and a full-width table auger with retractable fingers at the feed opening. Different headers were used at the Swift Current and Indian Head trials in 2016, but they were of the same model, size, and features at these two sites.

Figure 10. Belt pickup header.

The windrowers used in 2016 were the same as the previous year. A John Deere 30 ft model 2360 equipped with a batt reel was used at Swift Current, while at Indian Head a modern New Holland 36 ft windrower with a 35.75 ft cut width was used.

Extensive support equipment was required to facilitate testing and transport of the machinery between locations. PAMI supplied equipment such as

- semi-tractor and equipment trailer for combine transport,
- tandem-axle grain truck with onboard scales,
- header trailer,
- fully-equipped service truck,

- all-terrain vehicle for field use,
- grain moisture meter and scales to measure grain samples, and
- loss pan dropper to measure combine loss.

The project partners at each site also supplied all-terrain vehicles and grain trucks as needed to support the project.

3.5 Test Procedure

During the first year of the study, a significant amount of effort was put into developing the test procedure for the field trials. In subsequent years, this test procedure was refined and replicated. The following subsections describe the procedures used in Year 3.

3.5.1 Environmental Loss

Aluminum environmental loss trays measuring 7 x 44.5 in. with dual screen inserts (**Figure 11**) were placed between rows at the time of swathing and remained in the standing crop until harvest. **Table 1** on page 6 lists the placement timing of loss trays relative to both swathing and harvesting dates for each site. The screens were designed to collect and retain shattered pods and seeds while preventing rodents from accessing the seed material and suspending the seeds away from moisture saturation caused by rain or snow. Just prior to harvest, the trays were gathered, and the environmental loss was weighed and recorded. Further design details of the loss collection trays are included in **Appendix A**.

Figure 11. Environmental tray with screen inserts to deter rodents and prevent moisture saturation.

3.5.2 Header Loss

Header loss was determined by collecting seed loss from the same aluminum loss trays used for the environmental loss collection (with screen inserts removed). The trays were placed between the crop rows in a pattern across the width of the header (**Figure 12**). In order to facilitate the insertion of pans, all harvesting for header loss was completed parallel to the crop rows. Seventeen trays were used in 2016 as in 2015. At the Humboldt site in 2016, 23 loss trays were placed to better evaluate header losses with a focus on losses at and outside the divider area, as **Figure 12** shows. The additional trays aided to improve the resolution of the header loss measurement across the width of the header. The severely lodged crop at Swift Current in 2016 eliminated the ability to perform header loss tests.

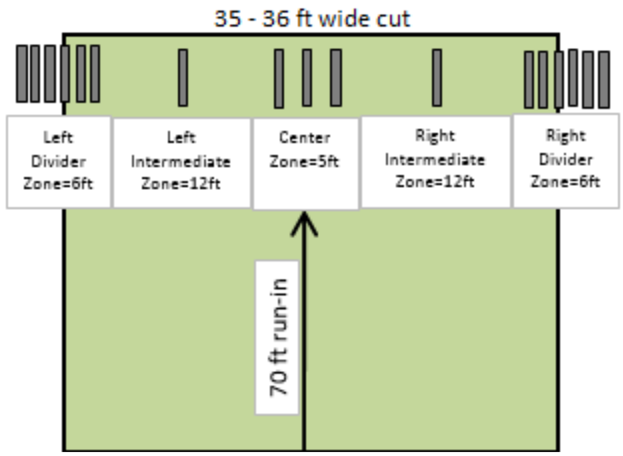


Figure 12. Header loss tray layout, 17 pans.

For the 17 tray loss tests, the center zone of the header was approximately 5 ft and was covered by three loss pans spaced two rows apart. The left and right intermediate zones spanned approximately 12 ft each and were covered by one pan on each side located approximately 10 ft from the center of the head. The left and right divider zones included a group of six loss trays on either side that spanned approximately 6 ft each. The divider for each header was targeted to align with the third tray from the inside of each of the divider zones. Because it was difficult to get the combine operator to align the divider rod perfectly with the desired tray, there was variation in which tray the divider aligned with once a test was completed. After each test, the divider position in relation to the outer trays was documented so that the loss tray data would be referenced from the same divider position for every run.

At the Humboldt 2016 site, the center loss area was covered by three trays spaced three rows apart and covering approximately 7 ft This was the same number of trays as the 17-pan layout, except with one additional row in between trays in order to encapsulate any possible losses at the outside of the center feeding area. No trays were placed in the left or right intermediate zones, as previous results showed the losses in this area were minimal compared to other regions. The left and right divider zones consisted of 10 trays placed on either side with five inside the header and five outside the divider (**Figure 13**). With the New Holland header, all ten trays were placed without spaces between, resulting in an overall width of approximately 10 ft The tray layout for the Honey Bee header was similar except for the divider zones where a one-tray gap was left between the furthest inside and outside trays on each side. The resulting area covered by this layout was approximately 12 ft on either side with half being inside the divider and the other half outside.

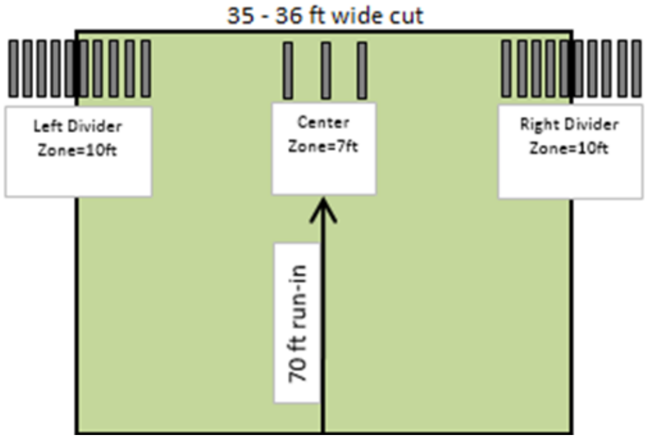


Figure 13. Humboldt header loss tray layout.

When laying out trays for the header loss tests, a tray placement gauge was used as shown in **Figure 14**. This gauge consisted of two upright stakes connected by a rope with tape markers indicating tray placement for the header. Due to minor header width differences and gauge wheel locations, a slightly different tray placement configuration was used for the New Holland and Honey Bee headers.

Figure 14. Tray placement rope with tape marking tray locations.

Similar to the 2015 trials, an access lane was cut out prior to the tests to allow space for field personnel to place the trays in the crop. The combine had an approximately 70 ft, or two header widths, run-in to ensure the header was full of crop, header feeding was consistent, and the target ground speed of 3.5 mph was sustained. After the combine header had passed over the trays and reached the access lane, the combine was stopped and did not pass over the trays (**Figure 15**). The header was allowed to clean out, then the header was raised and stopped and the combine backed up to expose the loss trays. With this method, the combine was in a position for cleanout so that no contamination of the trays occurred from either header or combine cleanout.

Figure 15. Combine approaching loss trays (left) and stopped to clean out (right).

After each test, field personnel emptied the material from each tray into an individual paper bag, with identification for that specific tray location. All individual bags from one test were placed in a larger bag that was labelled with header treatment, repetition, variety, and any other unique settings for that run. Samples were weighed offsite at a later date.

Some interpolation was required in order to calculate the total loss for each header since the loss trays did not collect header loss across the entire width of the header. It was assumed that loss was consistent across the left and right intermediate zones. This zone had the lowest losses, so any variation would have a minimal effect on total header loss.

Header Divider Modifications:

After the first two years of testing, the rough distribution of header loss across its width became apparent. The dividers were a significant area of loss with the drive end having a predisposition for higher loss on the New Holland head due to its width. In an attempt to mitigate these losses, tests were performed at Humboldt in 2016 with the addition of simple corrugated plastic deflectors on the fixed divider to ease the transition from the divider to the outside of the shield (**Figure 16**). Deflectors were made for both ends of the header with the focus on the wider, drive end.

Figure 16. Drive end with the fixed divider (left) and with the addition of a plastic deflector (right).

Reel Height

In an effort to further quantify header optimization and settings, pickup reel-height tests were also executed at Humboldt in 2016. All tests were performed on the New Holland header with the knife extension position set to an optimal position based on the crop. In this instance, the setting was 3.5 with 0 being retracted and 5 fully extended. The New Holland header was equipped with metal single-tine pickup teeth attached to a round bar extending the length of the reel. Two separate reel positions were evaluated. One was with the reel at the “optimal” height (**Figure 17**), with the tines slightly engaged in the crop, and the round attachment bar out of the crop. The other setting demonstrated a poorly set header with the reel aggressively in the crop and the entirety of the pickup finger and batt in the crop (**Figure 18**). Given the upright, dry conditions of the canola stand in 2016, such an aggressive reel setting was not necessary but demonstrates the importance of proper header settings. However, aggressive reel settings were needed for some site-years, such as the lodged canola experienced at Swift Current in 2016. Reel height tests were evaluated using the 23-tray layout.

Figure 17. Optimal reel placement with fingers engaging top of crop.

Figure 18. Low reel placement with fingers and bar in crop.

Table Auger Speed

Tests were conducted at Humboldt in 2016 using two table auger speeds, in an attempt to quantify the table auger’s contribution to header loss, primarily at the center of the header. Tests were conducted using the extendable knife header in both the retracted and extended positions. The range in auger speed was accomplished by changing the driven sprocket on the table auger (**Figure 19**). The original 38-tooth sprocket was replaced with a 47-tooth. The larger 47-tooth sprocket resulted in an auger speed approximately 80% of the original speed. For each header configuration (knife extended vs. retracted), six test replicates were completed using each sprocket.

Figure 19. Driven auger speed sprocket.

All tests were conducted at approximately the same travel speed, 3.5 mph, using an 11-tray layout, to capture losses across the entirety of the header (**Figure 20**).

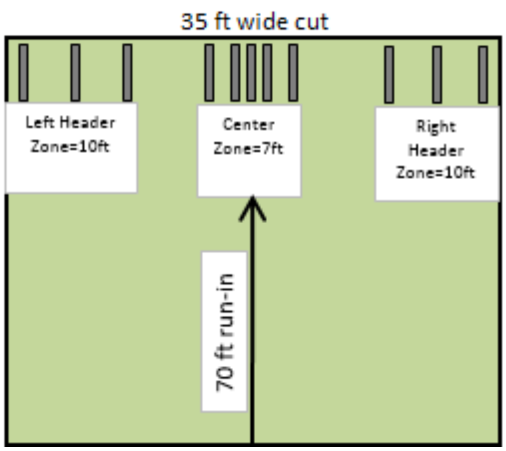


Figure 20. 11-Tray layout used during auger speed trials.

3.5.3 Yield Measurement

Yield was measured and recorded for each test plot run by starting the treatment with an empty combine grain tank. At the end of the test run, the harvested grain was emptied into a tandem grain truck and weighed. For the 2016 harvest, PAMI's grain truck was equipped with calibrated onboard scales that were used for measuring mass at both the Swift Current and Indian Head sites.

3.5.4 Grain Sample Quality

For each yield test, a grain sample was collected and was later analyzed for dockage, moisture content, TKW, and oil content. Moisture content was also recorded at the time of sample collection.

3.5.5 Combine Performance

Combine loss was periodically quantified during the yield trials by dropping a loss pan from under the combine (**Figure 21**). Loss tests were also performed to aid in initial combine setting and when a major change in conditions was encountered.

Figure 21. Pan dropped from beneath the combine to measure combine loss.

4. Results and Discussion

Crop conditions and characteristics, field loss measurements, harvest yield, and calculated harvest costs are reported in this section. This section contains only results from the 2016 trials. A cumulative analysis of all three trial years can be found in Section 5. Additionally, individual results from Year 1 and 2 can be found in the interim reports.

Specific conclusions drawn and data referenced should be used in the context of the site-year and crop that the data encompasses. Analysis of variance (ANOVA) tables can be referenced in **Appendix B.**

4.1 Crop Conditions

Conditions and observations gathered during field testing are discussed in the following sections.

4.1.1 Humboldt

The Humboldt site in 2016 was ideal for straight cutting canola. The trial plots were placed on a level field (**Figure 22**) with a portion left standing to straight cut, and the remainder of the field swathed. The standing canola stalks were adequately cured, and all plant material went through the combine easily. In this instance, the standing canola was straight cut concurrent to the cooperating farmer harvesting the swathed treatments in the same field, which had been windrowed seventeen days prior to straight cutting. The straight-cut treatment was left to naturally ripen. As this site was meant to primarily focus on header loss, no scientific yield trials were conducted; however, based on field calculations, yields were similar between straight-cut and swathed treatments. At the time of harvest, seeds were below the acceptable dry moisture content at approximately 9% moisture. Normal combine power usage (70%) and loss were experienced in these conditions at average ground speeds. The crop was harvested on September 14 and 15, which falls within the typical range for swathed canola.

Figure 22. Canola stand at Humboldt.

4.1.2 Swift Current

The Swift Current site in 2016 highlighted some of the risks associated with straight cutting canola. The trail plots were placed on a level, open field. A wet growing season delayed crop development, and the crop stayed vegetative late into the year. As a result, the entire plot area, aside from two check strips in the header loss blocks, was desiccated with a mixture of glyphosate at 360 grams a.i./ac, Heat LQ (saflufenacil) at 42.8 ml/ac, and Merge adjuvant, (at label rate) two days prior to swathing the windrowed treatments for the yield reps.

Before combining, the site also received significant snowfall, lodging the entire stand. Crop height, from the ground to the top of the canopy, was reduced from approximately 36 in. standing to between 10 and 18 in. laying down, with an average of 12 in. from ground to the top of the canopy (**Figure 23**). On average, the distance from the ground to the lowest pods of the laid down crop was 4 in.

Figure 23. Lodged crop at Swift Current.

The conditions at Swift Current also induced a large variation in yield, maturity, seed moisture, and harvesting efficiency. Seed moisture ranged from 9.5% to over 16% for individual treatments. Environmental loss was significant at Swift Current in 2016, with the typical variety having high losses (5.3 bu/ac), while the shatter-resistant variety had relatively low losses (0.2 bu/ac), given the conditions experienced.

4.1.3 Indian Head

The entire trial area was level, with uniform, upright crops throughout. At the time of harvest, the pods and seeds were mature with the seeds below the acceptable dry moisture content, ranging from 6.8% to 12.3% with values above 10% only occurring on the first samples harvested in the morning. However, the stems of both varieties were still green (**Figure 24**) resulting in increased combine fuel usage and straw chopper load to handle the heavy, wet material.

Figure 24. Mature seeds and green stems at Indian Head.

A significant wind event occurred during the week prior to combining with gusts up to 50 mph resulting in substantial shelling in the typical variety. The shatter-resistant variety had significantly less shelling as a result of the wind, but this variety's maturity was also approximately one week later than the typical variety. The typical variety may have been of acceptable moisture and green seed percentage to harvest before this wind event had resources permitted harvest then. The shatter resistant variety was not mature enough to harvest prior to the wind. Both varieties were harvested between September 29, and October 1.

Growing conditions throughout the year were adequate, with typical yearly moisture for the area. Crop maturity of this site, however, was marginally later than average for the region.

4.2 Field Observations

2016 offered the ability to expand the knowledge already acquired in the previous two trial years. As in previous years, all headers could effectively cut and handle standing canola when conditions were adequate. On flat land with even crop stands, all headers were able to reach maximum combine capacity with combine horsepower and cleaning area becoming the limiting factors for capacity.

At faster speeds with the draper header, it was noted that there were occasional material conveyance issues where the crop would hesitate on top of the drapers without feeding to the center drum. These issues were amplified when the crop stand became uneven. It was found that some of these issues could be minimized by changing the settings on the header's rear cross auger. This auger's speed was increased so that the flighting's horizontal speed matched or slightly exceeded that of the draper. Additionally, the cross auger was positioned to be more aggressive by placing the auger ahead and down toward the draper to aid in crop movement. There were situations when a greater adjustment range of the cross auger may have been beneficial, with the ability to move the auger further forward towards the knife of the header, in an effort to force conveyance on the draper.

The lodged crop conditions at Swift Current illustrated the benefit of a fully-functioning automatic header height control system (AHHC). Even on a relatively flat, stone-free field the operator was able to go over 1 mph faster with the height system enabled, and occurrences of the header digging into the ground were minimized. In addition to height control, crop lifters were also used in Swift Current in the header loss blocks (**Figure 25**). These were observed to aid in crop pickup but did not alleviate all problems; the operators still needed to be conscientious of travel relative to the crop lean. When travelling with the crop lean facing the combine, feeding was relatively easy with or without crop lifters (**Figure 26**). However, even with crop lifters, when the crop lean was the same as the direction of travel, there were both cutting and feeding issues and likely higher header losses. It is recommended that when straight cutting a lodged canola field, one cuts perpendicular to the direction of lean in order to minimize the amount of crop that is facing directly away from the combine.

Figure 25. Crop lifters on extended knife header.

Figure 26. Stubble from cut with crop dividers, crop lean towards combine (left) and away from combine (right).

The lodged crop also minimized the benefit and effectiveness of crop dividers. **Figure 27** (left) shows the fixed divider on the extendable knife header. In this lodged crop, the fixed dividers leading point remained above the crop, and the end of the header rode above any crop. The vertical knife divider shown in **Figure 27** (right) would cut into the crop in some locations and ride above the crop in others. It is positioned closer in height to the knife than the fixed divider but is still located higher.

Figure 27. Fixed divider (left) and vertical knife (right) in lodged crop.

4.3 Environmental Shatter Loss

The Swift Current site in 2016 experienced inclement weather later in the growing season that caused substantial environmental losses in the typical variety. Losses averaged 5.3 bu/ac in this variety compared with 0.2 bu/ac for the shatter resistant variety. **Figure 28** illustrates the number of seeds found on the ground in both of these varieties. The Swift Current site received snow before harvest, which laid down both crops and likely caused the bulk of the loss in the typical variety. Environmental trays were not placed back in the crop between the first day of harvest (October 27) and the rest of the harvest (November 4 and 5). Any further losses by either crop after October 27 were not documented. At Indian Head, there was a strong wind event the week before combining that resulted in sizable losses in the typical variety. Losses averaged 8.3 bu/ac in the typical variety and 1.5 bu/ac in the shatter resistant variety.

Figure 28. Environmental loss at Swift Current in the typical (left) and shatter-resistant (right) varieties.

4.4 Swathing and Belt Pickup Header Loss

Swathing and belt pickup loss was not measured as part of this project, but to a provide a context for equivalent comparison between harvesting systems, loss estimates were derived from previous PAMI field experience and testing as well as field observations of seeds/pods on the ground. Previous PAMI research found that belt pickup losses can vary between 0.4% and 3.3% of yield in canola and are dependent on belt pickup design, crop conditions, and travel speed.

Field equipment at each site also played a role in estimated pickup losses. At Swift Current, a 30-ft swather was used in 2016, whereas at Indian Head, a 36-ft windrower was used. In 2016, the procedure remained the same as 2015 where combine travel speed remained consistent across all treatments, regardless of header width.

Conditions such as those faced at Swift Current in 2016 would increase belt pickup losses outside the typical range. The uneven maturity, coupled with the batt reel used on the swather led to an unevenly distributed swath. The swath was then subjected to inopportune weather in the form of both rain and snow, resulting in windrow compaction. These factors made it necessary for the combine operator to go slower in these strips to ensure crop feeding. Additionally, on many occasions the swaths had a tendency to 'wad' feed on the combine pickup, increasing losses and causing the table auger to plug.

4.5 Header Loss

Over the course of the study, a strong emphasis was placed on straight-cut header loss. In 2015 and 2016, the Humboldt site was added to gain a better understanding of header settings and losses. This study focused on both the loss location across the header's width and the variation of header loss between the rigid, draper, and extendable knife headers. Over all the testing done, it was found that each header can effectively straight cut canola but with varying degrees of loss, especially when conditions are less than ideal.

Header loss results for 2016 are taken from the header performance testing done at Humboldt and the header comparison testing completed at Indian Head. Due to the lodged crop at Indian Head, it was not possible to evaluate header loss at this location using the loss trays.

Average divider losses for each of the three dividers tested at Humboldt are shown in **Figure 29**. Five trays were placed both outside and inside the divider on both ends of the header, and the average of both sides is presented.

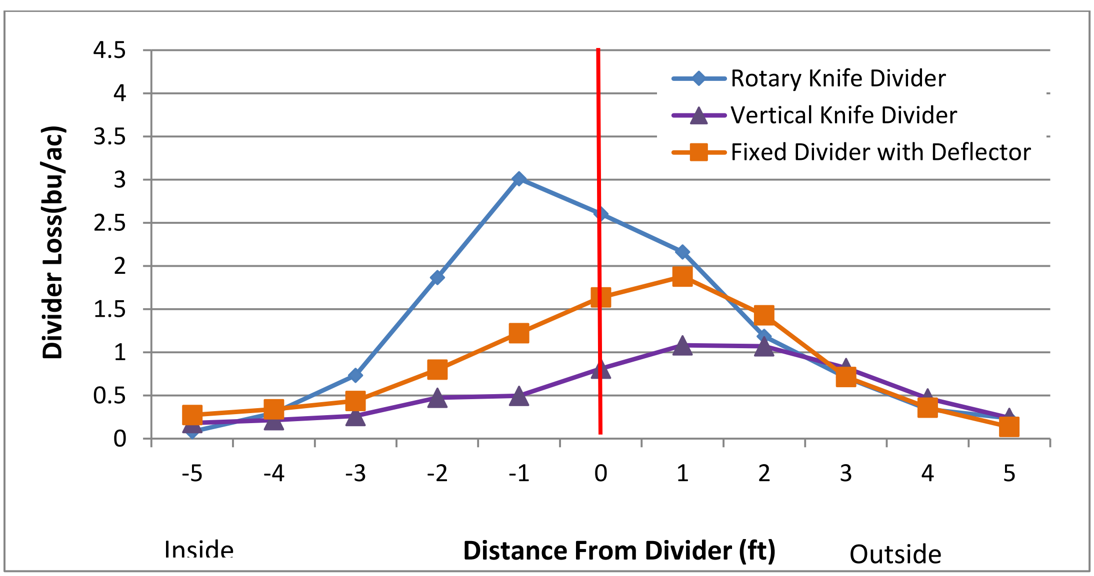


Figure 29. Divider losses at Humboldt for three divider types.

The rotary knife averaged higher losses followed by the fixed divider with the vertical knife divider creating the least loss. The loss distribution from each system is readily apparent. The wide shields on the extended knife header that stick past the divider clearly cause significant loss, as the highest loss point for both dividers using this header is outside of the divider itself. Alternatively, the flailing action produced by the rotary knife divider resulted in the highest loss point at the tray placed one row inside the divider.

This data is also significant in that it shows the degree of loss outside the header. Small amounts of loss could be found for all three headers in the tray five rows outside the divider. This demonstrates a combination of two factors: seed throw, where both the mechanical and fixed dividers caused seeds located at the divider area to be moved to adjacent rows, and crop canopy movement – as the header goes by the standing crop, any uncut crop immediately outside the divider gets pushed perpendicular to the combine's direction of travel. In a well-knit canola stand, it was observed that this effect would move the entire canola stand several rows outside of the divider. This shaking action as the header passes can cause environmental shelling and pod drop and contributes to overall header losses.

Figure 30 highlights the header loss distribution for the three headers tested at Indian Head. The right end of the header shows similar losses between all three headers. At the left end, the extended knife header had the lowest loss with both the rigid and draper headers experiencing slightly higher losses in this zone. As with certain sites in previous years, the rigid header experienced significantly higher losses in the centre and intermediate zones than any other header.

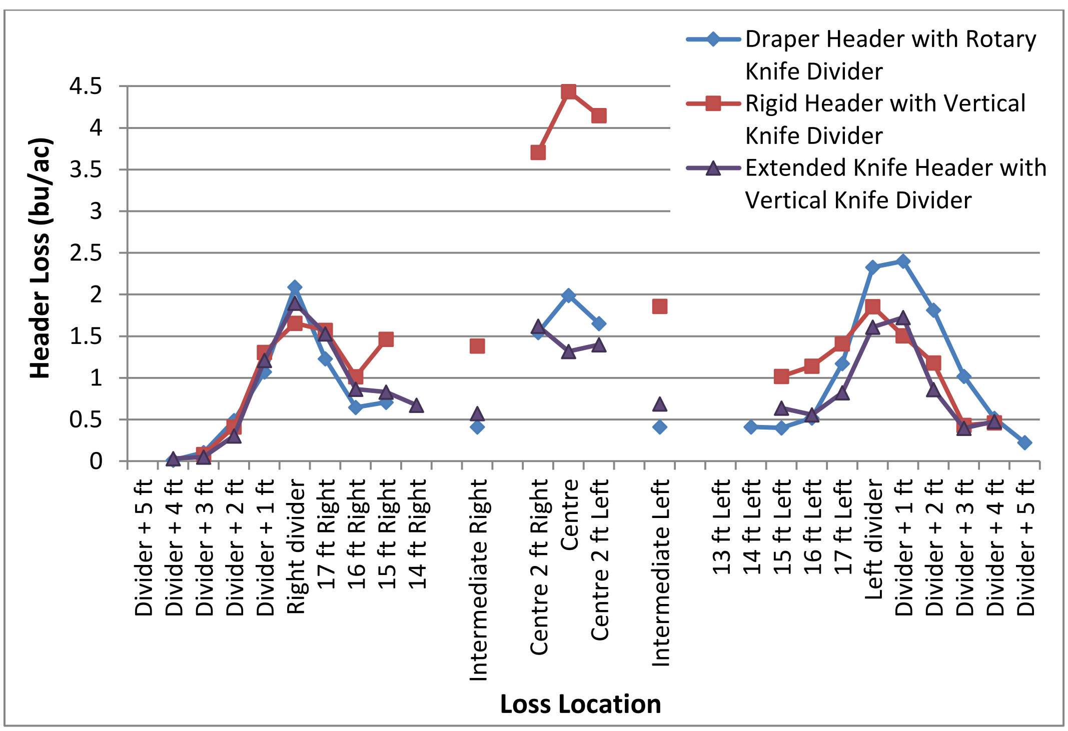


Figure 30. Header loss across width of header at Indian Head.

4.6 Header Optimization

At the Humboldt site in 2016, replicated tests were done on key areas of header adjustment, in an attempt to quantify the effects of proper header setting. The results depict only one site-year of data, but illustrate the importance of proper header setting in minimizing losses.

4.6.1 Reel Height

The header loss testing at Humboldt also provided valuable information for setting the reel. Through replicated tests, it was found that in good-standing crop having the reel back and the reel fingers slightly engaged in the crop resulted in good feeding and minimized loss. When feeding is not an issue, the reel could be positioned so that the ends of the fingers just engage the crop, and the reel bars supporting the fingers remain out of the crop. Having the bars in the crop resulted in higher header losses. The need for a reel could be further minimized with the extendable knife header, positioning the extension so that the cut canola crop could easily be conveyed by the auger. However, lodged crop such as the one in Swift Current demonstrated that these recommended reel settings cannot always be followed. In these conditions, the reel had to be moved ahead and down into the crop in order to pick up the crop. The reel speed was also increased relative to ground speed to harvest lodged crop.

Figure 31 and **Figure 32** depict the losses at the divider on the left and right ends, respectively, at two different reel heights. The losses at both heights are an average of the values obtained using fixed and mechanical dividers at testing conducted at the Humboldt site. As one might expect, the reel height deemed ‘optimal’ with the pickup fingers just engaging the crop resulted in lower losses than the ‘low’ reel height with the entire reel in the crop. The yellow vertical lines on the graphs represent the center of the header divider with higher tray numbers being outside the header and lower numbers inside.

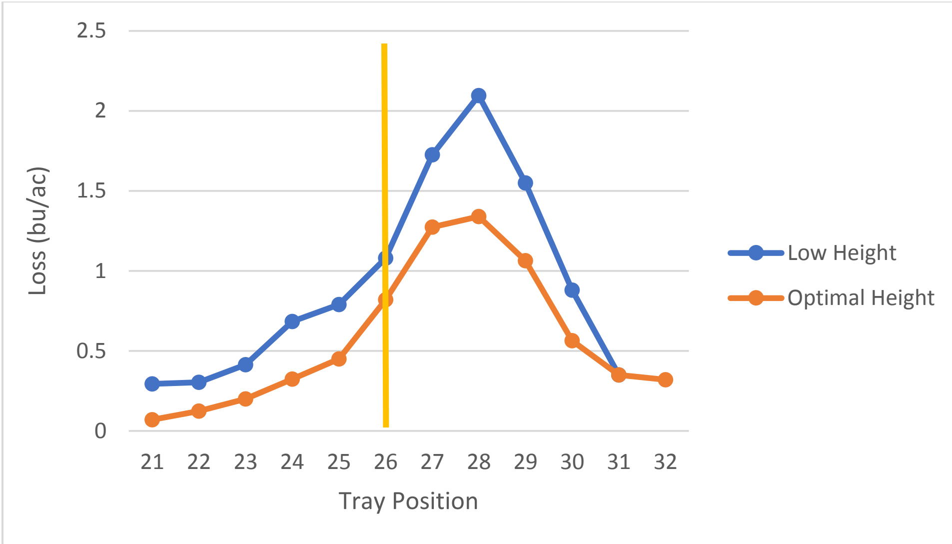


Figure 31. Header loss at left divider with two reel heights.

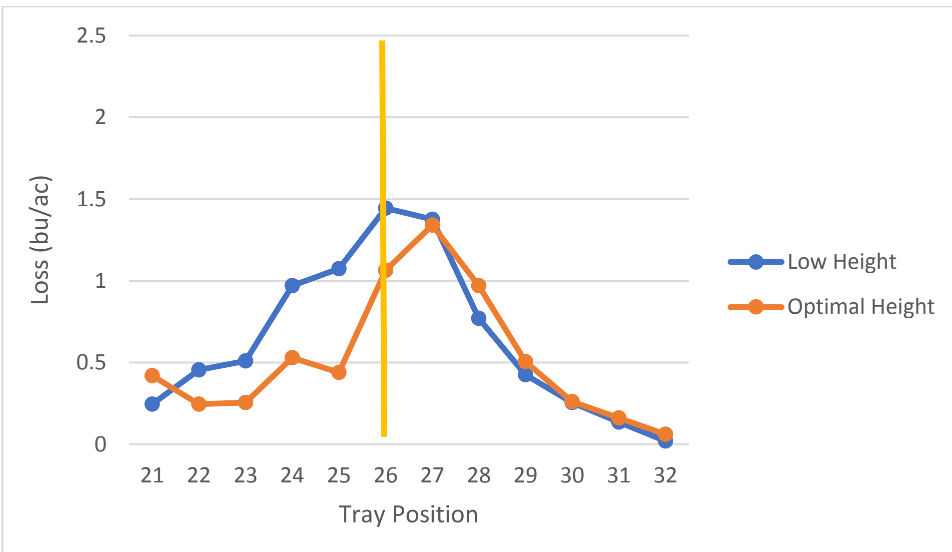


Figure 32. Header loss at right divider with two reel heights.

The two above figures represent the seed loss collected in the trays, and should not be used to infer total header loss, or cumulative header loss in a particular section.

4.6.2 Table Auger Speed

Table auger speed tests from Humboldt showed no clear benefit to a slower table auger (**Figure 33**). The two auger speeds were statistically identical both with the knife extended and retracted. The lack of difference could be due to the ground speed for the trials (3.5 mph) being equally suited between the two auger speeds. A slower combine ground speed may have facilitated a greater need for the slower auger speed, as the auger speed-to ground speed ratio would stay lower, keeping it in the desired range. More work over a greater range of crop conditions and travel speed is needed in order to validate any differences that auger speed has on header loss for a straight cut header in canola.

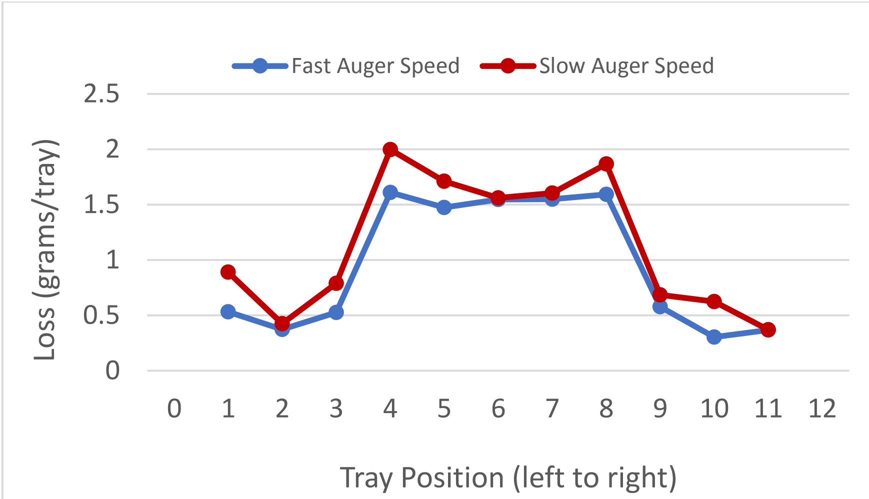


Figure 33. Effect of auger speed on header loss. 47-tooth (slower) and 38-tooth (faster).

4.7 Yield

Table 2 displays the dry (10% moisture) harvested yield, dockage, and dockage-corrected yield for each site, variety, and header. Cells with a green background indicate the most desirable condition for each site (highest yield or lowest dockage). Yellow-coloured cells show slightly lower yields and higher dockage levels. The red cells show the lowest yields and highest dockage for each site.

Table 2. Harvested yield, dockage, and dockage-adjusted yield for all treatments and sites.

Site	Variety	Header	Harvested Yield (corrected to 10% moisture) (bu/ac)	Dockage (%)	Dockage-Corrected Yield (bu/ac)
Swift Current	Typical	Draper	44.2	1.7	43.4
		Rigid	39.1	1.3	38.6
		Extended Knife	45.4	1.6	44.7
		Swathed	47.5	2.2	46.4
	Shatter Resistant	Draper	53.7	2.3	52.5
		Rigid	54.1	1.7	53.2
		Extended Knife	55.0	2.0	53.9
		Swathed	50.7	2.5	49.5
Indian Head	Typical	Draper	50.8	1.5	50.0
		Rigid	47.8	1.4	47.1
		Extended Knife	50.7	1.4	50.0
		Swathed	61.1	1.7	60.0
	Shatter Resistant	Draper	61.4	1.9	60.3
		Rigid	60.9	1.5	60.0
		Extended Knife	62.5	1.5	61.6
		Swathed	64.0	2.0	62.8

For each of the two varieties, the Indian Head site had higher harvested yields (47 to 63 bu/ac) than the Swift Current site (39 to 54 bu/ac). At both sites, the interaction between crop variety and header treatment significantly impacted yield. The shatter-resistant variety had a higher harvested yield at both locations.

In the typical variety, the swathed treatment had a higher yield at both Indian Head and Swift Current compared to the straight-cut treatments. The extended knife header had the highest average yield at both sites (tied with the draper at Indian Head). The rigid header had the lowest yields at both sites in the typical variety.

The Swath treatment in the shatter-resistant variety had a greater yield than any straight-cut varieties at Indian Head; however, the swathed was lower than any straight cut at Swift Current. The extended knife had the highest average yield of straight-cut headers at both sites followed by the rigid header at Swift Current and the draper header at Indian Head. Both the draper and rigid header had a yield average within 1 bu/ac at each site in the shatter-resistant variety.

Overall, dockage percentages were similar between the Swift Current and Indian Head sites with the latter having less variation between treatments. Dockage between treatments ranged from 1.3% to 2.5% at Swift Current and 1.4% to 2.0% at Indian Head. The dockage in the swathed treatments was higher than the straight cut treatments in both varieties at both sites. This difference suggests that the combine settings may not have been optimized for the swathed treatments.

Dockage percentages fall within typical values commonly realized by producers. More attention to initial combine settings could have further minimized dockage without compromising combine loss.

The average dockage-corrected yield shown in **Table 3** is of the greatest importance to producers, since this is the net amount of canola that a producer would be paid for. **Figure 34** compares the dockage-corrected yield between each header and each crop variety at Swift Current.

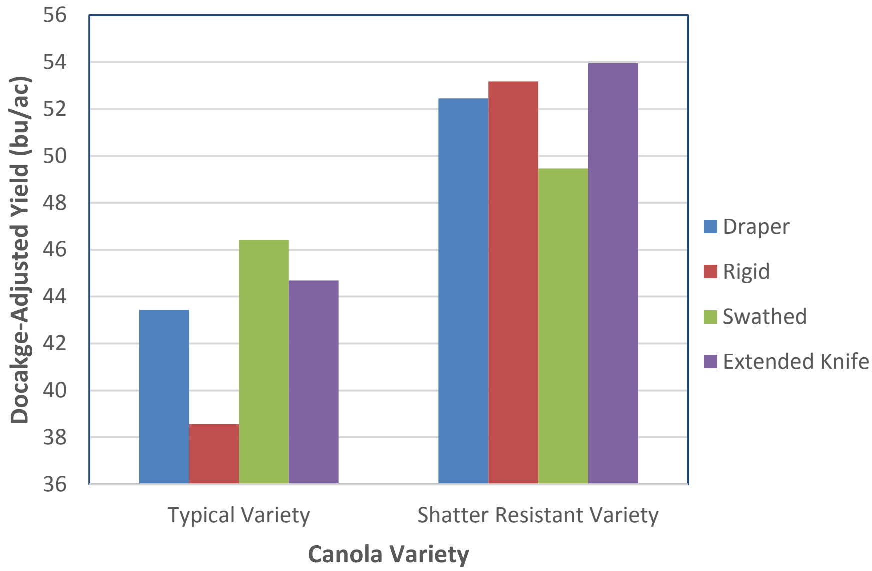


Figure 34. Swift Current dockage-adjusted yield for all header treatments and both varieties

Figure 35 illustrates the dockage-corrected yield at Indian Head between the header and crop treatments. The Indian Head data was very consistent due to crop maturity, and the yield difference between the straight cut typical variety versus shatter resistant variety correlated with the higher environmental loss observed in the typical variety, suggesting that yield potential between the two varieties was similar.

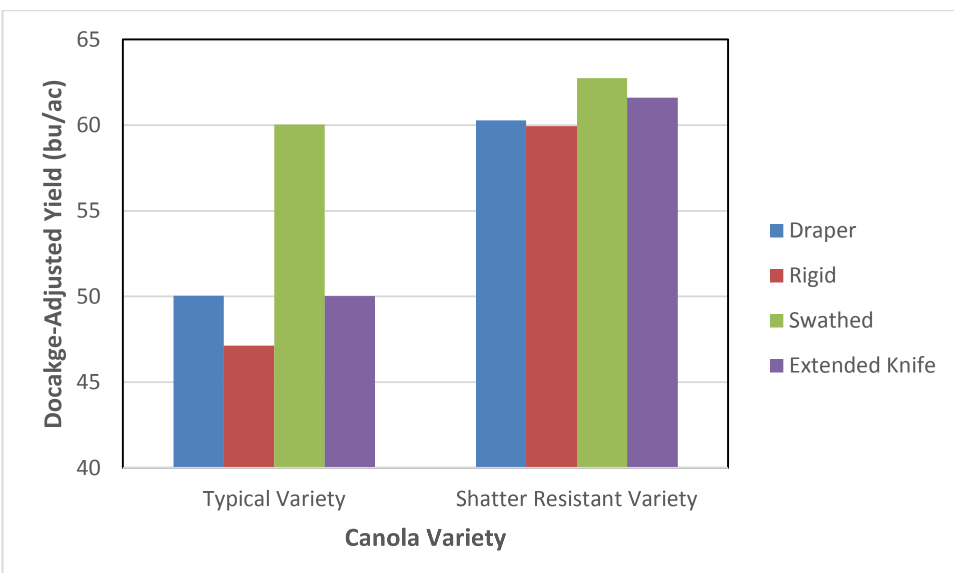


Figure 35. Indian Head dockage-adjusted yield for all header treatments and both varieties.

4.8 Crop Characteristics

Grain moisture, green content, TKW, and oil content are listed in **Table 3**. Cells with a green background indicate the most favourable values in each column. A yellow background highlights slightly unfavourable values, while a red cell background indicates unfavourable values that may be considered unacceptable by both producers and grain buyers.

At the Swift Current site, grain moisture was variable, and all treatments were not considered dry at time of harvest. Moisture content averaged 10.9% to 14.6% with the swath treatments 2.1% higher than straight cut in the shatter resistant variety and 3.4% higher in the typical variety.

At Indian Head, moisture content was low for all treatments with a range of 7.5% to 9.5%. At this site, the swathed treatments had lower average moisture contents for both varieties. The swathed typical variety was 1.5% lower in moisture than the straight-cut average, while the swaths were lower by a similar 1.2% for the shatter resistant variety.

Of particular concern at Swift Current is the green-seed percentage across all treatments. This range was 4.5% to 12.5%. All of these percentages are higher than the acceptable level for No. 1 canola, which equates to crop quality issues. The swathed treatments were higher than the straight cut at a 7.8% and 4.4% higher average for the typical and shatter-resistant varieties, respectively. It is unknown what the effect of the desiccation application was at this site with respect to crop quality. Presently, PAMI is conducting field-scale trials evaluating different desiccation options versus swathing in Manitoba, which may shed light onto managing desiccation and its possible effects.

At Indian Head, the green-seed count was low for all treatments with only the swathed shatter-resistant variety showing a considerable amount of green seeds at 0.7%. The later maturity of the shatter-resistant variety compared to the typical one likely influenced this difference.

The thousand kernel weight (TKW) at Swift Current had a higher average in all typical variety treatments (3.33 grams) than the shatter-resistant variety (3.09 grams). Differences between header treatments for a given variety were minimal. The TKW was similar between all headers and varieties at Indian Head, with the swathed treatments having a slightly lower average TKW (3.36 grams) than the straight-cut treatments (3.45 grams).

Oil content was very similar across treatments and sites in 2016 with neither variety nor header causing a significant effect. Oil content ranged from 49.9% to 50.8% at Swift Current and 48.8% to 49.2% at Indian Head.

Table 3. Grain moisture, green seed percentage, TKW, and oil content for all sites.

			Crop Characteristics			
Site	Variety	Header	Moisture (%)	Green Seeds (%)	TKW (g)	Oil Content (%)
Swift Current	Typical	Draper	10.9	4.50 b	3.3 a	50.3 ab
		Rigid	11.0	4.50 b	3.4 a	50.8 a
		Extended Knife	11.3	5.05 b	3.4 a	50.5 ab
		All Straight Cut	11.1	4.68	3.4	50.5
		Swathed	14.5	12.50 a	3.3 a	50.4 ab
	Shatter Resistant	Draper	12.7	6.65 ab	3.1 b	50.1 ab
		Rigid	12.3	5.40 ab	3.1 b	50.5 ab
		Extended Knife	12.5	6.10 ab	3.1 b	50.0 ab
		All Straight Cut	12.5	6.05	3.1	50.2
		Swathed	14.6	10.50 ab	3.1 b	49.9 b
Indian Head	Typical	Draper	9.5	0.05 b	3.5 a	48.9 ab
		Rigid	9.0	0.00 b	3.5 a	48.8 ab
		Extended Knife	9.0	0.00 b	3.5 a	49.1 ab
		All Straight Cut	9.2	0.02	3.5	48.9
		Swathed	7.5	0.15 b	3.4 b	49.2 ab
	Shatter Resistant	Draper	9.2	0.15 b	3.5 a	48.8 ab
		Rigid	8.8	0.05 b	3.4 ab	49.0 ab
		Extended Knife	8.9	0.00 b	3.4 ab	48.9 ab
		All Straight Cut	9.0	0.07	3.4	48.9
		Swathed	7.8	0.70 a	3.4 b	49.4 a

The letters behind individual values indicate significant differences at a 95% confidence level. The ‘a’ designation highlights the largest value for each characteristic, while ‘b’ has a significantly lower value from a statistical standpoint.

4.9 Combine Loss

In 2016 combine losses were gathered from a majority of the samples. However, contrary to other years, both straw and chaff were left spread for this collection instead of dropping both. This facilitated faster sampling but did not allow for the collection of absolute values for combine loss across treatments. This is due to the uneven distribution of seeds across the width of the spread. However, the combine spread pattern should be similar across all treatments and therefore the relative loss between treatments should be accurate. By assuming even distribution of seeds across the spread width, one can also derive approximate combine loss values.

Figure 36 highlights the approximate header losses at Indian Head. The values shown should not be taken as the absolute loss observed; however, trends between treatments are assumed to be representative. These loss values are not moisture-corrected, and weights represent the moisture content at time of weighing. Swift Current data is not shown due to missing repetitions, but averages ranged from 0.5 to 1.8 bu/ac.

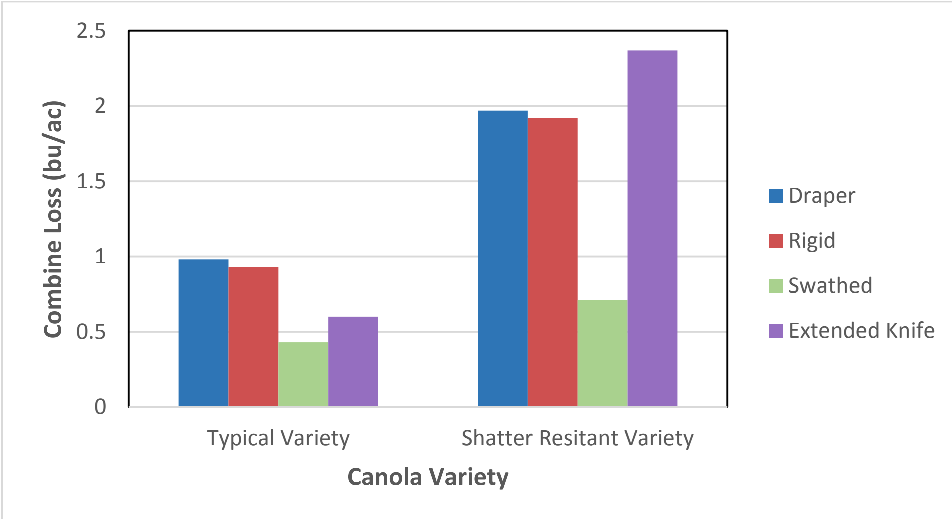


Figure 36. Combine loss at Indian Head for all header treatments and both varieties.

4.10 Calculated Harvest Cost

Harvest costs for the different systems were analyzed in 2016 as an update to the version found in the 2014 report. Results are based on data obtained through field repetitions as well as subjective observations made during harvest. The 2016 calculations include considerations for the yield between different headers and varieties based on the three-year Indian Head site average and a canola price of $12/bushel. Only the direct harvesting costs for each system in addition to the gross profit from the average yields are considered, as all other aspects and operations between the two systems are assumed to be identical. No difference in seed price is factored in between the two varieties, but any variance should be considered. Based on the scope of the project, all straight-cut treatments are presumed to have naturally dried without the use of a desiccant. The use of a desiccant may significantly change the harvesting costs and yields between systems.

Table 4 highlights anticipated cost differences between the different systems. It is important to note that average yield and attainable ground speed are based on the conditions experienced at the Indian Head site. Alternative conditions experienced may have a significantly different economic outcome. Combine and swathing costs are derived from the 2016/2017 Farm Machinery Custom and Rental Rate Guide. Machine costs are defined using the custom rate, which includes ownership costs, repair and maintenance, labour, fuel, and margins on these figures. Calculations are based on the associated work rates based on ground speed at 90% field efficiency.

Table 4. Economic comparison between harvest systems (2016 dollars).

Canola Variety	Header Treatment	Average Net Yield (bu/ac)	Gross Income ($/ac)	Est. Speed at 80% Engine load (mph)	Productivity at 90% field eff. (ac/hr)	Combine Operating Cost ($/ac)	Combine Header Cost ($/ac)	Swathing Cost ($/ac)	Total Equipment Cost ($/ac)	Net Outcome (gross-harvest) ($/ac)
Typical	Draper	50.3	$ 603.60	3.5	13.7	31.56	$ 3.93	-	$ 35.48	$ 568.12
	Rigid	49.7	$ 596.40	3.5	13.4	32.46	$ 1.46	-	$ 33.92	$ 562.48
	Extended Knife	51.2	$ 614.40	3.5	13.4	32.46	$ 4.04	-	$ 36.50	$ 577.90
	Avg. St. Cut	50.4	$ 604.80	3.5	13.5	32.16	$ 3.14	-	$ 35.30	$ 569.50
	Swath	57.1	$ 685.20	4	15.6	27.81	$ 0.77	$ 9.74	$ 38.32	$ 646.88
Shatter Resistant	Draper	58.1	$ 697.20	3.25	12.8	33.98	$ 4.23	-	$ 38.21	$ 658.99
	Rigid	56.8	$ 681.60	3.25	12.4	34.96	$ 1.57	-	$ 36.53	$ 645.07
	Extended Knife	59.2	$ 710.40	3.25	12.4	34.96	$ 4.35	-	$ 39.30	$ 671.10
	Avg. St. Cut	58.0	$ 696.40	3.25	12.5	34.63	$ 3.38	-	$ 38.02	$ 658.38
	Swath	57.7	$ 692.40	3.75	14.6	29.66	$ 0.82	$ 9.74	$ 40.22	$ 652.18

In the typical variety, the swathed treatment resulted in the highest profit with a large margin. This difference is primarily attributed to environmental shatter loss encountered in the straight-cut treatments. Green stalks in the standing canola resulted in the combine being able to travel approximately 0.5 mph faster with the same engine load. The average yield in the swathed treatment was slightly less than in the shatter-resistant variety, resulting in a $5.30/ac benefit in the shatter resistant variety.

For the shatter resistant variety, narrow margins were observed between treatments, as yields remained closer. As with the typical variety, a 0.5 mph combine speed increase was often practical in the windrowed variety. The slightly later maturity of this variety resulted in marginally greater engine load, expressed as a 0.25 mph ground speed advantage for the typical variety in all treatments.

Two of the three straight-cut headers had a higher profit margin than the swathed treatment in the shatter-resistant variety. The extended knife header is calculated at $671.10/ac followed by the draper at $658.99, the swathed at $652.18, and lastly the rigid header at $645.07/ac. The bulk of the profit differences result from average yield differences. When factoring in observed productivity potentials between different headers, total machinery cost for harvest was similar between all treatments, including the windrowed canola. The added harvest operation for swathing was largely offset by the higher cost of the straight-cut headers as well as greater combine costs resulting from lower ground speeds.

The relevance of the economic prediction shown will be operation dependent. Labour rates are included in applicable instances, but any labour shortages may result in a higher labour opportunity cost than what has been accounted for. Additionally, the equipment costs listed represent custom rates, and each operation’s realized cost per machine hour will vary. To add to this, the type of machinery that an operation has on hand will largely dictate the initial machine cost per hour for each harvest system, especially in the initial phases.

5. Cumulative Results

Results from all three harvest years were averaged, when possible, in order to give a full overview of the outcomes obtained. In some instances, results could not be accurately compiled due to significant differences in either the underlying environment and crop conditions and/or the sampling methods used. In these cases, results from individual site-years should be noted.

Generally speaking, the Indian Head site had consistent data between years, as crops and environment were favourable in the three trial years. The Swift Current site experienced a wider range of crop conditions, and therefore comparisons between years and between site locations are harder to make without misconstruing or disregarding the fundamental causes for the observed results. Due to the nature of the Humboldt site and its objectives, data and results obtained there are analyzed individually.

5.1 Header loss

Absolute header loss averages over all trial years could not be derived due to the range of methods and number of loss pans used from year to year to quantify loss across the header. Despite this, some site-years could be combined to give greater resolution of results.

In addition to quantifying total loss for each straight-cut header, an emphasis was also placed on the distribution of loss across the header's width. This knowledge helped identify where loss was occurring and what efforts may be worthwhile in mitigating loss, ranging from adjusting header settings, to simple modifications, to potential design improvements.

Figure 37 highlights the individual header losses across its width for all available site-years. This graph represents the loss, in bushels per acre, at an individual 7-in. wide tray used for collection. Individual loss point should not be taken as cumulative header loss, and the addition of loss points will not derive the total header loss.

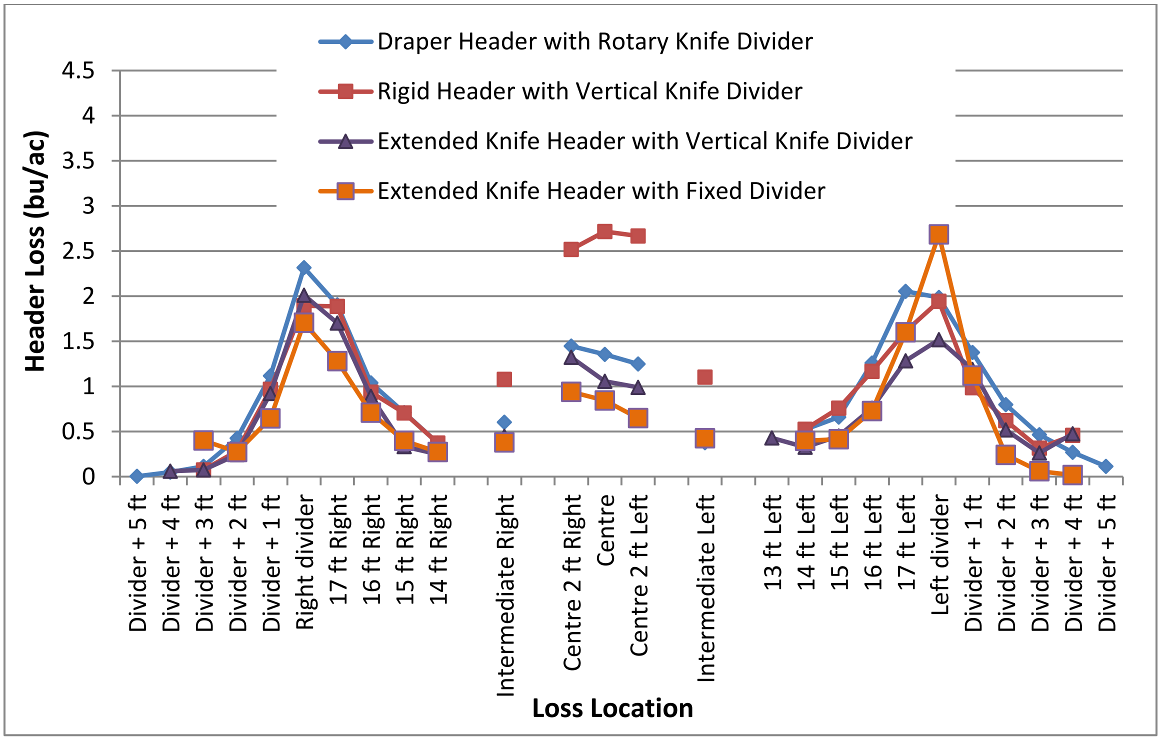


Figure 37. Combined header loss for all headers.

The higher losses incurred by the rigid header at the center and intermediate zones becomes quickly apparent. The extended knife header averaged the lowest losses of the three headers in this center zone. The fixed divider on the left (knife-drive) side of the header had significantly more loss directly at the divider itself, but losses were similar to other divider configurations over the remaining areas of the divider collection zone. Of all the headers tested, the draper header had intermediate losses across its entire width.

One challenge when comparing the divider loss between the three systems tested is that the fixed divider and rotary divider's point of contact with the crop varies with overall crop height and cutting height. With the vertical knife, these two factors become irrelevant to the performance of the divider, as the knife profile is constant along its height.

Figure 38 depicts the average cumulative loss in both of the divider zones. The losses shown total the mass of canola seed found in the loss trays under each side of the header during the loss tests. These numbers do not reflect a common metric of loss but clearly show trends betweeen the different dividers.

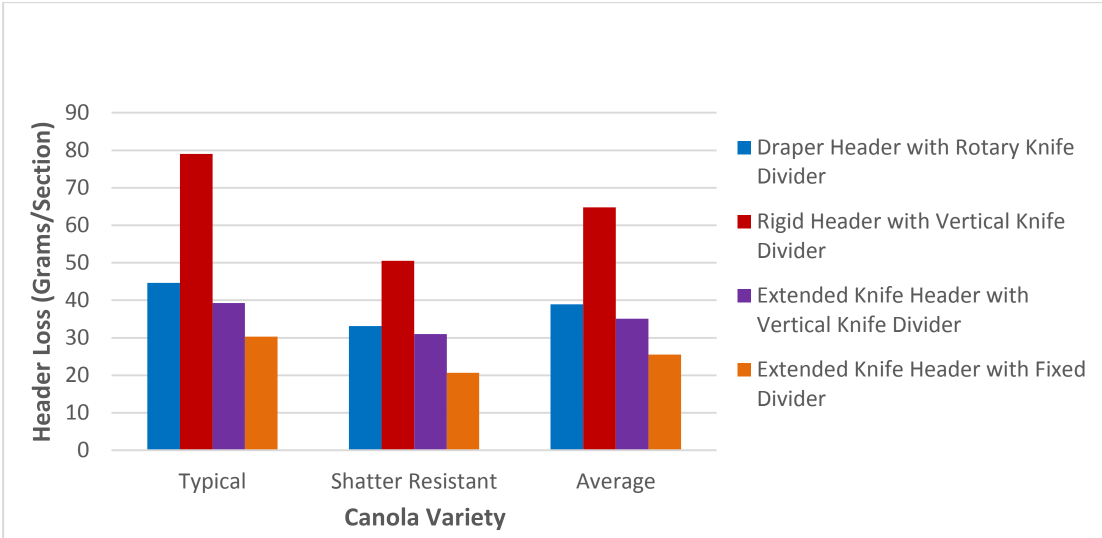


Figure 38. Average header in divider zone.

The rigid header with the vertical knife had the highest divider loss by a large margin. The other three headers were closer to one another in loss, but a clear trend was shown in both varieties with the fixed divider on the extended knife experiencing the lowest loss, followed by the vertical knife on the same header, and then the rotary knife divider on the draper header. It is noteworthy that these averages only represent results from the 17-tray layout used for some of the replicated header tests. The Humboldt site in 2016 used a more intensive tray layout with 10 trays on each divider end. **Figure 29** highlights those loss tests where the vertical knife had the lowest loss, followed by the fixed divider, and lastly the rotary knife.

The variability in header loss in different crop conditions is readily apparent in **Figure 39**, which shows the mean loss of all headers for each site-year with the 17-tray header loss resolution. Different site-years resulted in varying losses both in degree and distribution. This highlights the effect of crop conditions on loss and the importance of evaluating machine and crop performance in multi-year studies.

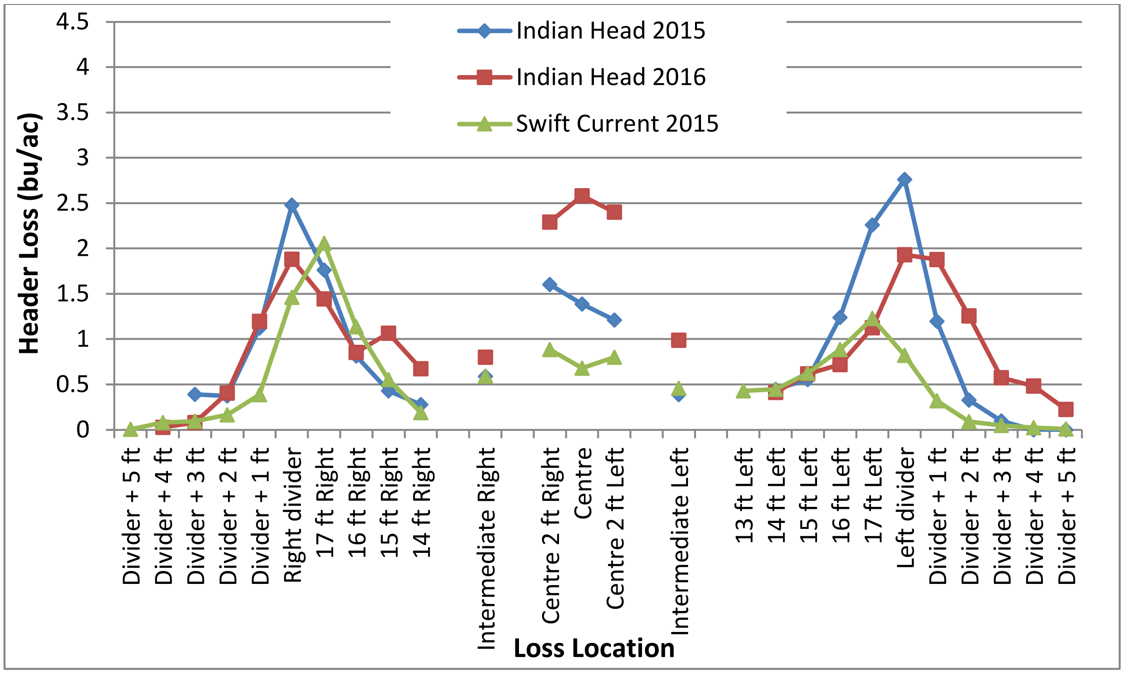


Figure 39. Cumulative header loss per site-year

Some conclusions can be made from the cumulative header loss data, both from individual site-years and combined analysis. For headers, the extended knife header resulted in the lowest losses followed by the draper. The rigid header had a higher amount of loss and is not recommended when straight cutting canola in large acres. With respect to dividers, the vertical knife and fixed dividers had lower losses than the rotary knife divider, and given the data collected, may be a better fit for ripe canola.

5.2 Yield

There was a high variance in canola yield between site-years, varieties, and in some cases, header treatments. Over the six site-years at Indian Head and Swift Current, environmental losses varied from near zero to over 7 bu/ac. With regards to headers, there was no single header that had the highest average yield in all conditions and varieties. Likewise, there was no consistent yield benefit from the straight-cut treatments over the swathed treatment; differences were dependant on year and largely on crop variety.

The severity of environmental shatter loss varied considerably based on variety, site, and year. **Table 5** summarizes the average shatter loss in bushels per acre based on these characteristics.

Table 5. Environmental shatter loss summary.

Site	Variety	2014	2015	2016	Average
Swift Current	Typical	0.1	7.0	5.3	4.1
	Shatter-Resistant	0.2	2.2	0.2	0.9
Indian Head	Typical	2.7	2.8	8.3	4.6
	Shatter-Resistant	2.0	0.3	1.5	1.3

Overall, the shatter resistant variety had substantially less environmental loss across all trial years, averaging 0.9 bu/ac at the Swift Current site, and 1.3 bu.ac at Indian Head. The mean typical variety environmental loss for these sites was 4.1 bu/ac at Swift Current and 4.6 bu/ac at Indian Head, a difference of over three bushels per acre at both sites.

These environmental losses show the merit of growing a shatter resistant variety over a typical one. It should be noted, however, that due to the scope of the trial, with both varieties being harvested simultaneously, the later-maturing shatter-resistant variety may have had a slight advantage over the typical variety from being harvested at a more opportune time relative to its maturity. Despite this, the relatively low losses in the shatter-resistant variety across all site-years shows the potential for this variety to reduce risk when straight cutting canola.

Figure 40 compares the header treatments and two canola varieties for yield across the three trial years at Swift Current. Dockage-adjusted yield is used as this represents the net amount of saleable grain. The shatter-resistant variety had higher average yields than the typical variety. The inclement weather experienced over the site-years at Swift Current led to high environmental losses in the typical variety contributing to the yield disparity between the two.

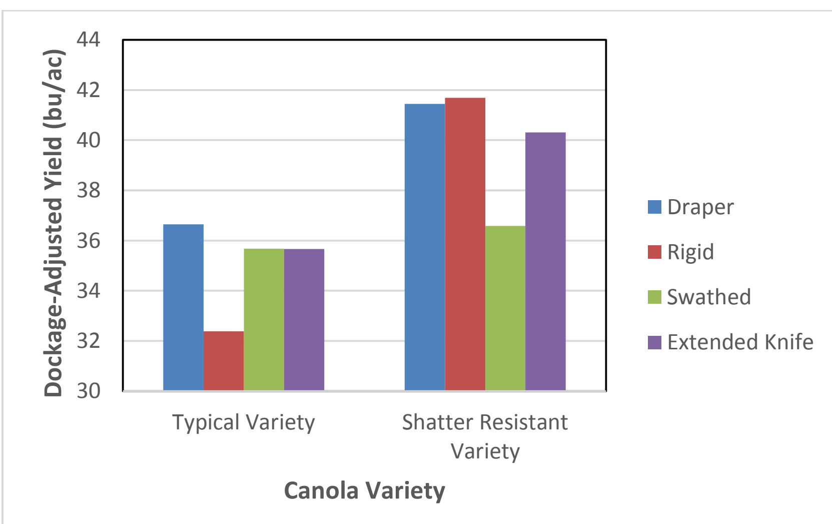


Figure 40. Swift Current three-year average dockage-adjusted yield for all header treatments and both varieties.

In the typical variety, the draper header had the highest overall yield with the swath and extendable knife headers slightly behind. The rigid header had the lowest overall yield, primarily due to the higher losses experienced with this header in 2016, where the lodged crop caused higher header losses. All three straight-cut treatments in the shatter-resistant variety had significantly higher yield than the swathed treatment. The rigid header narrowly had the highest average yield in this variety, with a 0.2 bu/ac higher average yield than the draper header, and a 1.4 bu/ac average yield advantage over the extendable knife header. The swathed treatment fell well behind of the rest in this variety, with a 5.1 bu/ac disadvantage compared to the rigid header. Due to the nature of the Swift Current plots, these yield numbers represent the headers being used in less than ideal crop conditions, and in some cases, in unevenly matured crop. Due to these factors, the results from this site may not be representative of a particular header's strength or weakness in certain conditions.

The Indian Head site presented good growing conditions for all three years of this study. The crop was placed on an even, uniform field, and the resultant crop stand was consistent and erect with high yields across all treatments (**Figure 41**). In both the 2015 and 2016 harvest years, a substantial wind event occurred prior to combining but after swathing. In both these years, the typical variety suffered large environmental losses in the standing treatments. Overall yield between the two varieties is reflective of these events with the shatter-resistant variety averaging 57.9 bu/ac across all treatments and the typical variety 52.1 bu/ac.

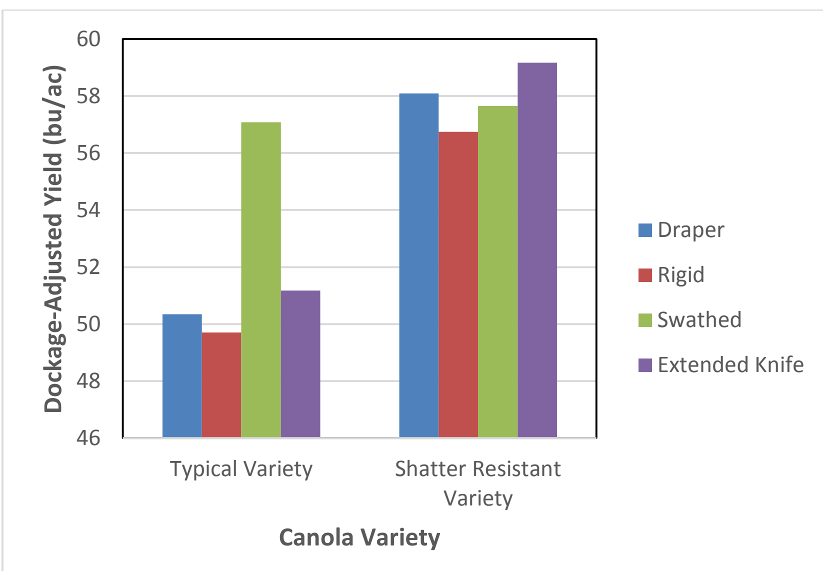


Figure 41. Indian Head three-year average dockage-adjusted yield for all header treatments and both varieties

The wind event in the typical variety resulted in the swathed treatment's yield being significantly higher than any of the three straight-cut ones. The swathed treatment averaged 57.1 bu/ac, followed by the extendable knife at 51.2 bu/ac, the draper at

50.3 bu/ac, and lastly the rigid header at 49.7 bu/ac. Due to the consistency in the plant stand, there is high confidence that the differences between treatments is a result of the associated losses with each specific header.

The smaller magnitude of environmental loss in the shatter-resistant variety caused greater equity between the header treatments. The extendable knife header had the highest average at 59.2 bu/ac followed by the draper at 58.1 bu/ac, the swathed treatment at 57.7 bu/ac, and lastly the rigid header at 56.8 bu/ac. The higher yield in two of the three straight-cut treatments over swathing shows potential for this practice to produce higher yields under ideal conditions.

Average yields, dockage, and dockage-adjusted yields are separated by crop variety and treatment and shown in **Table 6.** Green cells indicate the best outcome achieved while yellow highlights mediocre results. Cells with a red background show values that are undesirable and potentially unacceptable. This table is meant to give an overview of trial results. For a complete analysis of yields obtained and the underlying factors, consult the individual trial year results from the 2014 and 2015 interim reports, and **Table 2** for 2016 data.

Table 6. Average harvested yield, dockage, and dockage-adjusted yield over all three trial years.

Site	Variety	Header	Harvested Yield (corrected to 10% moisture) (bu/ac)	Dockage (%)	Dockage-Corrected Yield (bu/ac)
Swift Current	Typical	Draper	37.8	2.9	36.6
		Rigid	33.3	2.5	32.4
		Extended Knife	36.5	2.3	35.7
		Swathed	36.5	2.5	35.7
	Shatter Resistant	Draper	42.7	2.8	41.5
		Rigid	42.7	2.4	41.7
		Extended Knife	42.6	2.9	40.3
		Swathed	37.4	2.4	36.6
Indian Head	Typical	Draper	50.8	1.0	50.3
		Rigid	50.2	0.9	49.7
		Extended Knife	51.6	0.9	51.2
		Swathed	57.6	1.3	57.1
	Shatter Resistant	Draper	58.9	1.3	58.1
		Rigid	57.3	1.0	56.8
		Extended Knife	59.8	1.2	59.2
		Swathed	58.6	1.6	57.7

5.3 Crop Characteristics

Table 7 lists the cumulative results for crop characteristics from all three harvest years. As with previous charts, values in green show the most favourable values for each site for each different characteristic observed. Cells with a yellow background indicate slightly unfavourable values, while cells with a red background designate unfavourable values and results that may be unacceptable by producers. All values listed are the average of the three site-years of data. The results from individual years can be found in **Table 3** for 2016, and the 2014 and 2015 interim reports. Average results are not indicative of the performance of individual site-years, and conclusions drawn should be taken within the context of the underlying conditions.

Table 7. Average grain moisture, green seed percentage, TKW, and oil content over all three trial years.

			Crop Characteristics			
Site	**Variety**	**Header**	**Moisture (%)**	**Green Seeds (%)**	**TKW (g)**	**Oil Content (%)**
Swift Current	Typical	Draper	12.2	2.9	3.3	48.9
		Rigid	12.7	3.4	3.4	48.4
		Extended Knife	11.9	3.0	3.4	48.6
		All Straight Cut	12.3	3.1	3.3	48.6
		Swathed	12.0	5.2	3.2	47.2
	Shatter Resistant	Draper	12.0	3.1	3.1	49.1
		Rigid	12.3	2.8	3.1	48.9
		Extended Knife	11.9	3.4	3.1	48.8
		All Straight Cut	12.1	3.1	3.1	48.9
		Swathed	11.4	5.0	2.8	47.1
Indian Head	Typical	Draper	7.8	0.2	3.2	49.0
		Rigid	7.6	0.1	3.2	49.0
		Extended Knife	7.6	0.2	3.2	49.0
		All Straight Cut	7.7	0.2	3.2	49.0
		Swathed	6.8	0.2	3.1	49.1
	Shatter Resistant	Draper	7.6	0.2	3.1	49.1
		Rigid	7.5	0.2	3.1	49.2
		Extended Knife	7.6	0.2	3.1	49.2
		All Straight Cut	7.6	0.2	3.1	49.1
		Swathed	6.8	0.7	3.0	49.5

At the Swift Current site, many events in the 2015 and 2016 growing seasons led to serious issues in both crop quality and the ability to harvest the crop under ideal conditions. Average moisture ranged from 11.4% to 12.7%. In two of the three years, the crop was harvested above the dry moisture content, with the 2015 crop being harvested at approximately 15% moisture.

Generally favourable conditions at Indian Head for all three trial years resulted in desirable crop characteristics. Grain moisture content was dry for all three harvest years, with an average range from 6.8% to 7.8% and the swathed treatment having a moisture content 0.8% lower than the straight cut over all treatments and both varieties.

Along with the high average moisture content, the Swift Current site suffered from a high average green-seed content, which could significantly affect the producer's ability to sell the grain. The average green-seed percentage is higher for the swathed treatments than the straight cut at 5.1% compared to 3.1% when combining varieties, due in large part to the 2016 harvest. In the 2015 harvest, the swathed treatment at Swift Current had significantly less green seeds than the straight-cut treatments in both varieties, indicating that the difference between headers is dependent on the environment.

Green seed counts at Indian Head were low for all three years, with averages falling between 0.1% to 0.7%. In the typical variety, there was marginal difference between the straight cut and swathed treatments, while in the shatter tolerant, there was a 0.5% higher average in green seeds in the swathed treatment when compared to the straight-cut treatment. This greater difference in the shatter-tolerant variety is likely due to its tendency for later maturity, and since both varieties were swathed and harvested at the same time, swathing may have been slightly premature in some instances resulting in a higher green-seed percentage. Even with the higher percentage in the swathed treatment, the overall green-seed percentage falls well within the limit of 2% for No. 1 canola in Canada.

For Swift Current samples, the TKW stayed fairly consistent between varieties and years with only slight differences between treatments. The swathed treatments trended marginally lower than the straight cut with an average 0.1 grams lower in the typical variety and 0.3 grams lower in the shatter resistant, with the greater difference in the latter due to the swathed treatment in 2015 having a TKW 0.5 grams lower than the straight cut.

Thousand-kernel weight at Indian Head had a similar trend over all three years with the shatter-resistant variety having a lower weight per thousand seeds. Averaged over all years, the shatter resistant variety had a TKW of 3.1 grams compared to 3.2 grams in the typical variety. The swathed treatments averaged 0.1 grams lower than the straight-cut treatments in both varieties, showing that the delayed cutting can have an effect on seed size.

Oil content at Swift Current was comparable between the typical and shatter-resistant varieties with averages of 48.3% and 48.6%, respectively. The swathed treatment in both varieties trended lower, in large part due to significantly lower oil content in 2015. The swathed treatments in the typical varieties averaged 1.4% less than straight cut, and in the shatter-resistant variety, the difference was greater at 1.8%.

Contrary to Swift Current, the oil content at Indian Head trended higher in the swathed treatments, with a 0.1% higher average in the typical variety and a 0.4% higher average than straight-cut treatments in the shatter-resistant variety. Over all three years, the typical variety averaged a 49.0% oil content compared to 49.2% in the shatter-resistant variety.

6. Conclusion

This project highlighted the potential for straight cutting canola, and validated that it is a viable option for Western Canada. This study developed a strong comparison of headers for losses, and yield and crop quality differences between windrowing and straight cutting. Despite the knowledge gained, there are still many more unanswered questions that warrant additional research, in order to provide growers and the industry with the best possible advice for utilizing this harvest management system.

6.1 Discussion

With eight total site-years, this project encountered wide variation in canola stands and environmental conditions. The results show promise in the practice of direct cutting canola, as many successful harvests were had.

A key aspect of the project was the comparison between straight-cut canola and swathed canola. The results indicate that there is no system that will produce the greatest yield in every instance. In some site-years, the swathed treatment produced the highest yield in both canola varieties tested. The swathed treatments often yielded higher than the straight-cut treatments in the typical canola variety, in which environmental loss reduced yield obtained in the straight-cut treatments.

Like yield, there is no definitive system that is better with regards to crop quality based on this data. Results at Indian Head, where conditions were generally favourable, showed marginal differences between swathed and straight cut with regards to green seeds, TKW, or oil content. These results may indicate that general crop condition and management may play a larger role than harvest management for crop quality.

Each operation will have varying labour and equipment availability, and these two factors are likely the most important aspects when comparing the two systems from an operational standpoint. Straight cut harvesting, especially when utilizing natural drying, will have a lower labour requirement than the conventional approach of windrowing.

Although not a direct objective of the original project, the comparison between a shatter-resistant variety and a typical canola variety became a significant aspect of the study. The range in losses between varieties showcases the potential for risk mitigation by growing a shatter resistant variety, both under ideal and adverse environmental conditions. It is recommended that a producer consider growing a canola variety with documented shatter resistance, if they intend on utilizing straight cut harvesting. As there is no defined standard for shatter resistance in canola, it is important to evaluate individual varieties and note that varieties labeled as shatter resistant or shatter tolerant may not be a direct substitute for the variety used in this study.

From an industry standpoint, it will be necessary to create a rating system for shatter tolerance between varieties, such as those practiced for other aspects like lodging or disease. By implementing a set-up using loss trays such as those used in this study, differences in both the overall quantity and kind of environmental shelling loss are easily found. This system will allow producers make more accurate management decisions based on sound field data when selecting a canola variety to straight cut.

It is recommended that a producer contemplating straight cutting canola only harvest a small percentage of their acres using this method in the first year. This is to ensure it may benefit their operation before a large investment is made. As all header and divider combinations could successfully harvest standing canola, it is advised that a producer use their current header when initially trying the practice and invest in modifications or a specialized header if the number of acres and results warrant. The continual development of new canola varieties with this shatter-resistant trait may also further limit header losses and improve the usability of all headers when harvesting canola.

6.2 Future Work

The research conducted throughout the three test years for this project has made vast improvements to the knowledge pertaining to straight cutting canola, both from a harvest equipment aspect and the overall management practices surrounding canola grown with the intention to direct harvest.

Through all this research, producers will be able to plan and manage their crop throughout the growing season. They will also be able to make informed decisions regarding header selection and can find the right fit for their operation.

Despite all the advancements made, there are still unknowns when straight cutting canola. One of the main producer questions is related to the application of a desiccant and its effect on harvest timing, combine efficiency, crop quality, and overall profit. PAMI's station in Portage La Prairie, Manitoba, undertook a one-year study aiming to provide a preliminary comparison of swathing, natural drying, and desiccation on combine performance and seed quality. The results from this single site-year showed potential for desiccation to be a useful management tool in certain instances.

One of the unique aspects of the research performed in this study was the method of collecting header and environmental loss. The multi-layer environmental loss tray, as depicted in **Appendix A**, was useful for both protecting fallen seeds from predator, and to keep the seeds dry. This system worked flawlessly in the environmental loss, and could be implemented in future research, public or private, when quantifying environmental losses between canola varieties.

The same tray design principle could also be applied for measuring header losses, when comparing either canola varieties or straight cut headers. The unique array of collection trays across the width of the header was found to accurately depict header losses in the respective zones and showcased the type of loss, be it whole pods or individual seeds.

6.3 Technology Transfer

An avid attempt has been made throughout the course of the project to disseminate the findings through various means, including presentations at producer meetings, seminars, and farm shows, magazine and newspaper articles, and television broadcasts. A summary of the technology transfer events is presented below, based on the project's crop years.

6.3.1 First year of the project - 2014

A producer meeting was held in conjunction with SaskCanola at CropSphere 2014 to gain insight from producer experiences with straight cutting canola. Subsequent producer meetings are planned going forward, possibly even prior to spring seeding activities.

PAMI presented preliminary results from Year 1 in the Information Theatre at the Crop Production Show in January of 2015. Preliminary results were also presented to a grain producer association in British Columbia and at a local retail customer appreciation seminar in Lake Lenore.

IHARF and WCA also presented results at several Agri-Arm seminars and at SaskCanola regional producer meetings.

6.3.2 Second year of the project - 2015

Preliminary results from Year 1 and 2 were presented by PAMI personnel at the following 23 events from March 31, 2015, to March 31, 2016:

1. Jun 8, 2015 – New Holland Club Blue Customer Appreciation Event in Saskatoon, Saskatchewan
2. Jun 17, 2015 – Farm Progress Show Farm Credit Canada Information Theatre
3. July 22, 2015 – Ag In Motion outdoor farm show presentations near Langham, Saskatchewan
4. Jul 28, 2015 – Bayer Crop Science producer meeting in Yorkton, Saskatchewan
5. Jul 28, 2015 – Webinar for BASF customers from Humboldt, Saskatchewan
6. Aug 26, 2015 – BASF Field day in St. Brieux, Saskatchewan
7. Oct 26, 2015 – Dekalb Agronomist Meetings in Saskatoon, Saskatchewan

8. Oct 28, 2015 – Canola Council of Canada Canola Discovery Forum in Canmore, Alberta
9. Nov 17, 2015 – Bayer Crop Science producer meetings in Regina, Saskatchewan
10. Nov 17, 2015 – Oilseed Producer Days at Humboldt, Saskatchewan
11. Nov 19, 2015 – Oilseed Producer Days at Rosetown, Saskatchewan
12. Nov 20, 2015 – Oilseed Producer Days at Swift Current, Saskatchewan
13. Nov 24, 2015 – John Deere Harvester Works meeting with engineering and marketing personnel at Moline, Illinois
14. Nov 28, 2015 – Bayer Crop Science top producer meetings in Winnipeg, Manitoba
15. Dec 1, 2015 – Meeting with Macdon Engineering, Marketing, and Management in Winnipeg, Manitoba
16. Dec 2, 2015 – Decisive Farming agronomists and producers meeting in Banff, Alberta
17. Dec 8, 2015 – SK Agronomy Research Update in Saskatoon, Saskatchewan
18. Dec 8, 2015 – Farm Management Canada Webinar from Humboldt, Saskatchewan
19. Jan 25, 2016 – SK Ministry of Agriculture Farm Business Management Series in Yorkton, Saskatchewan
20. Jan 26, 2016 – SK Ministry of Agriculture Farm Business Management Series in Swift Current, Saskatchewan
21. Jan 27, 2016 – SK Ministry of Agriculture Farm Business Management Series in Saskatoon, Saskatchewan
22. Feb 2, 2016 - JRI Agronomy Representatives meeting in Saskatoon, Saskatchewan
23. Mar 1, 2016 - Bayer Crop Science sales and agronomy personnel meetings in Winnipeg, Manitoba

IHARF, WCA, and Jim Bessel of Bayer Crop Science have also presented preliminary results at several seminars and producer meetings.

Preliminary results were released through various media outlets and publications including CTV Farmgate, CTV News, Western Producer, SK Canola 20th Anniversary Research Summary, and Canola Digest.

6.3.3 Third Year of the project - 2016

Results from Year 1 and 2 were presented by PAMI personnel at the following events from April 1, 2016, to March 31, 2017:

1. July 27, 2016 – Webinar for Federated Cooperatives Ltd Agronomy Team; Humboldt, Saskatchewan
2. July 27, 2016 - Bayer Crop Science Cutting Edge Expo in Saskatoon, Saskatchewan
3. July 28, 2016 – Webinar for BASF; Humboldt, Saskatchewan
4. August 15, 2016 - Webinar for Dupont Pioneer Agronomy Team; Humboldt, Saskatchewan
5. November 2, 2016 – Crop Production Services (CPS) Agronomy Team Meeting in Saskatoon, Saskatchewan
6. November 22, 2016 – Farm World Customer Event in Humboldt, Saskatchewan
7. November 23, 2016 – Farm World Customer Event in Kinistino, Saskatchewan
8. November 24, 2016 – Farm World Customer Event in Prince Albert, Saskatchewan
9. February 15, 2017 – Top Notch Farming Event in Melfort, Saskatchewan

Various media interviews and media publications were also conducted through outlets including Fabmar Communications, Humboldt Journal/East Central Trader, and others.

7. Contributions and Support

Funding for this project was provided by the Agricultural Development Fund (ADF), Western Grains Research Foundation (WGRF), and the Saskatchewan Canola Development Commission (SaskCanola).

This project was accomplished with collaboration between Agriculture and Agri-Food Canada, IHARF, and Wheatland Conservation Area with leadership provided by the Prairie Agricultural Machinery Institute (PAMI).

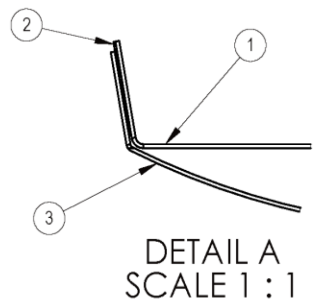
New Holland Agriculture aided by providing a new model combine for use in field testing throughout the duration of the project, as well as providing a Varifeed straight-cut header and belt pickup header as needed throughout. Honeybee supplied the draper header used for the entirety of the project.

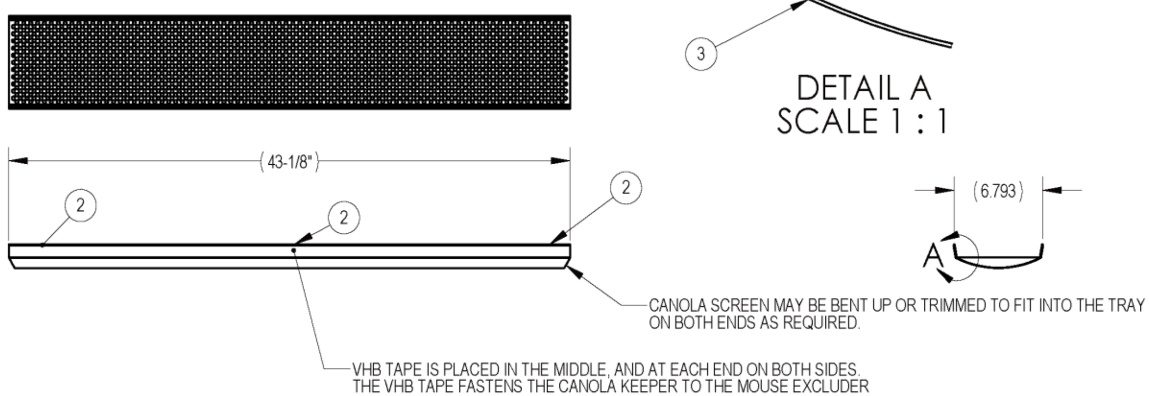
Bayer Crop Science has provided seed and chemical to the Swift Current and Indian Head plots for the entirety of the project, and Dekalb has provided seed for the Humboldt site.

Appendix A

Loss Collection Tray Drawings

ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	A0514_Mouse_Excluder	MOUSE EXCLUDER, 1/4" PERF GALV SCREEN
2	6	D0514-3M-VHB TAPE	3M - VHB DOUBLE SIDED TAPE 1" WIDE BY 3" LONG
3	1	A0514_Canola_Keeper	CANOLA KEEPER, SCREEN





THIRD ANGLE PROJECTION

STD. UNITS INCHES
STD. TOLERANCES:

HOLES: +1/32",-0
FRACTIONS: ±1/16"
X.XX: ±0.06"
X.XXX: ±0.015"
ANGLES: ±0.5°

REV	DATE	DESCRIPTION	INITIAL
A	18-AUG-2014	AS BUILT	AHW

TITLE: ASSY, CANOLA SCREENS

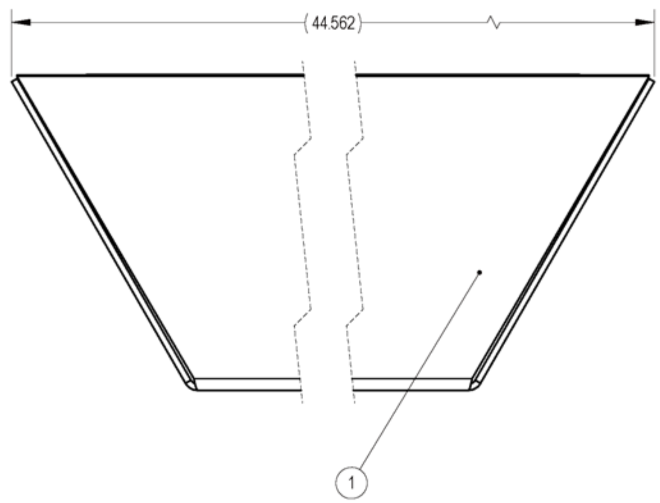
Prairie Agricultural Machinery Institute
P.O. Box 1150 Humboldt, SK
PAMI

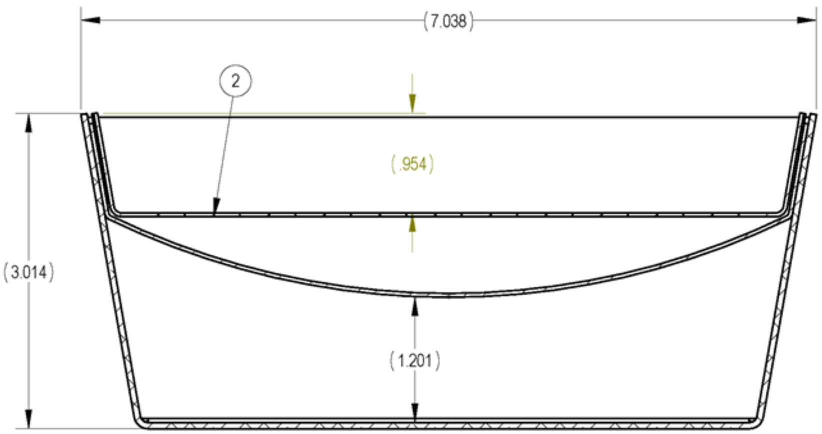
DRAWN BY: AHW
DATE: 18-AUG-2014
CHECK BY: N/A
MATERIAL:

EST WEIGHT	SCALE	PAGE	DWG SIZE
LB	1:8	1 OF 1	B

DWG. #: A0514_ASSY_SCREENS
REVISION: A

ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	A0514_Tray_Base	COLLECTOR TRAY
2	1	A0514_ASSY_SCREENS	ASSY, CANOLA SCREENS



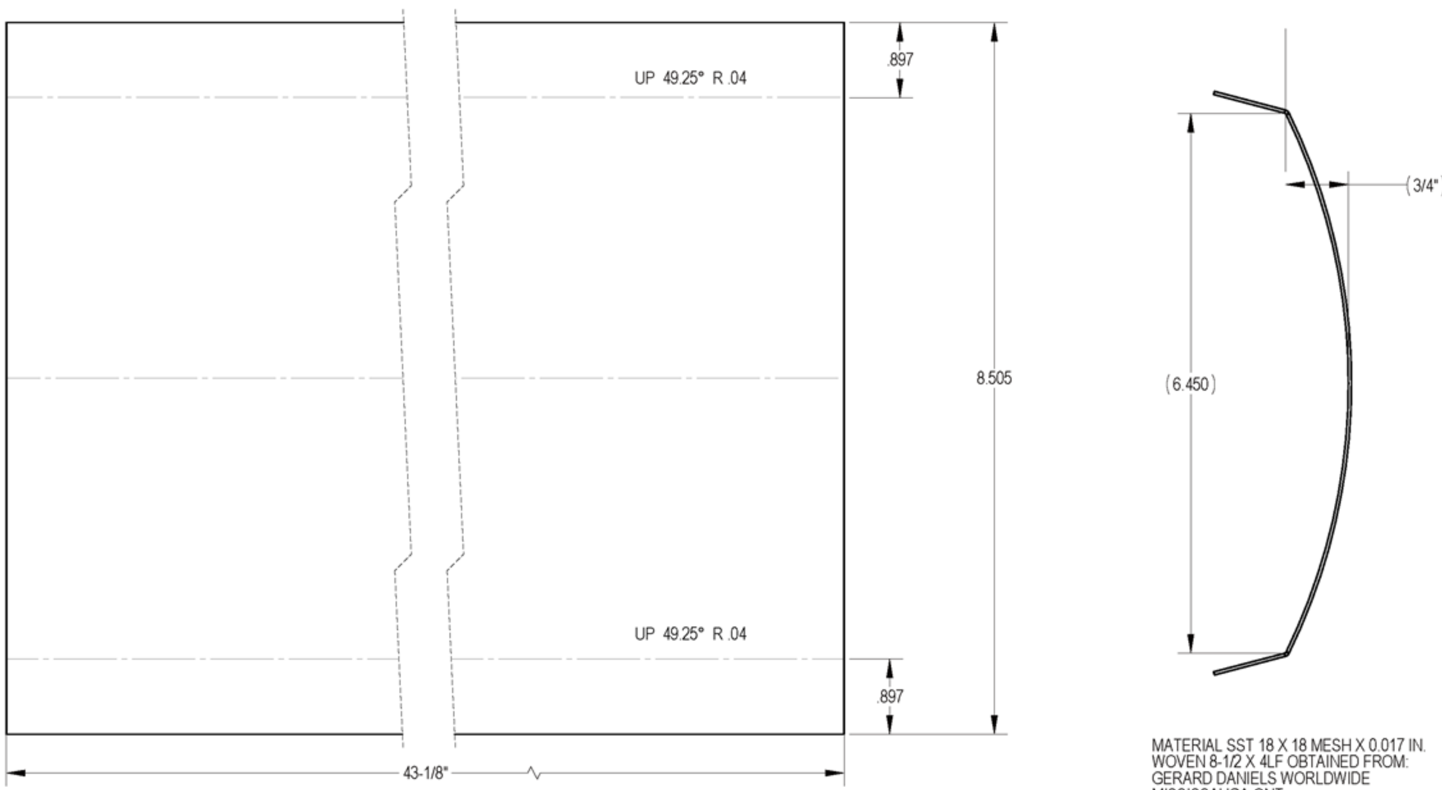


SECTION A-A

THIRD ANGLE PROJECTION	TITLE: TRAY ASSY, FIELD SAMPLING					Prairie Agricultural Machinery Institute P.O. Box 1150 Humboldt, SK PAMI
STD. UNITS INCHES STD. TOLERANCES:	DRAWN BY: AHW	CHECK BY: N/A	EST WEIGHT: 9.9 LB	SCALE: 1:1	PAGE: 1 OF 1	DWG SIZE: B
HOLES: +1/32",-0 FRACTIONS: ±1/16" X.XX: ±0.06" X.XXX: ±0.015" ANGLES: ±0.5°	DATE: 19-AUG-2014	MATERIAL:	DWG. #: A0514_Assy_Tray			REVISION: A

REV	DATE	DESCRIPTION	INITIAL
A	18-AUG-2014	AS BUILT	AHW

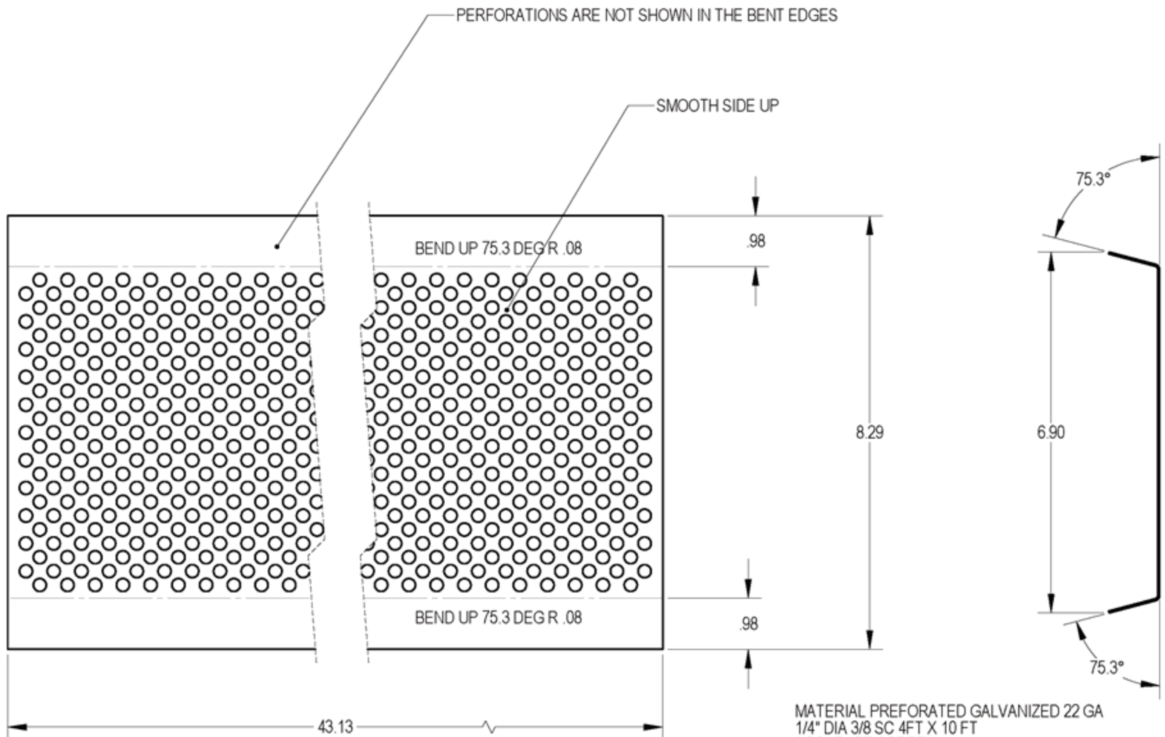
MAKE ONLY THE EDGE BENDS IN THE FLAT CONDITION.
THE LARGE ARC IS FORMED WHEN THIS SCREEN IS
INSTALLED IN THE NEXT ASSEMBLY



MATERIAL SST 18 X 18 MESH X 0.017 IN.
WOVEN 8-1/2 X 4LF OBTAINED FROM:
GERARD DANIELS WORLDWIDE
MISSISSAUGA ONT.
905-670-8558 LINDSAY HOUSTON

THIRD ANGLE PROJECTION				
STD. UNITS INCHES				
STD. TOLERANCES:				
HOLES: +1/32", -0	A	18-AUG-2014	AS BUILT	AHW
FRACTIONS: ±1/16" X.XX: ±0.06"	P01	07-AUG-2014	RELEASE FOR PROTOTYPE	NJG
X.XXX: ±0.015" ANGLES: ±0.5°	REV	DATE	DESCRIPTION	INITIAL

TITLE: Canola Keeper Screen		Prairie Agricultural Machinery Institute P.O. Box 1150 Humboldt, SK PAMI			
DRAWN BY: AHW	CHECK BY:	EST WEIGHT: 3.9 LB	SCALE: 1:1.25	PAGE: 1 OF 1	DWG SIZE: B
DATE: 17/Jul/2014	N/A				
MATERIAL: 18 X 18 MESH X 0.017"		DWG. #: A0514_Canola_Keeper			REVISION: A



MATERIAL PREFORATED GALVANIZED 22 GA
1/4" DIA 3/8 SC 4FT X 10 FT
ACCURATE SCREEN
CALGARY, ALBERTA
403-723-0323

THIRD ANGLE PROJECTION
STD. UNITS INCHES
STD. TOLERANCES:
HOLES: +1/32",-0
FRACTIONS: ±1/16"
X.XX: ±0.06"
X.XXX: ±0.015"
ANGLES: ±0.5°

REV	DATE	DESCRIPTION	INITIAL
A	18-AUG-2014	AS BUILT	AHW
P02	07-AUG-2014	Changed bends & bend locations to accommodate foam tape	NJG
P01	17-JULY-2014	RELEASE FOR WO_A0514_002	AHW

TITLE: MOUSE EXCLUDER

Prairie Agricultural Machinery Institute
P.O. Box 1150 Humboldt, SK
PAMI

DRAWN BY:	AHW	CHECK BY:	N/A	EST WEIGHT:	SCALE:	PAGE:	DWG SIZE:
DATE:	17-JULY-2014			2.8 LB	1:2	1 OF 1	B

MATERIAL: PERF GALV 22 GA 1/4" DIA

DWG. #: A0514_Mouse_Excluder

REVISION: A

Appendix B

Results and Analysis of Variance (ANOVA) Tables

F value in ANOVA for grain yield in 6 site-years of testing two cultivars (L130 and L140P and four harvest systems (swath. rigid header, extended knife header and draper header).

Source	IH14	SC14	IH15	SC15	IH16	SC16
Cultivar	134.4***	11.48*	14.84*	2.32	231.9***	14.9*
Header	9.11***	8.19***	5.07**	1.45	39.9***	1.47
C x H	7.17**	0.207	10.95***	3.21*	16.2***	3.66*

* significant, $p<0.05$

**highly significant, $p<0.01$

***very highly significant, $p<0.001$

F-value in ANOVA for environmental loss in 6 site-years of testing two cultivars (L130 and L140P). Environmental loss was collected prior to combining.

Site-year	F
IH14	114.56**
IH15	70.93***
IH16	170.96***
SC14	2.11
SC15	18.66***
SC16	63.71***

* significant, $p<0.05$

**highly significant, $p<0.01$

***very highly significant, $p<0.001$

F-values from ANOVA for oil content of canola seed in 6 site-years of testing two cultivars (L130 and L140P and four harvest systems (swath. rigid header, extended knife header and draper header).

	IH 2014	SC 2014	IH 2015	SC 2015	IH 2016	SC 2016
Cultivar	3.6	7.9	1.0	0.7	0.0	0.5
Header	1.2	16.9***	0.9	20.6***	2.9	1.3
C x H	0.7	5.7**	1.7	0.6	1.0	0.1

* significant, p<0.05

**highly significant, p<0.01

***very highly significant, p<0.001

F-values from ANOVA for canola seed size (TKW) in 6 site-years of testing two cultivars (L130 and L140P and four harvest systems (swath. rigid header, extended knife header and draper header).

	IH 2014	SC 2014	IH 2015	SC 2015	IH 2016	SC2016
Rep	18.9*	8.9	2.1	3.7	2.23	3.8
Cultivar	311.5***	508.0***	7.1	60.0**	0.78	35.9**
Header	2.0	6.2**	2.2	18.9***	5.77**	2.0
C x H	1.1	6.0**	1.0	0.6	0.81	0.2

* significant, p<0.05

**highly significant, p<0.01

***very highly significant, p<0.001

F-values from ANOVA for canola green seed % in 6 site-years of testing two cultivars (L130 and L140P and four harvest systems (swath. rigid header, extended knife header and draper header).

	IH 2014	SC 2014	IH 2015	SC 2015	IH 2016	SC 2016
Rep	0.96	1.20	0.31	0.84	0.41	0.73
Cultivar	0.95	4.67	0.03	29.18*	5.44	0.03
Header	1.91	4.81*	1.34	7.01**	5.50**	3.80**
C x H	2.25	1.06	0.26	1.95	2.29	0.31

* significant, p<0.05

**highly significant, p<0.01

F-values from ANOVA for header loss in 5 site-years of testing two cultivars (L130 and L140P and three harvest systems (rigid header, extended knife header and draper header).

	IH14	SC14	IH15	SC15	IH16
Cultivar	61.06**	8.44*	63.08***	22.4***	15.25***
Header	14.2***	1.66	25.28***	5.8***	41.24***
Position	2.56	1.99	41.55***	10.15***	19.62***
C x H	32.2***	32.44***	7.25***	1.33	4.97**
C x P	0.8	0.82	0.76	2.78***	1.08
H x P	3.78***	0.77	4.14***	0.95	5.72***
C x H xP	1.65	1.27	0.95	1.34	0.67

Probability of a greater F-value for integrated header loss in segments and total losses for three headers over five site-years. The total represents both ends of the header in the crop. Right and left totals are the calculated total with one end in the crop.

Source	Total	Left total	Right total	Right end	Middle	Centre	Left end
Site	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.003	< 0.0001	0.001
Crop	< 0.0001	< 0.0001	< 0.0001	0.165	0.003	0.000	0.000
Header	< 0.0001	< 0.0001	< 0.0001	0.001	0.000	< 0.0001	0.197
S x C	0.349	0.377	0.508	0.222	0.238	0.540	0.019
S x H	< 0.0001	< 0.0001	< 0.0001	0.055	0.040	< 0.0001	0.001
C x H	0.020	0.028	0.074	0.768	0.378	0.008	0.007
S x C x H	0.486	0.415	0.329	0.549	0.512	0.458	0.425
Levene's test	0.122	0.320	0.272	0.083	0.321	0.002	0.000

ANAOVA table for Auger speed by table position experiment, Humboldt 2016.

Source	DF	Sum of squares	Mean squares	F	Pr > F
Rep	5	12.0	2.4	6.1	< 0.0001
Auger speed	1	2.3	2.3	6.0	0.015
Table	1	82.9	82.9	211.2	< 0.0001
Position	10	84.7	8.5	21.6	< 0.0001
A x T	1	1.2	1.2	3.1	0.079
A x P	10	1.3	0.1	0.3	0.976
T x P	10	35.1	3.5	8.9	< 0.0001
A x T x P	10	2.8	0.3	0.7	0.720
Error	215	84.3	0.4		

ANOVA table for divider by reel position experiment, Humboldt 2016

Source	DF	Sum of squares	Mean squares	F	Pr > F
Divider	1	12.00	12.00	40.34	**< 0.0001**
Reel	1	8.08	8.08	27.16	**< 0.0001**
location	26	112.33	4.32	14.52	**< 0.0001**
Divider*Reel	1	0.42	0.42	1.43	0.233
Divider*location	24	19.06	0.79	2.67	**< 0.0001**
Reel*location	25	4.25	0.17	0.57	0.953
Divider*Reel*location	22	4.79	0.22	0.73	0.806
Error	359	106.83	0.30		

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