Project No. R0917
Date: July 29, 2021
Humboldt, Saskatchewan

Final Report

Research Report

Effect of Cereal Crop Residue Distribution on the Following Year's Canola Emergence and Yield

For:
Saskatchewan Canola Development Commission (SaskCanola)
Saskatchewan Wheat Development Commission (SaskWheat)

PAMI
Innovative Solutions for Agriculture and Beyond

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Effect of Cereal Crop Residue Distribution on the Following Year's Canola Emergence and Yield

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- Redekop Manufacturing

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1. Executive Summary

Residue management is a significant challenge for producers on a year-to-year basis. Uneven and poorly distributed residue can lead to many complications for the producer including uneven seed depth the following spring, blocked drill openers, and uneven plant stands and emergence. Wheat crops have a tendency to produce large amounts of residue. Because Western Canadian producers often seasonally rotate wheat and canola crops, it is important to have a better understanding of how wheat crop residue management can affect the emergence of canola in a rotation. The Canola Council of Canada highlights how wheat can produce high amounts of residue per acre, which may negatively affect canola seed placement and establishment (Canola Council of Canada, 2020). Canola seed is typically seeded shallower than cereals and pulses, at a recommended target depth 1/2 to 1 in. (12 to 25 mm; Canola Council of Canada, 2020).

While there is a vast knowledge base in literature on the agronomic impacts of crop residues (specifically as it pertains to soil nutrients and organic matter content), one important gap that has been identified is in the area concerning the impacts of residue management or distribution. The conditions specific to canola performance, as well as regional considerations, contribute even further to this gap.

The objective of the research conducted for this project was to analyze canola emergence and yield based on different wheat residue harvest management strategies. The sites were replicated over three years, each at different locations, to account for different soil properties, climatic variation, and management. The treatment comparisons included assessing two different combine choppers ("good" distribution vs "poor" distribution) as well as three post-harvest treatment areas (a check with no further management, a heavy-harrowed treatment, and a tilled treatment).

The results from the three trial years indicate that implementing a management strategy to level wheat residue provides little effect on the following year's canola emergence and yield. Using an aftermarket chopper to shred the residue into finer pieces (to provide a more even distribution width) resulted in a more even field finish than the poorly set original equipment manufacturer (OEM) chopper; however, it also left a clumping effect of larger residue pieces behind the combine. When comparing the canola emergence between the two choppers as well as the post-harvest treatments, the results varied by year with very few significant differences. The yield data collected across the treatments also showed few significant differences throughout the three years.

Though there were few significant differences found across the data, implementing a residue management strategy on farm can provide some benefits. These studies were conducted at different sites each year, and the results may have differed if they were conducted on the same site over a number of years. Future work may include repeating the methods used in this project on one site to assess yearly differences with poor residue management.

2. Project Description

This project evaluated three years of data beginning in the fall of 2017 and ending in the fall of 2020. The Year 1 (2018) site was located near Delmas, Saskatchewan (RM 438); Year 2 (2019) was located near Saint Front, Saskatchewan (RM 368); and the final site in Year 3 (2020) was located near Nipawin, Saskatchewan (RM 457). Each site year started with a wheat harvest comparing two residue distribution strategies (good versus poor distribution), followed by post-harvest treatments of heavy harrowing as well as tillage with a high-speed disc. These two post-harvest treatments were replicated four times in the field. During the following spring, the sites were planted to canola and managed to match the producer's other canola crops. Plant emergence as well as yield data for each treatment were measured in the fall.

To represent accurate on-farm management techniques, a full quarter section of land was utilized each of the three years to accommodate use of real-world equipment and management techniques. By incorporating the field-scale component into the project, the results can more accurately be related to producer practices for their farming operations. Four replications of each treatment were used to mitigate potential spatial variability differences (soil zones, climatic differences, etc.) as well as past management practices.

The experimental design included four repetitions of the six treatments per year over the three years, resulting in 24 plots per site, and the residue of two harvest methods were compared. These included original equipment manufacturer (OEM) and aftermarket (AFT) choppers, where the OEM straw chopper was configured to represent "poor" (uneven) residue distribution.

In-field measurements were then conducted on the canola and included soil moisture measurements, soil temperature, plant emergence counts, leaf staging, weed counts, as well as end-of-season yield.

Project management and coordination was performed by the Prairie Agricultural Machinery Institute (PAMI) in Humboldt, Saskatchewan. Degelman Industries provided and conducted the post-harvest treatments with the heavy harrow and high-speed disk throughout the project. Redekop Manufacturing assisted with cooperator selection and aftermarket (AFT) chopper features for Year 1. Pioneer Hi-Bred provided canola seed for the Year 1 trial, and Nutrien Delmas branch provided the preburn and in-crop glyphosate and surfactant for Year 1.

3. Procedure and Methodology

This project analyzed data from three field sites over three growing seasons in 2018, 2019, and 2020. The field sites used were near Delmas, Saskatchewan (Year 1), Saint Front, Saskatchewan (Year 2), and Nipawin, Saskatchewan (Year 3). The sites were predominately managed by the producer, with some assistance provided by PAMI during the harvest and post-harvest treatments.

3.1 Field Sites and Treatments

The following subsections describe each site and the experimental treatment designs used. At each site, four replicates of each treatment were used with partial randomization between repetitions. The site layouts were designed to optimize field operations and minimize logistical hurdles when using field-scale equipment for individual treatments as the plots were only a couple acres in size.

3.1.1 Delmas, Saskatchewan, Year 1

Field site selection in Year 1 was focused on securing a high-yielding, heavy-straw wheat field for harvest. A cooperator was found by Delmas, Saskatchewan, that was interested in the project, willing to help execute treatments, and had a combine suitable for one of the harvesting residue management treatments. The wheat variety grown was Faller, a common variety in the Canadian Northern Hard Red (CNHR) class.

Experimental treatments were designed to facilitate use of the full-scale equipment. Treatment layout for the 2017/2018 site at Delmas is shown in **Figure 1**. Two harvest treatments focused on residue distribution at the time of harvest. An OEM straw chopper was compared to an AFT chopper quantifying differences in terms of both evenness of residue distribution across cut width and sizing of residue. These configurations were targeted and selected to achieve “poor” (uneven) and “good” (even) residue distribution, respectively.

Post-harvest, three sub-treatments were laid out inside each harvest treatment block. These treatments were created to represent common field operations performed after harvest to manage residue prior to seeding the following year. The treatments were a check treatment (no post-harvest residue management), a heavy harrow, and a high-speed disk. **Figure 1** shows how these post-harvest operations were overlaid with the two harvest-residue treatments.

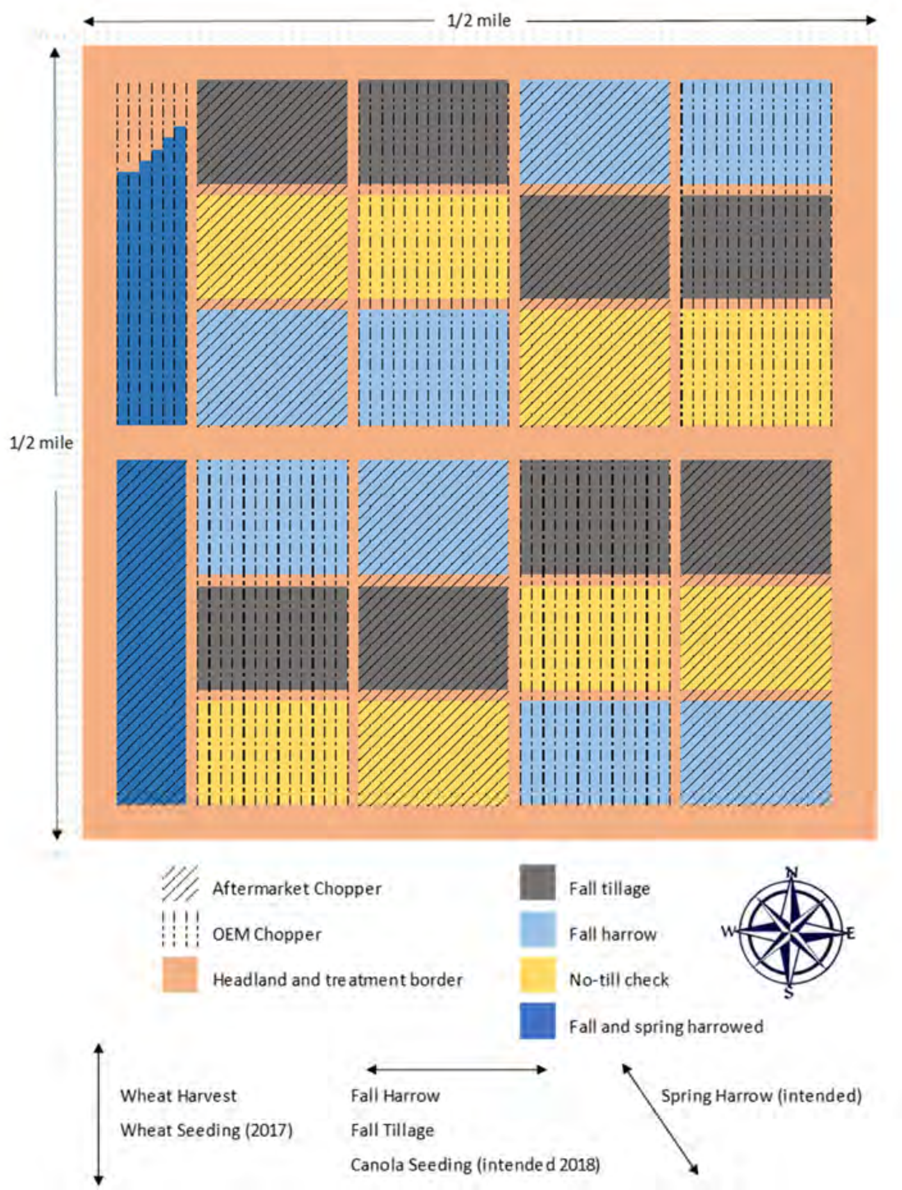

Figure 1. 2017/2018 treatment layout at Delmas, Saskatchewan.

In addition to the replicated treatments, an additional non-replicated treatment was included for the Year 1. This treatment consisted of both a spring and fall harrow application over the same area (referred to as double harrow) throughout this report.

3.1.2 Saint Front, Saskatchewan, Year 2

The field site for Trial Year 2 was again selected based on similar criteria as the first year. A field was selected near Saint Front, Saskatchewan, with the CDC Landmark VB wheat variety. The field was surrounded by trees, and the topography was reasonably even with some small inclines and low spots. The north-east and south-west corners of the field were not included in the trial, as the treeline intruded into the field in these areas. **Figure 2** shows the treatment map for this location, with both harvest and post-harvest treatment areas indicated. Due to field constraints, not all treatments were of equal size or as evenly arranged as the Year 1 site. However, four replications of each treatment were arranged with the post-harvest sub-treatments conducted within those with larger harvest distribution. No additional area was set aside from the double harrow treatment for Year 2 of the field trial. Additionally, two machines were used to represent the OEM chopper, the second (referred in this report at OEM 2) was only used for four treatment areas at the south end of the field.

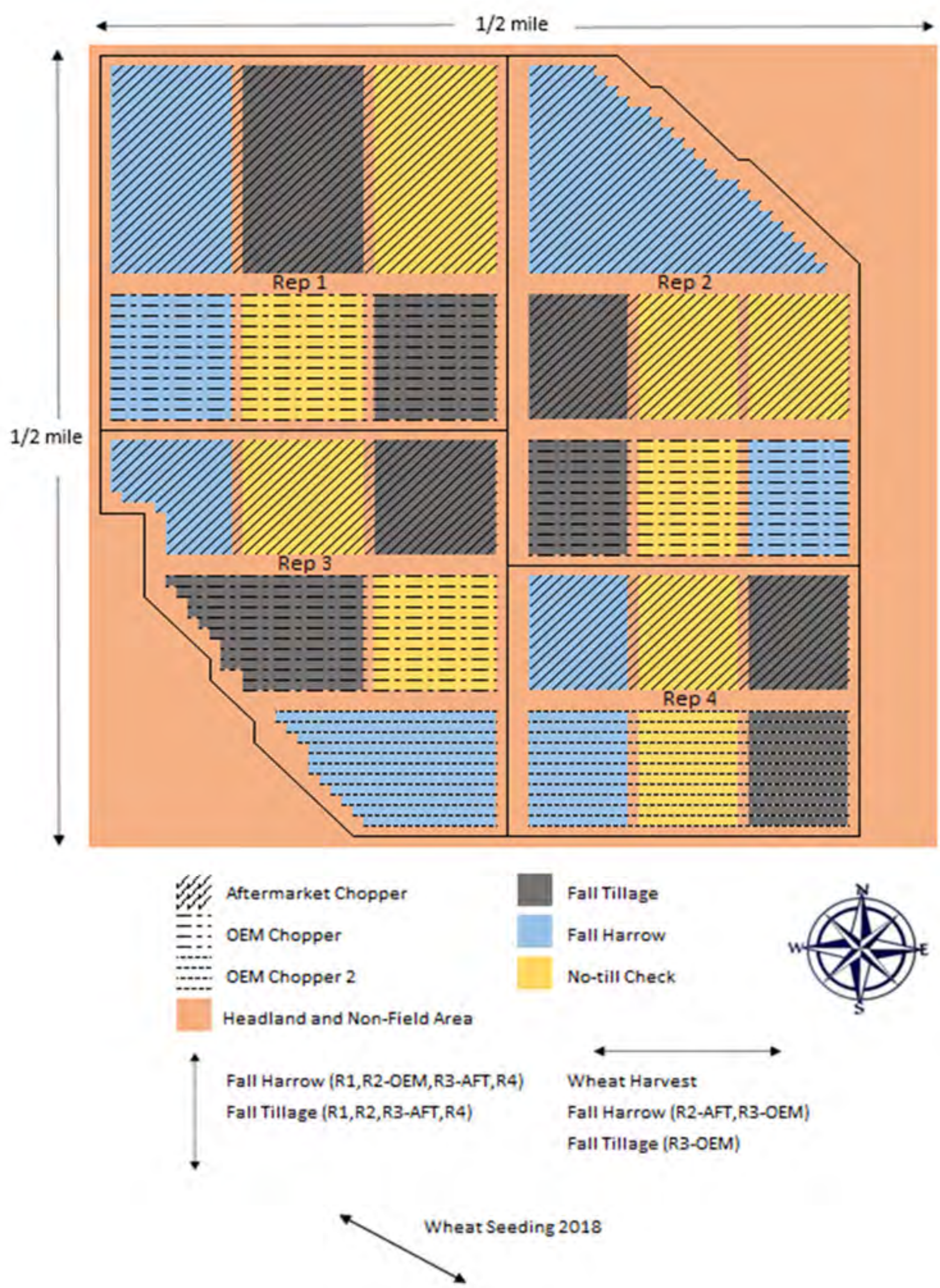

Figure 2. 2018/2019 treatment layout at Saint Front, Saskatchewan, Year 2.

3.1.3 Nipawin, Saskatchewan Year 3

The field site for Trial Year 3 was selected to accommodate similar criteria as the first two years. A field was selected near Nipawin, Saskatchewan, with the wheat variety AAC Brandon seeded in 2019. This field has relatively flat topography with a water run along the southwest side. Due to spring 2019 drill issues, a large section on the south end of the field had to be eliminated from the treatment area. Due to these field constraints, the treatment sizes were smaller than the previous two years; however, they were equally arranged, as shown in **Figure 3**. This figure shows the treatment map for this location with both harvest and post-harvest treatment areas outlined.

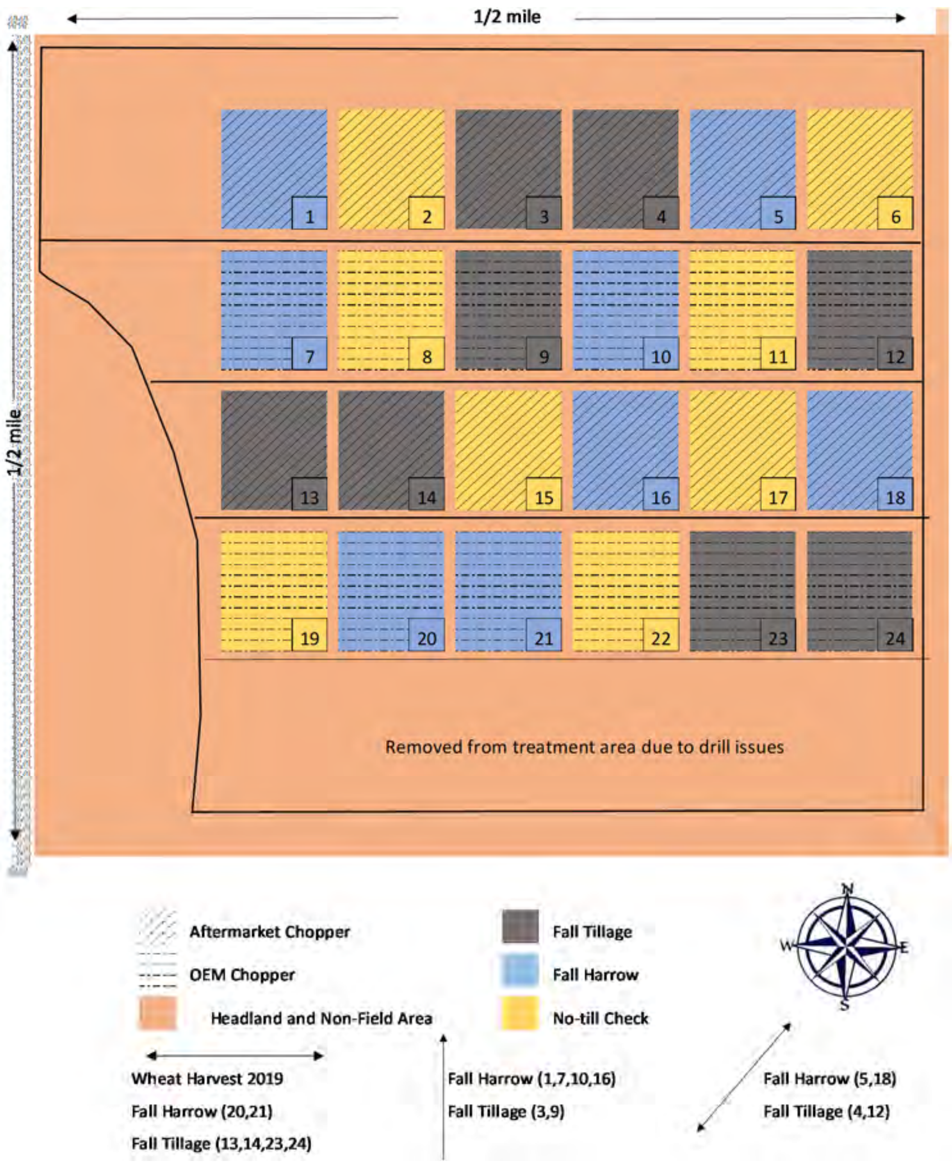

Figure 3. 2019/2020 treatment layout at Nipawin, Saskatchewan, Year 3.

3.2 Wheat Harvest

At each site, six experimental treatments were considered:

1. OEM combine distribution system set poorly (representing poor residue distribution).
2. AFT combine residue management system (representing good residue distribution).
3. Poor OEM distribution followed by post-harvest harrowing.
4. Good AFT distribution followed by post-harvest harrowing.
5. Poor OEM distribution followed by post-harvest high-speed disking.
6. Good AFT distribution followed by post-harvest high-speed disking.

The beginning of each trial year began with the producer harvesting a high-yield wheat crop with both the OEM and AFT chopper experimental treatments.

Year 1 started in the fall of 2017 at the Delmas site, using the wheat variety Faller. The harvest was completed September 30, 2017, using two separate combines. Both combines were used to harvest the respective treatments on the same day and were similar, although not identical, machines.

Weather conditions were ideal at the time of harvest. The temperature was approximately 68.0°F (20.0°C) in the afternoon with a breeze from the south east at 12.0 mph (19.3 km/h). Both the grain and the straw were dry during harvest and were suitable for chopping and spreading.

Wheat harvest for the Year 2 site occurred on October 18, 2018, near Saint Front. This site contained the wheat variety CDC Landmark VB. Three separate combines were used (two represented the OEM, and one represented the AFT).

Weather conditions were good at the time of harvest. The temperature high for the day was approximately 68.0°F (20.0°C) with west-north-west winds of 20.0 mph (32.2 km/h) gusting to 30 mph (48.3 km/h). Both the grain and straw were dry and in good condition for chopping and spreading.

Year 3 of the project began in fall 2019 with the wheat harvest at a field near Nipawin seeded to AAC Brandon wheat. The OEM chopper machine harvested on September 23, 2019, and the AFT chopper machine harvested on September 26, 2019. Two different combines were used for the harvest.

Due to adverse weather conditions, it took four days to complete the Year 3 wheat harvest. On September 23, the weather was favourable for the OEM machine to harvest a good portion of the crop. The daytime high was 68.4°F (20.2°C) with an average north-east wind speed of 10.7 mph (17.3 km/h). September 25 had a delayed start due to equipment issues with the AFT combine. The temperature high was 60.6°F (15.9°C) with a 12.2 mph (19.7km/h) average north-north-east wind speed. Once combining started, only a small portion of the field was harvested before rain caused operations to halt, with approximately 0.07 in. (1.78 mm) total falling (starting around 7:00 p.m.). The remaining portions of the AFT machine sections of the field were harvested on September 26 with a temperature high of 49.6°F (9.80°C) and north-north-east winds at an average of 7.50 mph (12.0 km/h). Once this portion was completed, the OEM was brought back in the field to clean up any remaining areas. On the first two days, the grain and straw were dry and in good condition for chopping and spreading; however, third-day data may differ due to rains from the previous night.

A brief summary of the machines used for the wheat harvest in each year is shown in **Table 1**.

Table 1. Summary of harvest equipment used over the three testing years.

Year 1	**OEM Chopper Machine** •Case IH 8230 •Case factory internal chopper -Stationary knife bank was removed •Case Factory Spreader •40’ Macdon FD75 header	**AFT Machine** •Case IH 9120 with factory internal chopper •Redekop MAV external chopper/spreader -With stationary knife bank engaged -64 chopper blades – significant wear visible •40’ Macdon FD75 header	
Year 2	**OEM Chopper Machine (1)** •Case IH 8120 •Case factory internal chopper -with stationary knife bank engaged •Case factory spreader •36’ (14.6 m) Honeybee header	**OEM Chopper Machine (2)** •Case IH 8230 •Case Magnacut chopper -with stationary knife bank engaged •Case factory spreader •36’ (14.6 m) Honeybee header	**AFT Machine** •Case IH 8240 •Case factory internal chopper •Redekop MAV 4 row external chopper/spreader -with stationary knife bank engaged •35’ (14.2 m) Macdon header
Year 3	**OEM Chopper Machine** •Case IH 8120 •Case factory internal chopper -Disengaged stationary knife bank for treatment area •Case factory spreader •35’ (10.7 m) D60-S MacDon straight-cut header	**AFT Machine** •Case IH 9240 •8-row extra fine cut chopper Stationary knife engaged (set at 1.5) -No internal chopper •Redekop MAV external chopper/spreader •35’ (10.7 m) D60-S MacDon straight-cut header	

During the wheat harvest, residue distribution was recorded. For Year 1, only the residue distribution by weight was recorded. It was noted that the approximate size of the OEM residue was 5.20 in. long, and the AFT residue was approximately 2.75 in. long. The finer-sized particles were not factored into these measurements. For Year 2 and 3, the residue distribution as well as residue fraction size was recorded. These samples were collected using a 48.0 in. (122 cm) wide by 16.0 in. (40.6 cm) deep area. The samples were taken across the entire header width to represent one full pass, resulting in a 10-pan width for Year 1, and a 9-pan width for Years 2 and 3. The pan used was for area reference to gather the material and can be seen in **Figure 4**. A forage separator was used to separate the residue by size to determine coarse, middle, and fine fraction categories by percentage for each chopper. The fractionation method for these samples can be found in Appendix A.

Figure 4. Residue collection pan.

Further data recorded during the wheat harvest included crop height, total above ground biomass, field average grain yield, chopper distribution and sizing, as well as material other than grain (MOG) calculation. This MOG-to-grain ratio gives a quick indication of the amount of residue relative to grain affecting both combine performance and capacity, and subsequently residue processing capacity relative to cleaning capacity.

3.3 Post-Harvest Treatments

The post-harvest residue management treatments occurred after the wheat harvest the same fall. Each year, the sites had three post-harvest treatments: a harrowing treatment, a high-speed disk (vertical tillage) treatment, and a check treatment (no post-harvest residue management). A summary of the equipment is displayed in **Table 2**.

Table 2. Summary of the post-harvest treatments over the three years.

	Harrow Equipment	**Tillage Equipment**
Year 1	100 ft Degelman Strawmaster Pro heavy harrow	40 ft Degelman Pro-Till high-speed disc
Year 2	80 ft Degelman Strawmaster Pro heavy harrow	26 ft Degelman Pro-Till high-speed disc
Year 3	80 ft Degelman Strawmaster Pro heavy harrow	26 ft Degelman Pro-Till high-speed disc

To optimize field efficiency, the site layouts were designed using partial randomization. A summary if all treatments and replications can be seen in **Table 3**.

Table 3. Number of reps for each treatment combination, by year.

Treatment	OEM	AFT	OEM2*
Year 1			
Check	4	4	
Harrow	4	4	
Heavy Harrow	1	1	
Tilled	4	4	
Year 2			
Check	3	4	1
Harrow	2	4	2
Tilled	3	4	1
Year 3			
Check	4	4	
Harrow	4	4	
Tilled	4	4	

*OEM2 represents the year 2 second OEM combine used for the chopper treatments

3.3.1 Delmas, Saskatchewan, Year 1

The post-harvest residue management treatments for Year 1 occurred on October 18, 2017. Straw and residue material were sufficiently dry at that time. The air temperature was cool, with a temperature high of 50.0°F (10.0°C) and a wind speed of 30.0 to 40.0 mph (48.3 to 63.4 km/h) for the duration of the field events.

Harrowing was conducted using a 100-ft model Degelman Strawmaster Pro heavy harrow (**Figure 5**). This harrow featured five rows of 0.630 in x 26.0 in (1.59 cm x 66.0 cm) harrow tines and hydraulic down pressure capability. Ground speed during operation was approximately 10.0 mph (16.1 km/h). The size of the harrow relative to the overall plot size negated the ability to operate the harrow on an angle relative to the seed rows, so a perpendicular direction was selected.

Figure 5. Degelman Strawmaster Pro heavy harrow.

Straw was effectively spread during harrowing, and some chaff was also moved resulting in an even field finish (**Figure 6**). Ideally, the harrowing would have been performed on a day with warmer air temperatures to help aid in residue movement and breakdown.

Figure 6. Field finish after heavy harrow.

High-speed disking was carried out with a Degelman Pro-Till high-speed disc. The unit was a 40-ft model equipped with notched front discs, smooth rear discs, and rubber packers (**Figure 7**). Ground speed during operation was approximately 10.0 mph (16.1 km/h).

Figure 7. Degelman Pro-Till high-speed disc.

The high-speed disc left a reasonably even field finish (**Figure 8**). Some of the straw and residue was incorporated while some was left on the surface. A depth of 3.00 in. (7.62 cm) was targeted with the tillage. As with the harrowing, the discing was done travelling in an eastward and westward direction, perpendicular to the wheat seed rows.

Figure 8. Field finish after high-speed disc.

3.3.2 Saint Front, Saskatchewan, Year 2

Year 2 post-harvest treatments were conducted on October 23, 2018. Straw and wheat residue were dry and in good condition for the post-harvest operations. The temperature high was 59.0°F (15.0°C) with a south-east wind of 15.0 to 20.0 mph (24.1 to 32.2 km/h).

The heavy harrow treatments were executed using an 80-ft model Degelman Strawmaster Pro harrow, featuring four rows of 0.630 in x 26.0 in (1.59 cm x 66.0 cm) harrow tines and hydraulic down pressure. Ground speed during operation was approximately 10.0 mph (16.1 km/h). Harrow direction varied depending on treatment, as the direction was chosen to make the harrow operation as efficient as possible. No noticeable difference was observed in the field finish with change of direction.

For all the harrow treatments, the combination of overall straw yield and size distribution of the straw resulted in less bunching of the straw than is typically seen under high straw yields. Straw was sufficiently spread, and the harrow tines did disturb some soil during operation. Overall field finish was even following the harrow operation (**Figure 9**).

Figure 9. Field finish in heavy harrow treatment.

Like the previous year, a Degelman Pro-Till was used for the high-speed disc treatments. For Year 2 of the project, a 26-ft model was used (**Figure 10**). As with the harrow, multiple directions were used depending on operational aspects. No noticeable differences were found with the high-speed disc between working directions. Ground speed during operation was approximately 10.0 mph (16.1 km/h).

Figure 10. Degelman Pro Till high-speed disc.

The high-speed disc left a blackened field finish (**Figure 11**). A considerable amount of residue was incorporated during the operation, with some remaining on the field surface. Tillage depth was approximately 3.00 in (7.62 cm).

Figure 11. Field finish in high-speed disc treatment.

3.3.3 Nipawin, Saskatchewan, Year 3

The post-harvest treatments for Year 3 were conducted on October 17, 2019, starting at 9:45 a.m., and both the harrow and tillage treatments were finished by approximately 1:00 p.m. The temperature high was 46.0°F (7.78°C) with wind from the north-east at an average speed of 7.00 to 10.0 mph (11.3 to 16.1 km/h). It should be noted that due to snow on October 16, field conditions started as wet. To make the operation as efficient as possible, treatments were conducted in various directions to decrease turnaround times and reduce unnecessary lifting and lowering of the equipment. As in previous years, the heavy harrow treatments were performed using an 80-ft model Degelman Strawmaster Pro harrow, featuring four rows of 0.630 in x 26.0 in (1.59 cm x 66.0 cm) harrow tines and hydraulic down pressure.

The heavy harrow treatments aided in distributing the straw more evenly and in separating the residue clumps so that they were more spread out, which provided a more even field cover. This treatment also slightly disturbed the soil, which helped to incorporate some of the finer residue. **Figure 12** shows the overall field finish after the harrow operation.

Figure 12. Field post heavy-harrow treatment on the right side of the image, untreated on the left.

As in the previous years, Degelman supplied a Pro-Till to demonstrate the high-speed disc treatments. The Pro-Till incorporated the residue to a depth of approximately 3.00 in (7.62 cm), which replicated the target depth of the previous trial years. The residue in the tillage treatments was incorporated, darkening the surface (**Figure 13**). The tillage treatments incorporated a large amount of residue; however, the longer pieces of straw were still evident on the surface.

Figure 13. Tilled treatment with the high-speed disc (left) compared to untreated (right).

3.4 Canola Seeding

Canola seeding took place the spring following the wheat harvest treatments. The fields were seeded using the producer's equipment with typical seeding and fertilization methods and rates, and the in-field management was also the responsibility of the producer (herbicides, fungicides, etc.). At the time of seeding, general observations were noted including seeding conditions, seed depth and field finish.

3.4.1 Delmas, Saskatchewan, Year 1

In Year 1, seeding took place on May 28, 2018. Canola seed for the entire quarter was donated by Pioneer Hi-Bred. The 45CM36 variety was used, which features Pioneer's HarvestMax straight-cut technology. A 12.0-in (30.5-cm) spaced SeedMaster air drill was used to seed the field using the producer's typical seeding and fertilizer rates. The entire quarter was seeded in the east/west direction, perpendicular to both the previous years' seeding and combining direction. Depth was targeted at approximately 1.00 in (2.54 cm); however, actual depth varied slightly by treatment.

General observations were noted between the treatments at time of seeding. In the harrow treatment, there was a noticeable difference in field finish between the OEM and AFT choppers. Both had seed depths of around 1.00 in. (2.54 cm), with the OEM chopper trending slightly deeper. The OEM chopper had more bunches of straw, although this was still minimal in a field context. Even with the AFT chopper, one could still distinguish between heavier and lighter residue areas of the field (**Figure 14**).


Figure 14. Field finish in harrow treatment.

In the tilled treatments, the seeding depth also trended slightly deeper in the OEM chopper, with the aftermarket remaining close to 1.00 in. (2.54 cm) or shallower in the centre wheel tracks. In the OEM portion, the chaff rows were still visible after seeding. For both tilled treatments, most of the straw present on the surface was found between the furrows after seeding, although the OEM chopper did have marginally more straw found in the furrow where the higher straw amounts were present (**Figure 15**).


Figure 15. Field finish in tilled treatment.

The check treatment saw the widest spread in field finish post-seeding between the two choppers. The check OEM treatment had a high quantity of bunches with much of them covering multiple seed rows (**Figure 16**). In the lighter-residue areas between chaff rows, the OEM treatment was noticeably better. The finish in the aftermarket treatment was significantly better than the OEM and was just slightly behind the harrow treatments in finish (**Figure 17**). Even in the aftermarket treatment, the chaff rows had a visibly worse finish than the area between them.

Figure 16. Straw bunches covering multiple seed rows.

Figure 17. Field finish in check treatment.

Soil temperature and moisture were taken during seeding or during the first plant count at a limited number of locations for each treatment. The soil temperature was taken at seed depth, and the moisture measurements were done by collecting soil samples and weighing, drying and re-weighing for moisture percent.

3.4.2 Saint Front, Saskatchewan, Year 2

Year 2 seeding took place on May 21, 2019, with the L233P canola variety. The entire quarter was seeded in the north/south direction. A 9.80 in. (24.9 cm) row spacing was used, and the field was seeded using a Bourgault 3320 Series Paralink Hoe Drill with a depth targeted at about 0.750 in. (1.91 cm); however, this varied slightly with the different treatments. General observations were made at the time of seeding, and the pictures presented in this section were taken at the time of the first count (eight to nine days after seeding), and show little to no emergence.

Visual differences in the residue distribution were noted after the treatments. Both of the OEM treatment areas had some residue bunches; however, the harrow did aid in spreading these. The OEM treatments also had larger straw pieces, which tended to clump in larger groups. The seed depth was near to what the cooperator had targeted, ranging from 0.750 to 1.00 in. (1.91 to 2.54 cm). The comparison of the AFT chopper and OEM choppers after seeding are shown in **Figure 18.**

Figure 18. Field after harrow treatment; AFT treatment (left) and OEM treatment (right).

In the tilled treatments, the majority of the residue was incorporated into the ground, which left the surface blackened by the turned soil. As in Year 1, the seed in the tilled treatments tended to be sown a bit deeper compared to the other treatments, around 1.00 to 1.25 in. (2.54 to 3.18 cm). Though the residue was incorporated, there was still a considerable difference in the straw clumps left behind the OEM chopper treatments. The larger residue pieces from the OEM chopper did not incorporate into the soil as well as the smaller, finer pieces that were characteristic of the AFT chopper. A visual comparison of the two treatments is presented in **Figure 19.**

Figure 19. Tilled treatment field finish; AFT (left) and OEM (right).

The check treatments showed the biggest visual difference in residue between the OEM and AFT chopper. There were notable differences in the residue clumps left by the OEM chopper, which had longer straw pieces and more clumping in certain areas. The variation in seed depth was also most notable with the OEM treatment. In the chaff row, the seed was shallowly sown; in some areas, only 0.500 in. (1.27 cm) deep due to the heavy residue, whereas outside of the chaff row, it was slightly deeper at approximately 0.750 to 1.00 in. (1.91 to 2.54 cm). **Figure 21** shows the difference in field finish after the two chopper treatments.

Figure 20. Field finish in check treatment; AFT treatment (left), OEM treatment (right).

3.4.3 Nipawin, Saskatchewan, Year 3

Year 3 seeding took place on May 20, 2020, with the variety L233P. The quarter section was seeded in an east/west direction with a 10.0 in. (25.4 cm) row spacing by a Seed Hawk air drill, targeting a speed of 4.00 mph (6.44 km/h) and used the producer's typical seeding and fertilizer rates. The seeding depth was targeted between 0.500 in. (1.27 cm) and 0.750 in. (1.91 cm); however, similar to the previous years, the depth varied slightly by treatment.

Like the previous years, the field finish for the OEM chopper left clumps of residue that were more concentrated in the area directly behind the combine. This was more noticeable in the check treatments where no harrow or tillage post-harvest treatment was applied. It must be noted that due to some spring flooding, some residue floated and deposited in larger clumped areas around the field. Effort was made to manually level some of these larger clumps prior to seeding.

The harrow was able to level the remaining residue clumps from the OEM treatments, as well as any clumps left in the AFT treatments. It also helped incorporate some of the residue into the soil, aiding in a smoother field finish. The field finish in the harrowed treatments can be seen in **Figure 21.** Visually, there were more areas of heavy residue clumps in the OEM versus the AFT treatment areas.

Figure 21. Harrow treatment field finish; AFT treatment (left) and OEM treatment (right).

The field finish for the tillage treatments was similar to previous years, with more residue incorporated into the soil compared to the harrow and check treatments (**Figure 22**). There was also a blackening effect of the soil, which is a typical of a tillage treatment. It was noted that in the OEM treatments, the longer pieces of residue did not incorporate as well as some of the finer pieces, resulting in a clumping effect in some areas.

Figure 22. Tillage treatment field finish; AFT treatment (left) and OEM treatment (right).

The greatest visual differences noted in the treatments was the check treatments that did not receive a harrow or tillage post-harvest treatment. The AFT chopper successfully spread the residue across the header width, whereas the OEM chopper left large piles of residue directly behind the middle of the header, resulting in very little residue distribution to the outer edges of the header. These comparisons can be seen in **Figure 23.**

Figure 23. Check treatment field finish; AFT treatment (left) and OEM treatment (right).

3.5 In-Season Measurements

PAMI performed plant emergence counts, soil temperature measurements, and general observations at the time of seeding. The in-season emergence counts were conducted twice: the first count was targeted at first emergence, and the second at approximately two weeks after the first count. This timing varied with the year and the growing conditions. At each sample location, plant counts were taken in the “chaff row”, referring to the area directly behind last year’s combine and outside the chaff row. This outside count was therefore taken half in each of two adjacent combine passes, making it the furthest away from the centre of the two chaff rows. The intention with using this procedure was to better capture any effect on germination from the two-combine spread quality treatments. During these field visits, plant counts, growth stage, weed counts, soil temperature and general field conditions were observed. Soil moisture samples for Year 1 were taken at the time of seeding, and Years 2 and 3 moisture samples were taken at the time of the first emergence counts. Each soil sample for the soil moisture measurements were done by taking a 0.00 to 6.00 in. core (0.00 to 15.2 cm).

3.5.1 Delmas, Saskatchewan, Year 1

Year 1 plant counts were taken at two timings: 9 and 21 days after seeding (DAS). Counts were taken at two separate locations within each treatment and were marked and sampled from the same spot for both timings. The counts were taken in the chaff row and outside the chaff row (6.10 m, [20.0 ft] away from the first count).

The counting procedure consisted of measuring out 10.0 ft (3.05 m) parallel to the seed rows. One row on either side of the tape measure was then counted, making for a total 20.0 ft² (1.86 m^2) sampling area for each individual count, given the 12.0 in. (30.5 cm) row spacing (**Figure 24**).

Figure 24. Canola plant count.

3.5.2 Saint Front, Saskatchewan, Year 2

Plant counts for Year 2 of the project were difficult to time due to growing season challenges and an extremely dry spring. The plant counts were taken at two timings, plant count 1 at 8 to 9 DAS and plant count 2 at 31 DAS. Plant emergence counts, stage, weed pressure, and soil temperature at seed depth were all recorded during both counts, and all varied across the treatments. Soil moisture was also recorded by taking soil samples during the first plant count, which were then dried to determine the percentage of moisture.

The plant count process followed the same method as that used in Year 1. One of the rows was in the “chaff row” (area behind last year’s combine) and the other row was “outside” of the chaff row. This second row was taken the furthest point from the center of the chaff row. Both headers used in the fall were 36.0 ft (11.0 m) wide; therefore, the second row was measured approximately 18.0 ft (5.49 m) away from the middle of the chaff row. The plants were then counted on either side of the tape. **Figure 25** shows a difference in plant population variations that was documented in field.

Figure 25. Comparison of plant emergence and growth stages across the field.

3.5.3 Nipawin, Saskatchewan, Year 3

Following the same procedure as the previous years, Year 3 plant counts were taken at 13/14 and 33 DAS. Plant emergence and leaf stage, soil temperature, and weed counts were collected at each treatment location, and replicated twice per location. Similar to the first two years of the project, the same method was followed to conduct the plant counts. Each plant emerged in the row was counted along a 10.0-ft (3.05-m) long tape measure parallel to the seed rows, on both side of the tape.

One plant count was conducted in the chaff row, and the other outside the chaff row. As the header width was 35.0 ft (10.7 m), the measurement outside the chaff row was taken at approximately half that width (17.5 ft [5.30 m]) away from the middle of the chaff row. Like previous years, this allowed measurements to be taken directly behind the middle of the header as well as the farthest point it would spread, without crossing to over to the next pass. **Figure 26** displays an example of field variation across the chopper treatments.

Figure 26. Plant emergence in AFT check treatment (left), and OEM check treatment (right) during plant count 2.

3.6 Canola Harvest

Each treatment area was harvested individually by premeasuring plot length and the number of passes per plot. The plot area was determined by attempting to make as many passes as possible while leaving at least a full pass width on the ends as buffer zones where two treatments may have potentially overlapped. The grain weight was recorded for each treatment, and a grain sample was taken for each treatment to be able to test seed moisture content. This moisture content was used to determine moisture corrected yield per treatment as well as determine if there were moisture percentage differences across the treatments. For the first year, the producers weigh wagon was used to gather the grain weight whereas the second and third year, PAMI's grain truck equipped with a weigh scale was used.

3.6.1 Delmas, Saskatchewan, Year 1

Canola harvest for Year 1 took place on October 28, 2018. Canola was combined in a north/south direction, perpendicular to the seeding direction, to facilitate picking up lodged crop. Treatment blocks were cut out beforehand, and four 40.0 ft (12.2 m) header passes were used for weighing on each individual treatment (each about 300 ft [91.0 m] long). The resulting average sample size was approximately 1.20 ac (0.49 ha). The same combine was used for all treatments. Samples were weighed using the cooperator's weigh wagon, equipped with load cells and a digital readout. The wagon was emptied prior to filling every time to ensure consistency in the readings. Samples were taken from each treatment during filling and were later used to measure moisture content. No dockage measurements were taken for any samples, though dockage levels appeared to be both low and consistent for all treatments.

The only significant difference in the procedure was the harvesting of the double harrow treatments. To utilize their longer length, only two combine passes were completed in these, compared to four used on the rest of the treatments. This may have had a significant effect on the yield of these treatments; the combine was in a “full” state for a longer period of time, and the combine’s shoe would have only emptied twice during each sample (as opposed to four times during the rest of the treatments). In addition, there was only one repetition of each of the double harrow treatments, making it hard to conclusively establish whether the sample size actually impacted yield.

3.6.2 Saint Front, Saskatchewan, Year 2

Year 2 canola harvest took place on October 23, 2019. All treatments were harvested in the north/south direction with the same combine. The treatment blocks were cut out beforehand to facilitate the harvest, leaving at least four combine passes. The combine header was 35.0 ft (10.7 m), set at a 33.5 ft (10.2 m) target. The total length of each treatment, as well as total passes done, was dependent on the size of the plot. The maximum number of passes from each treatment was targeted to obtain accurate data. The average plot length was approximately 335 ft (102 m), and the passes ranged from five to seven passes. However, there were two outliers: one plot that had four passes, and one that had nine passes. The differences in plot size reflect the treatment layout across the field, and effort was made to harvest the most of each plot as possible to get the average. The resulting average sample size was approximately 1.5 ac (0.61 ha). The samples were weighed using PAMI’s scale and grain truck. Each sample was recorded as it was loaded into the truck.

3.6.3 Nipawin, Saskatchewan, Year 3

The Trial Year 3 canola harvest began on September 16, 2020 around 2:00 pm. The plots throughout the field varied significantly with water runs and weed patches, which may have altered the yield results. The header width on the combine used was set at 34.0 ft (10.36 m). The average plot size varied slightly across treatment, but was still considered to be fairly consistent. The average plot length was approximately 247 ft (75.3 m), and five passes per treatment were completed, resulting in an average plot size of 0.96 ac (0.39 ha). As done in Year 2, the grain was weighed using PAMI’s scale and grain truck, with each sample being recorded as it was loaded into the truck.

4. Results

This section contains the quantitative findings of this project from all growing seasons.

4.1 Wheat Harvest Residue Distribution

The data collected during the wheat harvest included crop height, total above-ground biomass, field-average grain yield, and chopper/spreader distribution and sizing. For Years 2 and 3 only, samples were taken to determine the fractional distribution, whereas in year one, only a limited amount of average residue size was recorded.

4.1.1 Delmas, Saskatchewan, Year 1

The average above-ground biomass in the wheat, from a limited number of sampling points, was 14,500 lb/ac (16.2 t/ha). Of this, the total straw yield averaged 7,110 lb/ac (7.97 t/ha), and un-threshed heads averaged 7,350 lb/ac (8.23 t/ha).

Crop height ranged from 33.0 to 41.0 in. (83.8 to 104 cm) when standing erect, with an average height of approximately 38.0 in. (96.5 cm). However, due to the lodged nature of the crop, there was a significant area of the field where actual crop height at harvest was approximately 12.0 in. (30.5 cm) (**Figure 27**).

Figure 27. Lodged crop was typical in the majority of the field.

Field residue distribution was collected by using loss trays across the width of the header after it was spread. Ten sample collections were obtained across this width, with the 16.0 in. x 48.0 in. (40.6 cm x 121.9 cm) pan encapsulating the entire cut width. Samples were collected after the wheat crop was harvested on both sides adjacent to the residue collection strip, so any residue distribution wider than the cut width (40.0 ft [12.0 m]) was still accounted for in an overall field context.

All distribution samples were collected in the same field orientation (west to east), so that environmental conditions such as wind were insignificant on the distribution pattern. Combine direction was not accounted for when collecting samples. This means that any tendency for the combine to distribute straw to one side or the other may have been offset over the replications. The distribution range from the centre of the combine to the edges would not be affected by this aspect.

Field residue distribution results from the 2017 harvest are shown in **Figure 28**. The aftermarket chopper resulted in a more uniform residue spread across the header width than the OEM chopper. The combine-specific chopper attributes should be noted along with this data as it does not represent the two different systems running in their optimal state. However, this data does highlight the importance of the harvest operation when managing residue distribution.

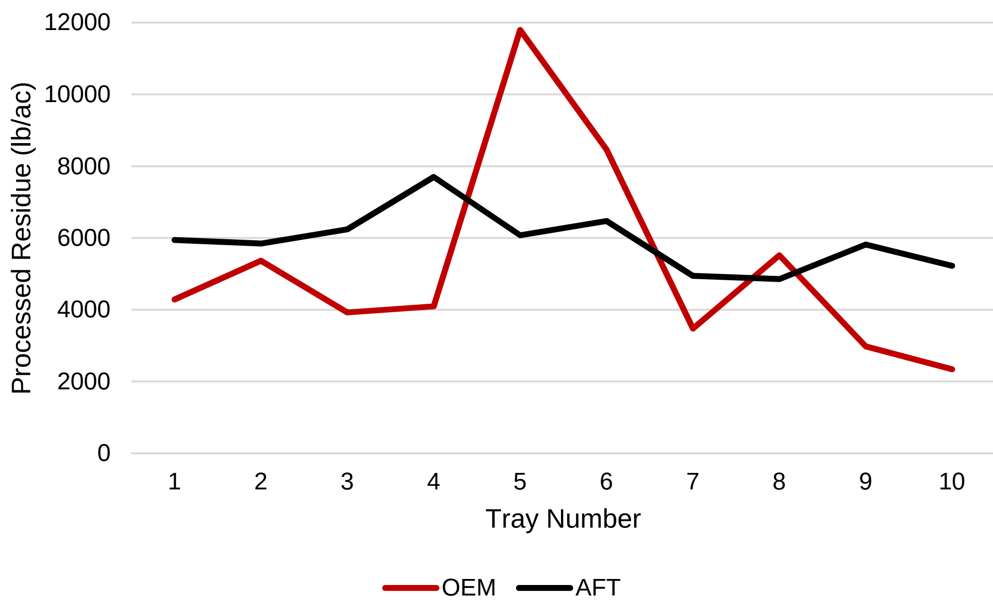

Figure 28. Comparison of residue distribution between OEM and aftermarket choppers.

Average MOG, or residue processed by the combine, was 5,230 lb/ac (5.86 t/ha) for the OEM chopper and 5,910 lb/ac (6.62 t/ha) for the AFT chopper from the measured distribution area. This MOG value consists of mostly chaff and straw but does not include actual clean grain or any fine dust particles. Grain yield for the field was approximately 70.0 bu/ac (4.71 t/ha) and represents field average, as it was not recorded in specific locations. Based on this approximate yield and the MOG values, the calculated MOG-to-grain ratio (MOG/grain) varied between 0.91 and 1.91 for the sampled data, with an average of 1.33.

Field observations coincided with the measured results. The OEM chopper exhibited uneven distribution across the cut width partly due to the chopper knife-bank disengagement which left longer straw pieces. The OEM chopper left a ridge of straw in the centre of the distribution path and did not distribute to the outer edges of the cut width (**Figure 29**). The AFT chopper left a more even field finish (**Figure 30**).

Figure 29. Residue distribution from OEM chopper showing uneven distribution.

Figure 30. Residue distribution from aftermarket chopper.

A rough average residue size was recorded when sampling distribution. The OEM chopper averaged straw particles that were 5.20 in. (13.2 cm) long, while the aftermarket chopper averaged 2.75 in. (6.99 cm). Chaff and extremely small particles were not factored into these measurements.

A stubble length of 5.00 in. (12.7 cm) remained in most places after the cut for both headers. There was no significant difference in cut height between headers. The lodged nature of the crop meant that both headers had to be set low to the ground to pick up all the wheat heads.

Fuel use was recorded from harvest in 2017 via the in-cab display. The 9120 Case with the aftermarket chopper averaged approximately 24 U.S. gallons per hour (gph; 91 litres per hour [Lph]), while the 8230 Case with factory chopper averaged close to 18 gph (68 Lph). It is important to note that the two combines in operation were of a different model and class, which may affect their normal fuel usage, even if equipped with similar choppers. Actual ground speed was similar between both machines during harvest, with the 9120 averaging slightly (0.20 to 0.32 mph [0.30 to 0.48 km/h]) faster in high biomass areas.

4.1.2 Saint Front, Saskatchewan, Year 2

For Year 2, two different combines were used to represent the OEM chopper. The aftermarket portion was completed with one combine, which was outfitted similar to the combine used in the previous trial year.

From a limited number of 1 ft^2 (0.09 m^2) samples, the average total above-ground biomass in wheat was 9,700 lb/ac (10.9 t/ha). Straw yield averaged 4,330 lb/ac (4.85 t/ha), while unthreshed heads made up the remaining 5,380 lb/ac (6.03 t/ha). These measurements were made at the time of harvest, and represent the material at its field moisture content.

The grain yield of the entire field was determined to be an average of about 60 bu/ac (4.03 t/ha). The MOG values were determined using this average yield value and processed residue measurements gathered, following the same methodology as Year 1. As in Year 1, the MOG value represents the chaff and straw, but not clean grain or any fine dust. The averaged MOG values were; 2,320 lb/ac (2.59 t/ha) for the OEM, 2,860 lb/ac (3.21 t/ha) for the OEM 2 and 2,620 lb/ac (2.93 t/ha) for the AFT. The calculated MOG-to-grain ratio (MOG/grain) varied between 0.41 and 0.96, averaging at 0.70 for the sampled data.

Crop height varied from 29.0 to 31.0 in. (73.6 to 78.7 cm) with the entire field standing well. The crop looked to be fairly consistent throughout the field, and a saline area along the eastern edge of the field was not included in the trial to increase the uniformity of the trial area.

Seven total residue distribution samples were taken, with at least one behind each of the three combines present in the field. Three replicates were taken from the OEM combine and AFT combine, while only one sample was taken for the OEM 2 machine. Samples were collected using a similar procedure as the previous year: collecting above-ground loose residue over a 48.0 in. (122 cm) wide by 16.0 in. (40.6 cm) deep area. Nine separate trays were taken across each header width, always in the same order, with the combine facing the same direction to capture any and all differences in residue distribution. Tray 1 always represented the left-hand side of the combine, when looking at it from the rear, and Tray 9 represented the right-hand side.

Residue distribution was quantified in two ways: First, the weight of the cumulative residue in each sample tray was weighed and recorded to capture the distribution across the combine's width. Second, size segregation was completed on each sample using the particle separator to separate the samples into three fractions based on approximate particle size. These fractions roughly equated to particles longer than 3.0 in. (8.0 cm), 0.5 to 3 in. (1.3 to 8.0 cm), and less than 0.5 in. (1.3 cm) lengths. These fractional proportions could then be compared across the cut width of the combine and between choppers. Of particular interest for this project is the top, coarse fraction of residue. This fraction is indicative of material that may cause issues during seeding or other operations.

Looking at the general distribution across the header width, a trend similar to that observed in the previous year emerged, with the AFT chopper having a more uniform distribution across the header width compared to the OEM chopper. Due to the wind direction and strength, no chopper had full coverage over the entire cut width, as shown in **Figure 31**. The OEM 2 chopper, which showed improved uniformity over the OEM chopper, was only used in one of the four in-field replicates so that any potential effects on the following canola crop can be accounted for.

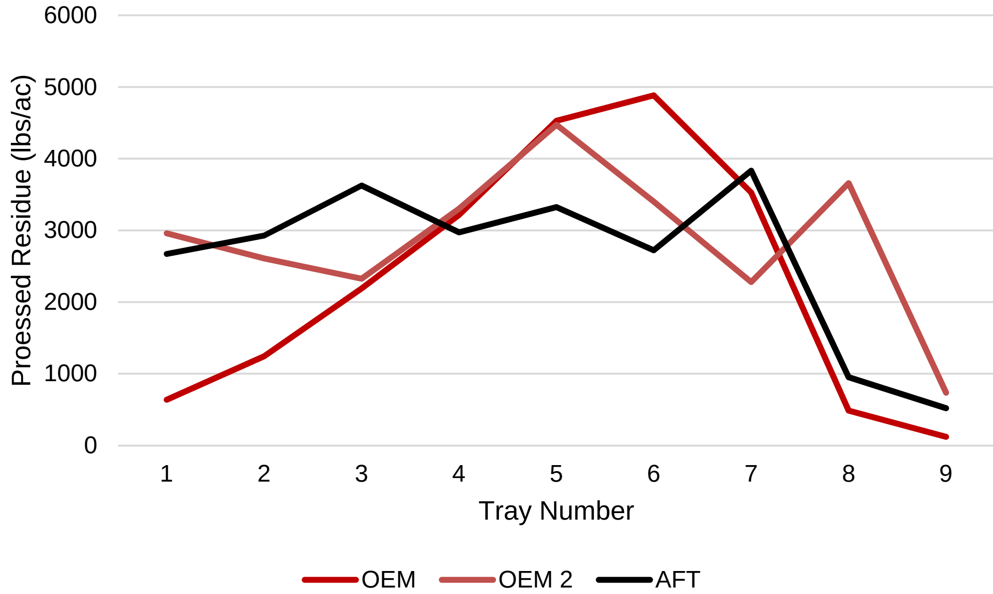

Figure 31. Comparison of residue distribution between OEM and aftermarket choppers.

In addition to distribution across the cut width, the fractioning of residue from each sample offered an improved look into the difference in performance between choppers and their potential effects on future crops. Averaging across the header width, the OEM chopper had 34.7% of its residue in the top, coarse fraction, followed by the OEM 2 at 30.4%, and the aftermarket at 15.7% (**Figure 32**). These numbers are important since this fraction contains the long straw that has the potential to cause trash clearance issues during seeding and can result in uneven or poor seed placement and germination. From the Year 2 results, it is apparent that the aftermarket chopper leaves, on average, finer residue than the other two choppers tested.

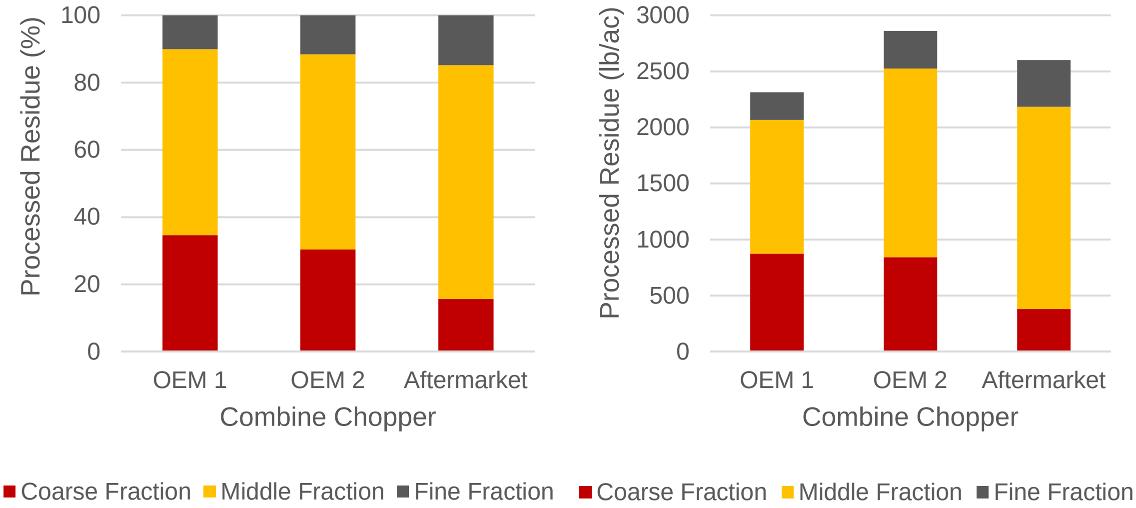

Figure 32. Comparison of average residue distribution fractions between OEM and aftermarket choppers as a percentage (left) and density (right).

Looking at the fractional division of residue across the cut width for each chopper provides further insight into the overall impact that the chopper has on managing residue. **Figure 33**, **Figure 34**, and **Figure 35** show the fractioning of residue across the header width for the OEM 1, OEM 2, and aftermarket choppers, respectively. The left graph for each figure highlights the fractions as a percentage of the total material in each tray while the right graph shows the fractions as the actual residue amount in pounds per acre.

As **Figure 33** shows, the percentage of residue in each fraction can be fairly consistent across the cut width, but due to the overall distribution of residue being focused in the centre trays, the overall residue amount in the coarse fraction is substantially higher in the centre trays than the outside ones. Alternatively, for the OEM 2 and aftermarket choppers, there is more consistency across the header width in the coarse fraction, due in part to the residue distribution being more even for each of these.

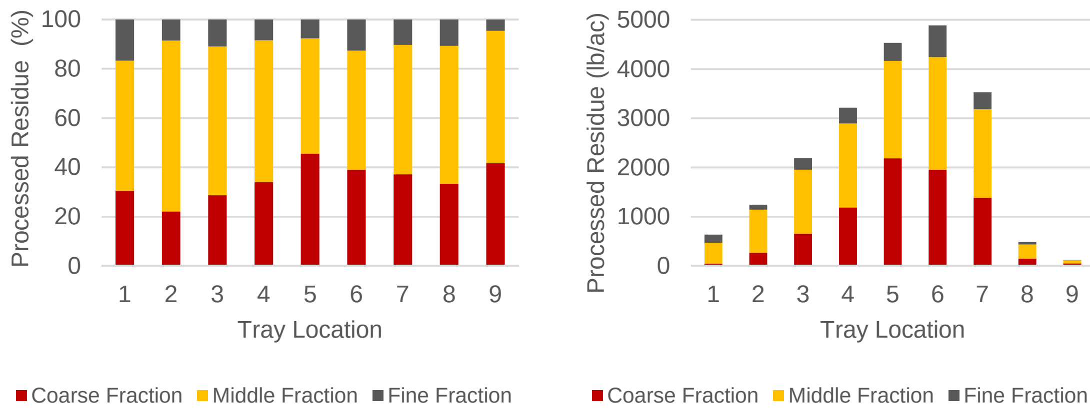

Figure 33. Fractional residue distribution of OEM 1 chopper by percentage (left) and density (right).

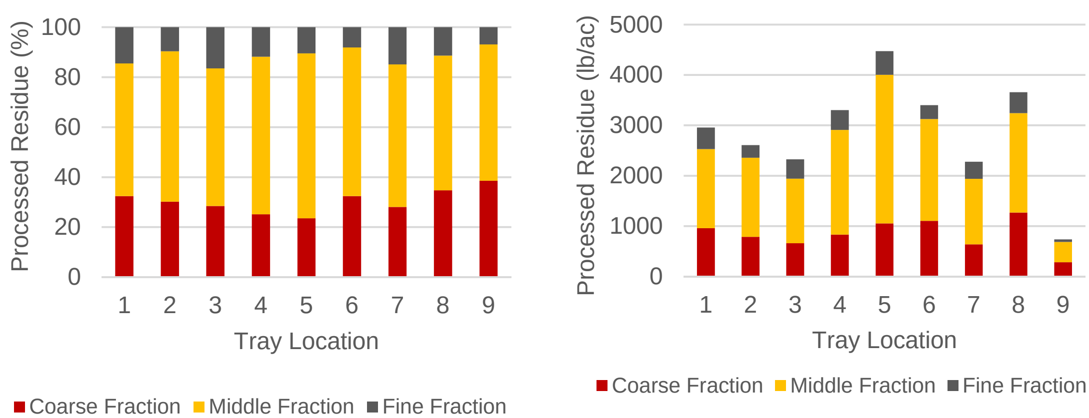

Figure 34. Fractional residue distribution of OEM 2 chopper by percentage (left) and density (right).

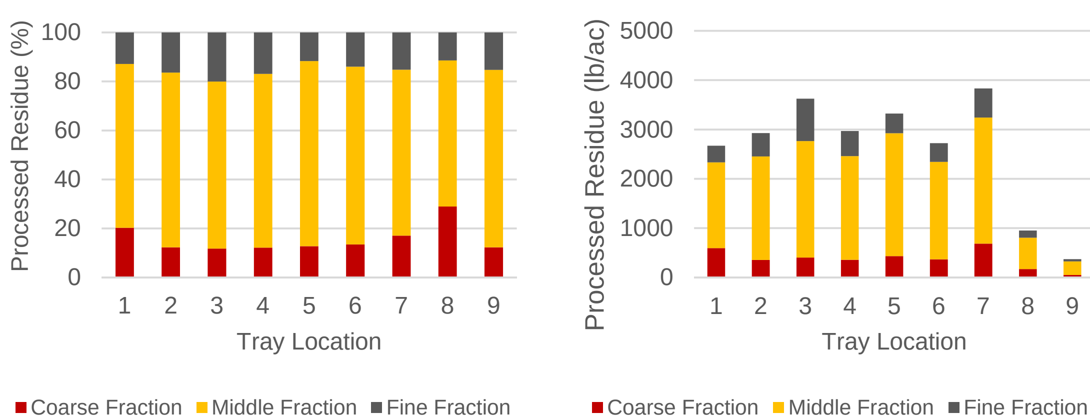

Figure 35. Fractional residue distribution of aftermarket chopper by percentage (left) and density (right).

4.1.3 Nipawin, Saskatchewan, Year 3

Two different combines were used, one to represent the OEM chopper and one equipped with an AFT Redekop chopper. This follows the methods used in the first two years of the project.

The data recorded during the wheat harvest again, as in the previous test years, included both pre-harvest plant height and post-harvest stubble height, above-ground biomass, grain yield, and combine chopper residue distribution and size.

Using the same methodology as Trial Year 2, a 1 ft^2 (0.09 m^2) sample area was used to determine the total above-ground biomass in the wheat. This was calculated to show that there was 10,900 lb/ac (12.2 t/ha). The straw yield averaged 4,370 lb/ac (4.90 t/ha), and lastly the unthreshed heads account for the remaining 6,550 lb/ac (7.35 t/ha). Again, as in Trial Year 2, these measurements were taken at the time of harvest, and, therefore, represent the material at its field moisture content.

The crop height measurement was recorded from the full height of the plants when stood upright manually (as some heads were lodged over). These heights varied from 32.0 to 34.0 in. (81.0 to 86.0 cm) when manually stood upright, and 27.0 to 30.0 in. (69.0 to 76.0 cm) without manual intervention. As a whole, the entire field was standing well and there was minimal lodging in the test area.

The average field grain yield was 69.0 bu/ac (4.64 t/ha). The MOG value for the OEM chopper averaged at 6,200 lb/ac (6.95 t/ha), and 6,430 lb/ac (7.21 t/ha) for the AFT chopper. Like the previous years, this value consists of mostly chaff and straw, not the actual clean grain. Using the approximate grain yield, the MOG/grain ratio was calculated to vary between 1.08 and 1.49, averaging at 1.31.

Residue distribution samples were taken from a total of four locations, representing two replications of each chopper. The same method as Year 1 and Year 2 was used to collect the samples. Above-ground loose residue was collected over a 48.0 in. (122 cm) wide by 16.0 in. (41.0 cm) deep area, represented by using a tray with these measurements. The tray was replicated nine times across the header width, to account for the full 35.0 ft (10.7 m) cutting width.

These residue samples were gathered and then dried to eliminate any moisture due to the wet conditions during harvest. Once dried, the individual samples were weighed to determine how the residue was distributed across the header width. The samples were then put through a forage separator to determine particle size to separate the residue into fractions. Four total trays were used to determine particle size, but due to the two top trays (the largest particle measurement sizes) being very similar, these results were combined to represent one sample size. This resulted in three size categories to be analyzed. Some rough average measurements were completed to determined the three fraction sizes to include: particles > 2.50 in. (6.40 cm) that represented the “coarse fraction”, particles 1/2 in. to 2.50 in. (1.30 to 6.40 cm) that represented the “middle fraction”, and particles less than 0.50 in. (1.30 cm) that represented the “fine fraction”.

Similar to the first two years of the project, the residue distribution shows more of a uniform trend from the AFT chopper compared to the OEM chopper (**Figure 36**). The OEM chopper had more residue in the area that would have been directly behind the chopper, in the chaff row. The samples represented in the results were collected on the second day of harvest (September 25). The sample trays were always recorded with tray 1 being the furthest north, and tray 2 being the furthest south. It should be noted that across all three days of harvest, the wind was from a north-north-east direction, and could account for the residue trending more to the right of the chart.

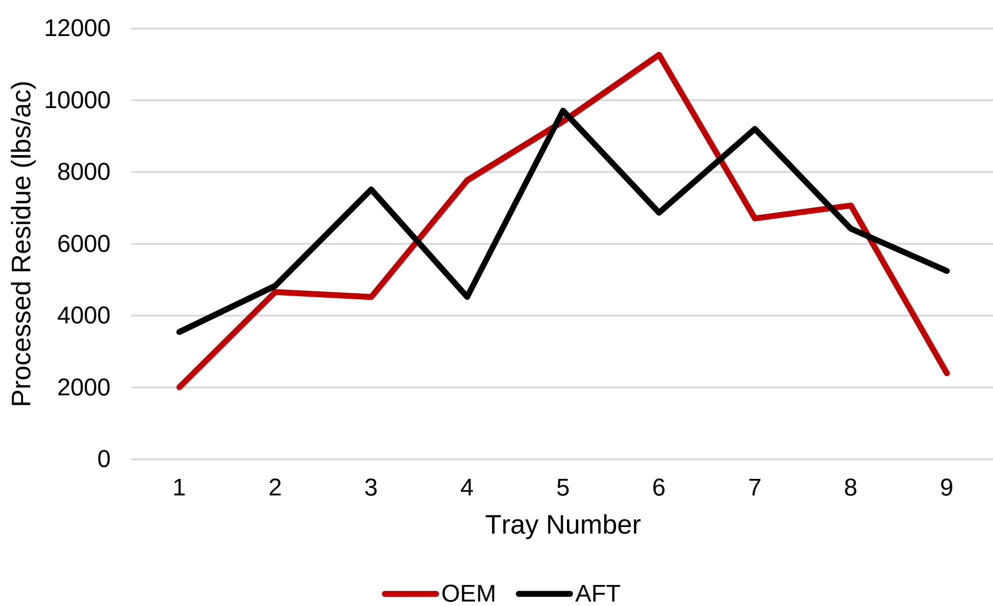

Figure 36. Comparison of residue distribution between OEM and AFT choppers.

The fractioning of the residue is an important component of this project, as it compares residue size across both headers. The OEM chopper had 19.1% of its residue in the top, coarse fraction, whereas the aftermarket had 15.6%. Following the same trend as Trial Year 1, this shows that there was a larger amount of the coarse material from the OEM chopper. This coarse material is what can cause issues during seeding. **Figure 37** displays the residue fractions that were processed by both the OEM and AFT choppers.

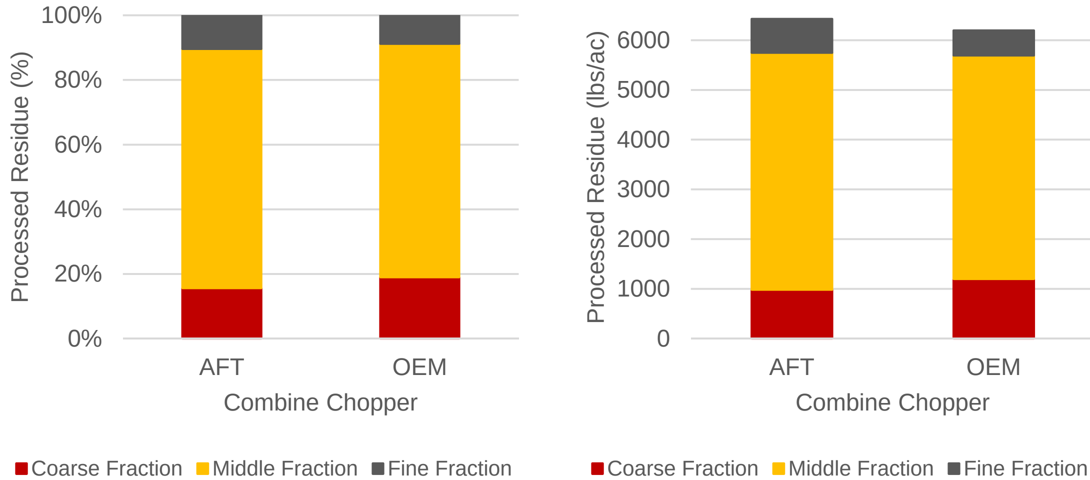

Figure 37. Comparison of the average residue distribution fractions between OEM and AFT choppers as a percentage (left) and density (right).

The fractional division across the header width is also a very important component to analyze, as this demonstrates how the residue was spread behind the combine and the fractional size differences across the spread. **Figure 38** and **Figure 39** show the fraction percentages of the residue across each header width for both the OEM chopper and AFT chopper, respectively. The graph on the left demonstrates the processed residue as a fractional percentage, which seems consistent, while the graph on the right shows the amount of residue per tray in pounds as well as the fractional differences by tray.

As displayed in **Figure 38**, the OEM chopper showed consistent fractioning across the header width; however, the actual amount of residue varied greatly. Trays 4 to 6 in particular had the highest residue amount from the OEM chopper, which demonstrates how the residue distribution was concentrated directly behind the chopper then trailed off on both outside edges of the total width.

Figure 39 shows a more even pattern of the residue distribution across the header width from the AFT chopper. Though there are clear differences in amount of residue processed across the header width with the AFT chopper, there is a more even spread with the AFT chopper than the OEM.

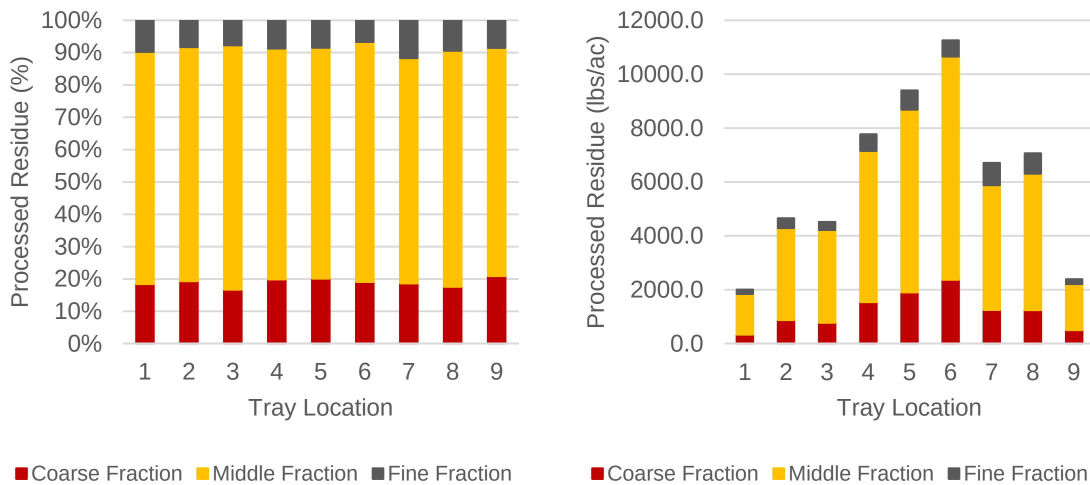

Figure 38. Fractional residue distribution of OEM chopper by percentage (left) and density (right).

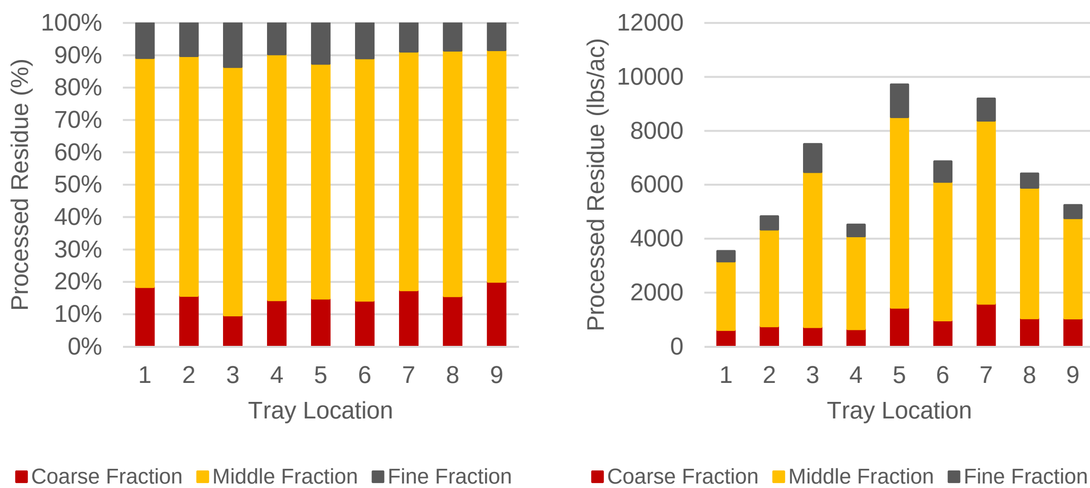

Figure 39. Fractional residue distribution of AFT chopper by percentage (left) and density (right).

4.2 In-Season Measurements

Spring plant count results were analyzed using an ANOVA at a 90% confidence level, and a Tukey Pairwise Comparison test was also used to indicate if there were any significant differences in the tests. As previously indicated, counts were done at two distinct locations for each sample; in the chaff row, directly behind the combine, and outside, referring to the outside of the header pass. During plant counts, soil temperature was also taken approximately at seed depth in the seed furrow at both timings.

In an attempt to limit potential variability caused by uneven distribution across the air drills' width, count locations were selected to be from the same side of the air drill for each count. However, samples from multiple rows were taken, so there is still potential for row-to-row variability to have affected the overall plant count. However, this is considered in the overall sampling error.

Error! Reference source not found. displays the formula used to calculate the plant counts.

Eq [1] contains the plant count formula using the metre stick method **(The Canola Council of Canada, 2020)**.

$$Plants/m^2 = \frac{plants\ per\ meter\ of\ row * 100}{row\ spacing(cm)} \qquad \text{Eq [1]}$$

4.2.1 Canola Emergence

The canola emergence field counts were taken based around when the crop emerged. Because of different field conditions, these timings varied during the three years. The counts were recorded and the results are presented below. The ANOVA analysis details for all treatments by year can be found in **Appendix B**.

Delmas, Saskatchewan, Year 1:

Across all sampling data, the emergence in the chaff row was statistically lower than the emergence in the area outside on both count timings. At nine DAS, the average plant count/ft^2 in the chaff row (1.62) trailed the 2.19 plants/ft^2 found outside the chaff row. At 21 DAS, the chaff row averaged 5.16 plants/ft^2, while outside had 5.84 plants/ft^2. Although these differences are not far apart, they are statistically different, and show an inherent impact on plant count based on location in the combine cut width, presumably due to differences in residue distribution.

Comparing the effect of residue distribution at harvest on canola emergence resulted in no significant differences between treatments. The OEM chopper had marginally higher plant counts averaged across all post-harvest sub-treatments, but none at a statistically significant level. When comparing the post-harvest operations on canola, no significant differences were found. Canola plant counts were again higher at the second plant count, but no post-harvest treatment differences emerged. These counts can be seed in **Figure 40**.

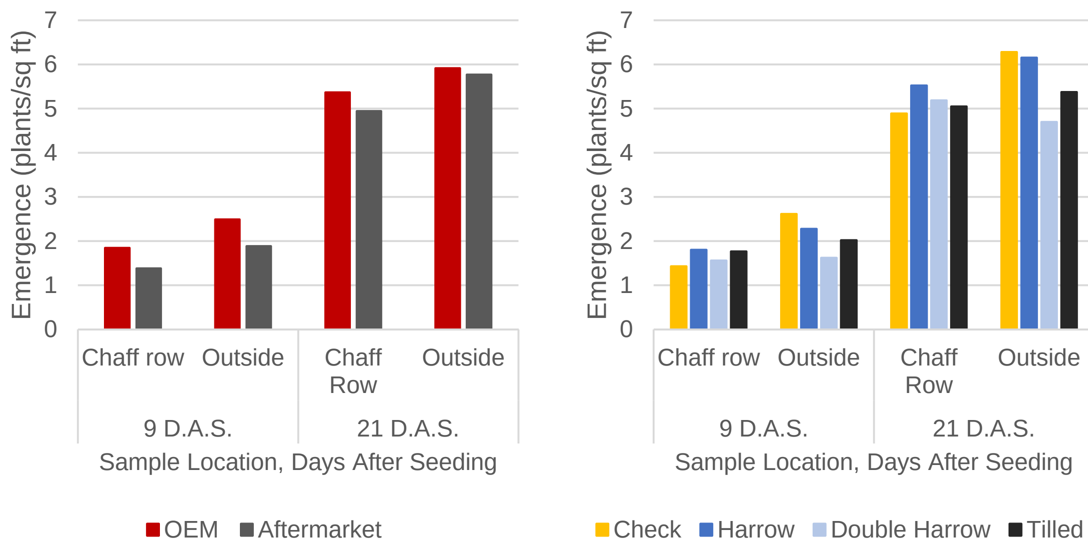

Figure 40. Canola emergence as a function of combine chopper, days after seeding (left) and post-harvest treatment, days after seeding (right).

Saint Front, Saskatchewan, Year 2:

The spring plant counts were repeated twice in the growing season. Plant count 1 was 8 to 9 DAS, and plant count 2 was at 31 DAS. These counts were taken at two distinct locations in the field: in the chaff row (directly behind the combine) and outside the chaff row. Both sets of spring plant counts were analyzed using an ANOVA analysis at a 90% confidence level.

Similar to Year 1, samples from multiple rows were taken so row-to-row variability had potential to affect plant count. Due to the very dry spring, plant emergence was delayed and uneven.

It must be noted again that the replication orientation needs to be taken into account when reviewing the data. The OEM and AFT chopper treatments were replicated across the entire quarter four times when the OEM 2 chopper was just used on the southern-most treatment area of the field and not replicated throughout. Because of this, the OEM 2 chopper treatments cannot be comparable to the entire field as a whole, as they only represent a specific area of the field.

In analyzing the data from the plant counts, plant count 1 (8 to 9 DAS) was found to have very few plants emerged. As previously mentioned, the dry spring greatly affected the plant emergence, causing a varied initial plant count. The 8 to 9 DAS results did not show a statistical difference of plant emergence in and out of the chaff row. The average plant count in the chaff row was 0.10 plants/ft^2 and outside the chaff row was 0.18 plants/ft^2. However, plant count 2 (31 DAS) did show a significant difference in plant emergence. The average plant count in the chaff row was 3.81 plants/ft^2 and outside the chaff row was 3.15 plants/ft². Relating back to the dry spring, the greater number of plants in the chaff row could be due to more moisture held in the soil by protection of the residue. Plant count 2 showed uneven emergence across the field.

There were no significant differences between the emergence of the OEM chopper, OEM 2 chopper, and AFT chopper during both counts. When comparing the post-harvest operations on canola emergence, no significant differences were found in count 1. Plant count 2 however did show significant differences with the post-harvest treatments. The check and harrow treatments grouped (Tukey Pairwise Analysis) together significantly higher than the tilled treatment in the chaff row. Outside the chaff row in plant count 2 there were also significant differences with the harrow and check treatment grouped higher than the grouping of the check and tilled treatment. This describes that the harrow and check treatment were as a group, significantly different than the tilled treatment, and the check and tilled treatment were grouped significantly different than the harrow treatment. These comparisons can be found in **Figure 41**.

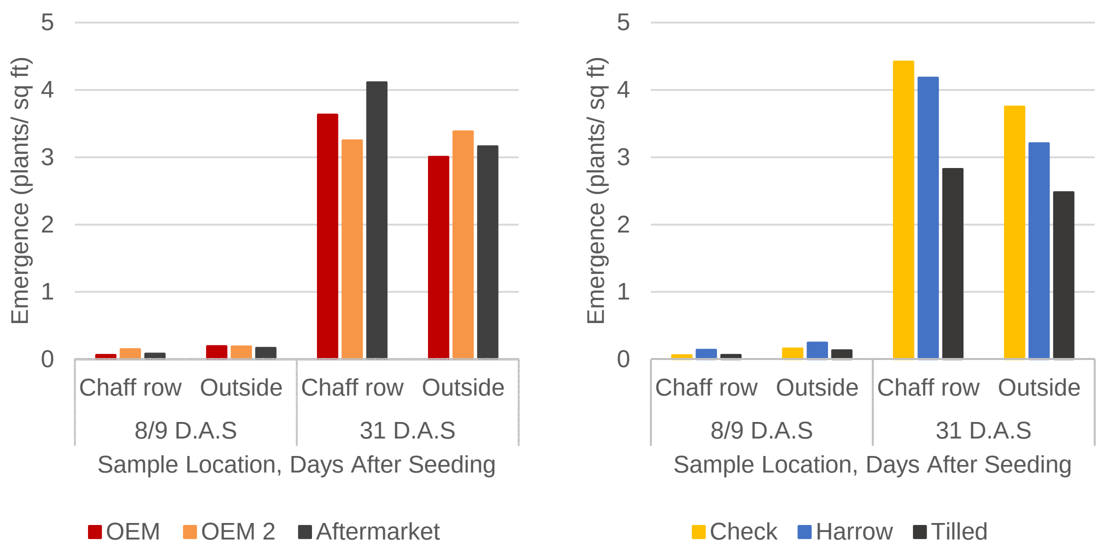

Figure 41. Canola emergence as a function of combine chopper, days after seeding (left) and post-harvest treatment, days after seeding (right).

Across most of the data sets analyzed, though some of the results did not prove to be statistically significant, the trend seemed to be higher plant emergence in the chaff row versus outside. This supports the suggestion that soil moisture was the limiting factor influencing emergence during the growing season.

Nipawin, Saskatchewan, Year 3:

Following the same method as the previous years, spring counts were taken at two intervals during the growing season. These included measurements at 13/14 DAS for plant count 1, and 33 DAS for plant count 2. Following the same methodology as previous years, the plant counts were taken both inside and outside of the chaff row.

Emergence counts comparing the two chopper types trended that the OEM had higher emergence counts than the AFT chopper, however there were no significant differences when comparing the averages of the two counts, both inside and outside the chaff row. The only significant difference found when comparing emergence between chopper types was in plant count 2, the OEM had a significantly higher emergence versus the AFT, outside the chaff row. Emergence counts comparing the post-harvest treatments trended that the harrow treatments had the highest emergence counts, followed by the check then the tilled. There were however no significant differences between all data, across the treatments in the chaff row, outside the chaff row or by plant count timing. **Figure 42** displays these differences.

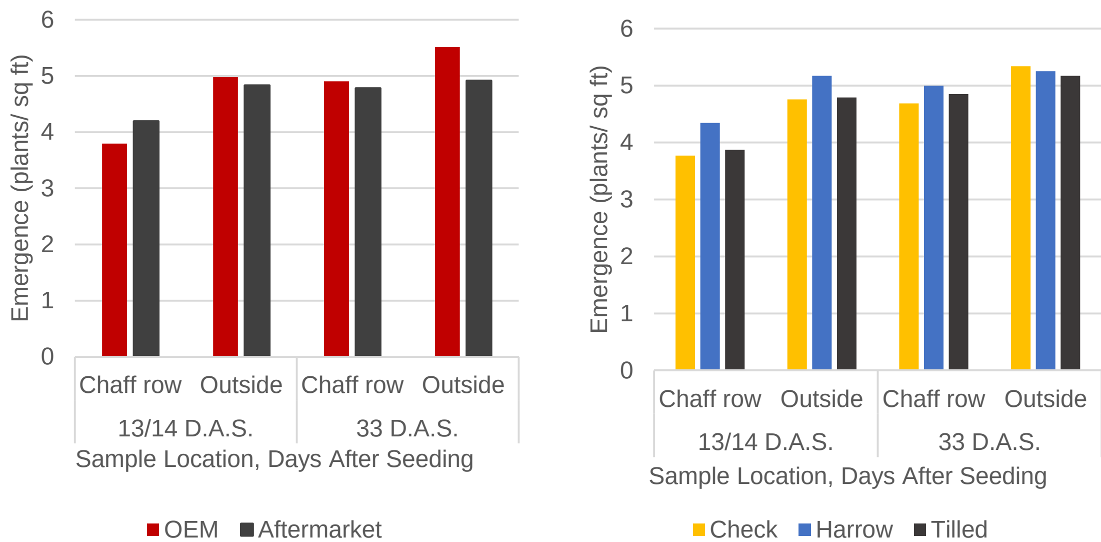

Figure 42. Canola emergence as a function of combine chopper, days after seeding (left) and post-harvest treatment, days after seeding (right).

4.2.2 Soil Temperature and Moisture

Soil temperature was recorded during the emergence counts at seed depth for all treatments. Soil moisture was determined by taking soil samples from each treatment and determining the soil moisture content.

Delmas, Saskatchewan, Year 1:

As with emergence, soil temperature was also consistent between the OEM and aftermarket choppers with no significant differences between the two. Across all treatments, at 21 DAS, the soil temperature was statistically higher outside the chaff row at 77.0°F (25.0°C) compared to 72.9°F (22.7°C) in the chaff row. Due to the later seeding date (May 28), any possible differences between both choppers and sample location on soil temperature may have been mitigated compared to an earlier seeding date where the higher residue areas would be more likely to have a lower temperature. Post-harvest treatments did have a limited effect on the soil temperature, but only in the chaff row. The tilled treatment in the chaff row had a significantly higher temperature (72.7°F [22.6°C]) than the harrow treatment (66.2°F [19.0°C]), with the double harrow (67.5°F [19.7°C]) and check (67.8°F [19.9°C]) treatments being statistically the same as both the tilled and harrow areas. This small increase in temperature in the tillage treatment does highlight the innate benefit of tillage with the likelihood of increased seed bed temperatures and potential canola germination as a result. These results are displayed in **Figure 43**.

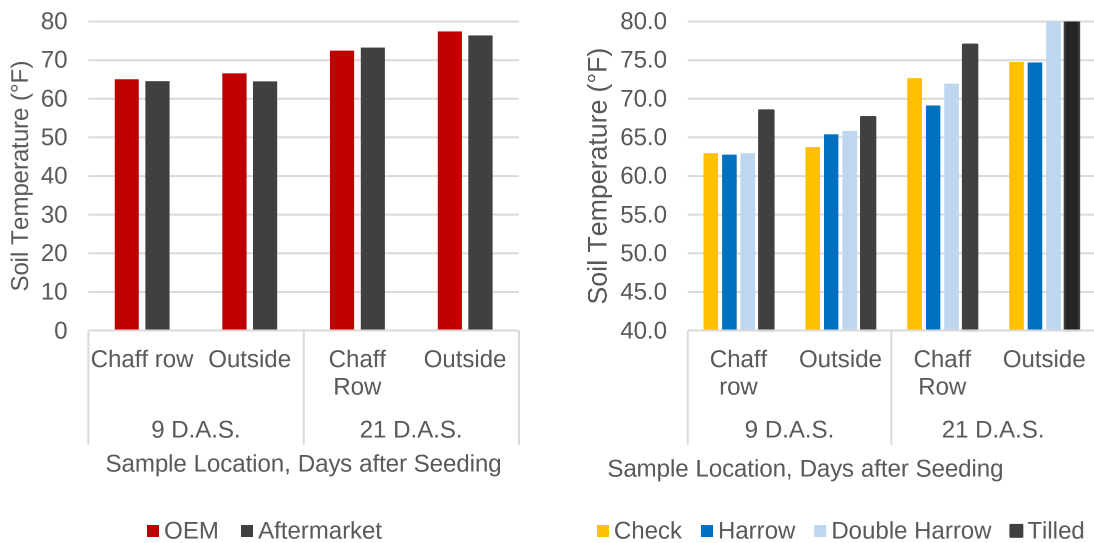

Figure 43. Soil temperature as a function of combine chopper and days after seeding (left) and post-harvest treatment and days after seeding (right).

The soil moisture measurements were taken at seeding time. Two samples from each treatment were combined, weighed, and dried in PAMI's oven, then weighed again to determine the soil moisture content (% dry basis). The AFT treatment had a significantly higher moisture percent at 27.3% versus the OEM treatment at 11.8%. Comparing the post-harvest treatments, there was no significant difference found. There was a significant difference found from the moisture measurements taken in the chaff row and outside the chaff row between choppers, with the AFT treatments having a greater moisture percentage. Comparing post-harvest treatments to moisture in the chaff row, as well as moisture outside of the chaff row, showed no significant difference. Lastly, there was no significant difference found when comparing the moisture across all treatment areas inside and outside of the chaff row. These results are displayed in **Figure 44**.

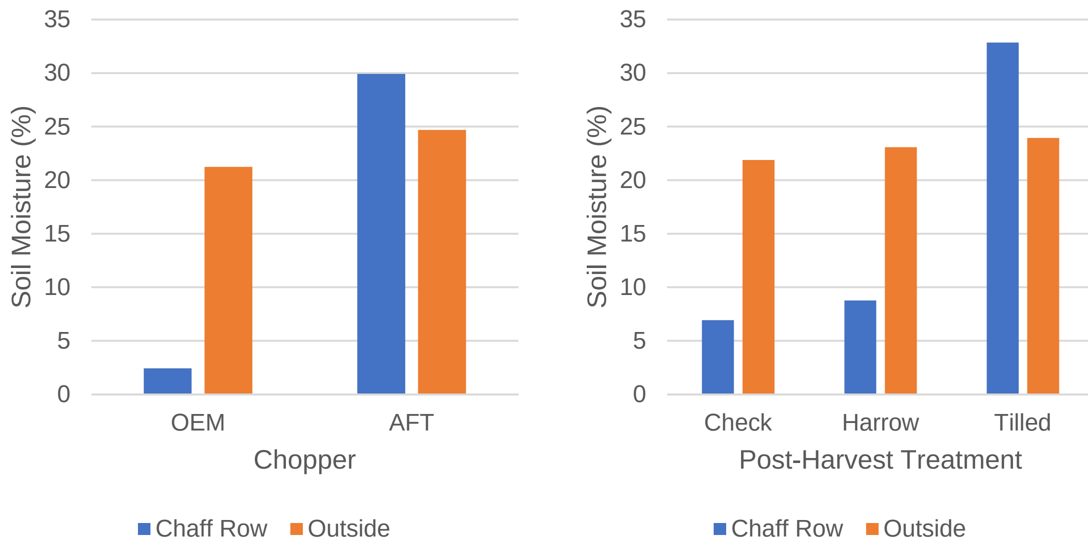

Figure 44. Soil moisture as a function of combine chopper (left) and post-harvest treatment (right).

Saint Front, Saskatchewan, Year 2:

The soil temperature was recorded at seeding depth during both plant counts. The soil temperature in the chaff row versus soil temperature outside the chaff row in plant count 1 (8 to 9 DAS) showed a statistical difference in temperature. The soil temperature in the chaff row averaged at 60.4°F (15.8°C) whereas outside the chaff row was 61.9 °F (16.6°C). Though this is a small difference, it is still statistically significant. This could be due to less residue on the surface, which could result in a higher temperature due to the sun warming the exposed soil. Other than this comparison in plant count 1, there was no other significant comparison between the temperatures. There were no significant statistical differences across the treatments when relating the post-harvest treatments to soil temperature. There was, however, a slightly higher temperature in the tillage treatment across all comparisons. A warmer seed bed is a benefit of a tillage operation. This increase is not statistically significant compared to the other treatments. **Figure 45** displays the soil temperature comparison between choppers as well as post-harvest treatments.

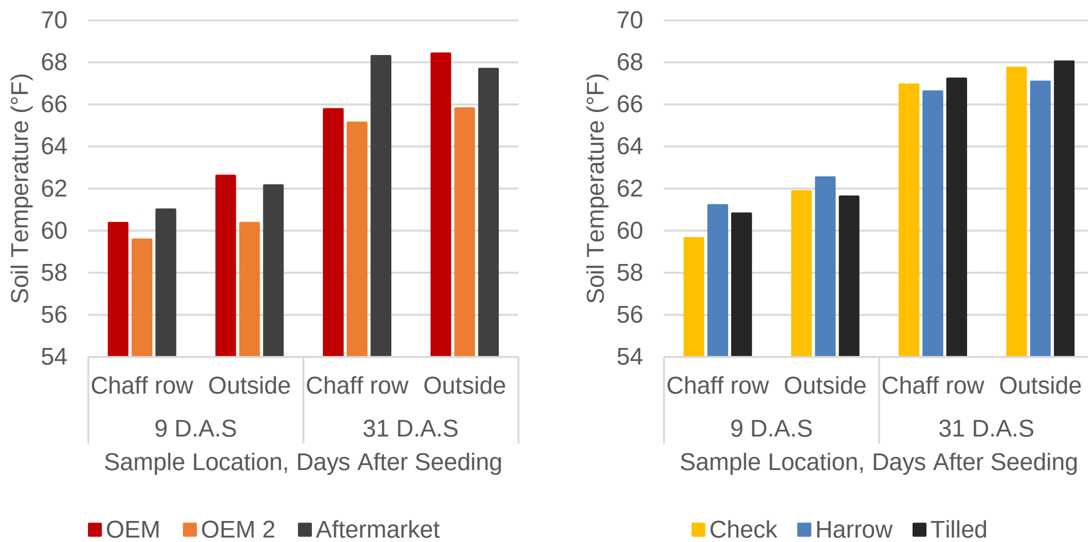

Figure 45. Soil temperature as a function of combine chopper and days after seeding.

Soil moisture was determined per treatment during plant count 1. These samples were then dried at 149°F (65°C) for 40 hours then weighed again to determine the soil moisture percentage in each of the samples. There was a significant difference between soil moisture and chopper type; however, there was not a significant difference between the post-harvest treatments. The AFT treatments had significantly higher moisture than the OEM 2 treatment, with average soil moisture at 13.5% and 10.0%, respectively. The OEM treatment statistically grouped with both the AFT and OEM 2 separately, with an average of 12.9% soil moisture. This same trend was followed with the chopper and soil moisture in the chaff row. The AFT soil moisture at 14.2% was significantly higher than the OEM 2 at 9.4%, with the OEM percentage falling in between the two, grouping with both separately at 12.8%. The high moisture levels in the aftermarket can be due to the more even spread of residue, which helps to lock in soil moisture, as less bare soil is exposed. **Figure 46** displays these findings.

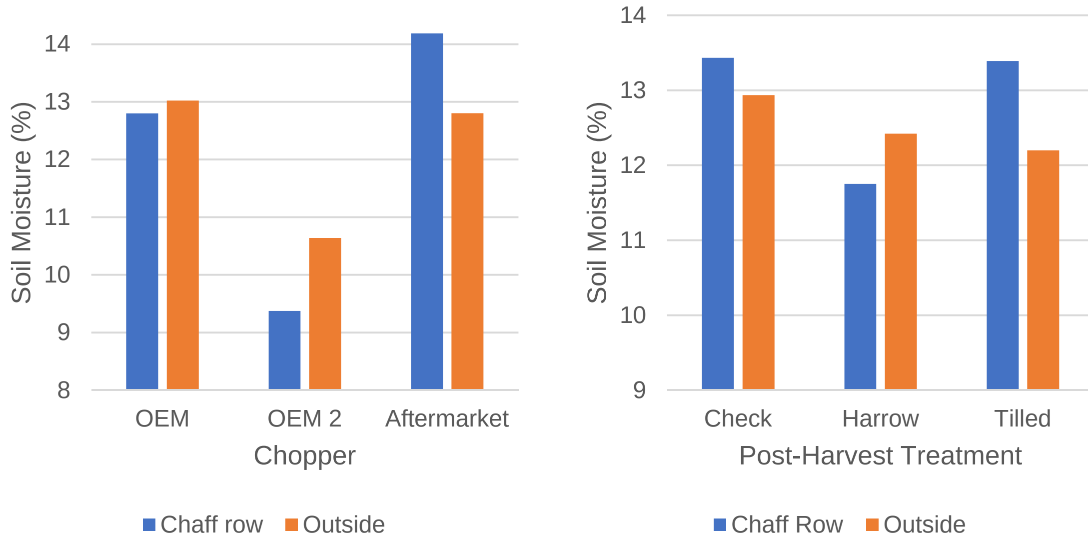

Figure 46. Soil moisture as a function of combine chopper (left) and post-harvest treatment (right).

Nipawin, Saskatchewan, Year 3:

Soil temperature, similar to Year 2 was recorded at seed depth during both plant counts. **Figure 47** displays the difference in soil temperature.

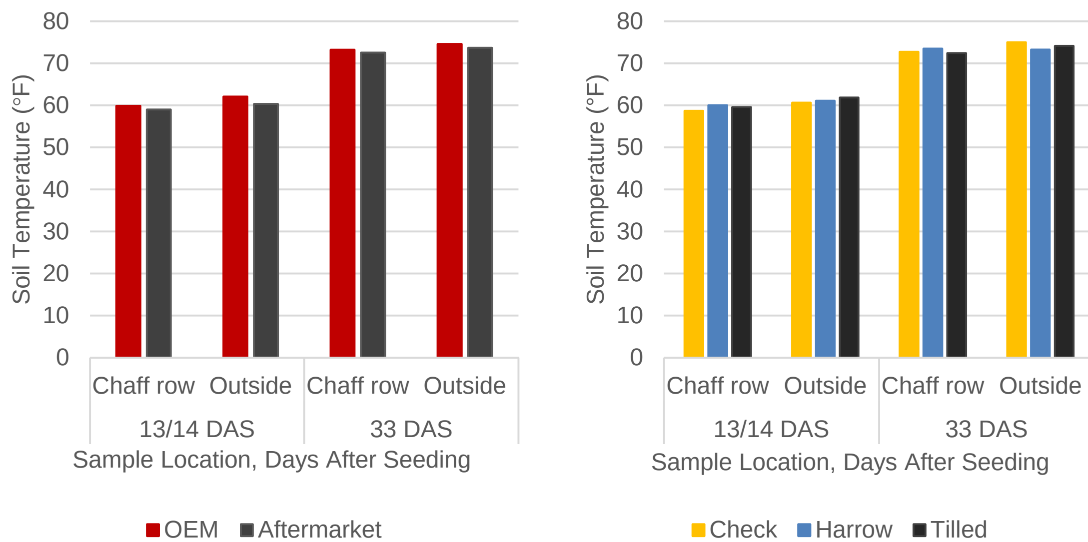

Figure 47. Soil temperature as a function of combine chopper and days after seeding (left) and post-harvest treatment and days after seeding (right).

Soil moisture comparisons for Year 3 are shown in **Figure 48**. The samples were taken at the first plant count following the same method as in previous years. There was a significant difference between choppers and soil moisture, with the OEM significantly higher (25.5%) than the AFT (24.0%). As in the previous years, there was no significant difference between post-harvest treatment and soil moisture. When analyzing both the chaff row and outside the chaff row versus chopper, the OEM had significantly higher soil moister than the AFT (26.1% vs. 24.6% and 25.0% vs. 23.4%, respectively). There was no significant difference in or outside the chaff row versus post-harvest treatment. Lastly, there was a significant difference between soil moisture across all treatments in the chaff row (25.3%) and outside the chaff row (24.2%).

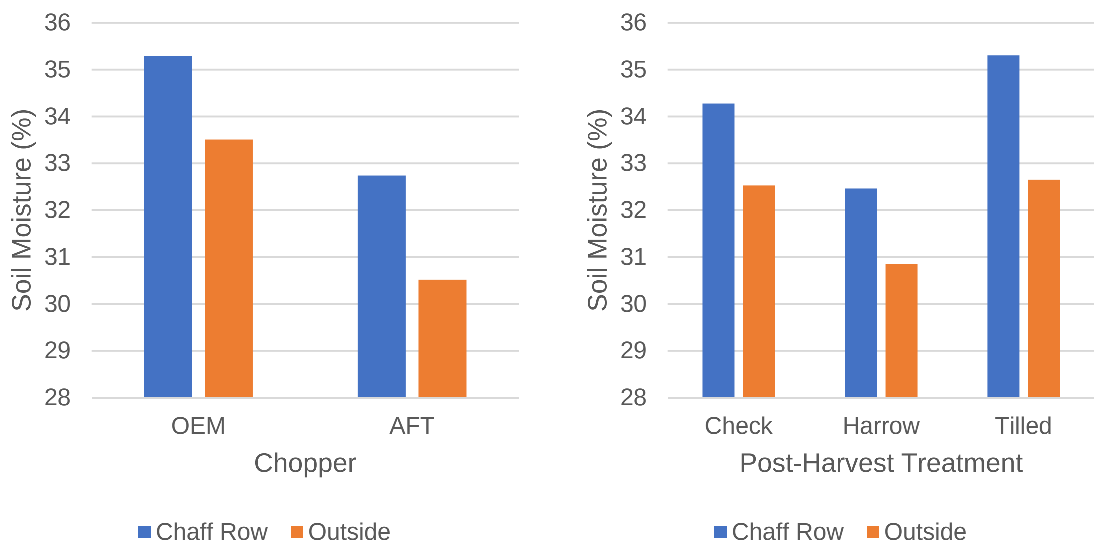

Figure 48. Soil moisture as a function of combine chopper (left) and post-harvest treatment (right).

4.2.3 Leaf Stages and Weed Counts

Leaf stage for the canola plants was taken during plant count 2, after the canola was out of the cotyledon stage. At this time, weed counts were also done to determine if there were any differences in weed density across the plots. Weed counts were taken during plant count 2 and taken only within the measurement area where the canola plants were counted. An ANOVA and Tukey Pairwise comparison was completed for this data. There were minimal significant differences between the treatments and leaf stage, as well as treatments and weed counts, and the summary of these can be found in **Appendix C**.

Delmas, Saskatchewan, Year 1:

For Year 1, there was a significant difference when comparing leaf stage (chaff row) to post-harvest treatment. The double harrow treatment had a significantly lower leaf stage than the tilled and harrow treatments but paired (Tukey Pairwise Comparison) with the check treatment. The check treatment paired with the tilled and harrow treatments. It must be noted that there were only two double harrow treatments in close proximity on one side of the field only, which may have affected the results. There were no significant differences in leaf stage versus chopper. There were also no significant differences found in weed counts across all treatments and choppers in Year 1.

Saint Front, Saskatchewan, Year 2:
Year 2 saw no significant differences in leaf stage across the post-harvest treatments or chopper treatments. However, there were some significant differences noted in weed counts across the treatments. Both in and outside of the chaff row OEM 2 had significantly higher weed counts than the OEM and AFT choppers. The OEM 2 chopper had been used specifically for the most southern plots of the treatment area, and it was noted visually that this area had a higher weed density than the rest of the field. Due to this, it is difficult to confirm or state that the weed population was caused by chopper type.

Nipawin, Saskatchewan, Year 3:
During the counts in Year 3, the only significant difference in leaf stage was noted in the chaff row when comparing chopper types. The OEM chopper had a significantly higher leaf stage than the AFT chopper. When comparing the leaf stage outside the chaff row as well as across post-harvest treatments, no differences were found. The only significant difference found when reviewing weed counts across the treatments was the weed count outside the chaff row versus chopper treatment. The OEM showed a significantly higher weed count than the AFT This could be due to the residue being heavily distributed directly behind the combine, resulting in less ground cover outside the chaff row and a greater chance of weed seeds germinating without residue cover.

4.3 Canola Harvest

As was done with the previous data, the canola yield data was put through the ANOVA analysis test with a 90% confidence interval, as well as the Tukey Pairwise Comparison test. This section summarizes the findings of the data analysis, while the detailed charts of the comparisons can be found in **Appendix C**.

4.3.1 Delmas, Saskatchewan, Year 1

Canola harvest results showed few differences between treatments. Across all the treatments, canola yield averaged 63.9 bu/ac (3.58 t/ha) when corrected to 10% moisture content. The average moisture content of all samples was 9.5%.

No significant differences in canola yield were found between the two combine choppers. The average yield with the OEM chopper across all treatments was 64.3 bu/ac (3.60 t/ha), with the aftermarket chopper trailing slightly at 63.6 bu/ac (3.56 t/ha)

All the post-harvest treatments also had statistically the same yield. The double harrow treatment averaged 66.2 bu/ac (3.71 t/ha), followed by the check at 64.6 bu/ac (3.62

t/ha), the tilled treatment at 63.8 bu/ac (3.58 t/ha), and finally the harrow at 62.9 bu/ac (3.53 t/ha). However, it should be noted that the sample area used for determining yield for the double-harrow treatments was larger than that used for the rest of the treatments, which may have skewed the yield higher. This double-harrow treatment also lacked the four repetitions that the other post-harvest management treatments had.

One difference between treatments during canola harvest was the canola moisture content. The harrow treatment had a lower moisture content (9.3%) than the check (9.6%) and tilled (9.7%) treatments. Despite these numbers being statistically different, they are not large enough to coincide with significant maturity differences. The late harvest timing, coupled with the multiple snowfalls that the crop experienced prior to harvest, may have provided the opportunity for maturity differences to be minimized compared to an earlier harvest.

Environmental conditions, coupled with the timing of pertinent operations, may have acted together to limit the overall effect of any difference between treatments. The later seeding date, on May 28, may have allowed potential soil temperature differences between treatments to be mitigated, as the soil had longer to warm up than if the canola had been seeded earlier in May. As well, with the delayed harvest due to numerous rain and snowfall events, the crop was left standing in the field for a longer period of time than typical. This lengthened time until harvest may have also minimized any maturity differences between treatments, resulting in seed moisture contents that were fairly even across all treatments.

4.3.2 Saint Front, Saskatchewan, Year 2

The canola harvest showed an average of 54.3 bu/ac (3.04 t/ha) when corrected to a 10.0% seed moisture content. The average moisture of all treatments was measured at 9.1% seed moisture. There were no significant differences found in the canola yield between the two chopper types in all scenarios analyzed; however, the trend mostly showed the OEM chopper to have the lowest yield (though insignificant). The OEM chopper across all treatments averaged 53.7 bu/ac (3.01 t/ha), the OEM 2 chopper averaged 54.8 bu/ac (3.07 t/ha), and the AFT chopper averaged 54.5 bu/ac (3.05 t/ha).

There was a statistical difference when comparing yield across the post-harvest treatment areas. The check at 53.1 bu/ac (2.97 t/ha) had a significantly lower yield than the harrow treatment at 54.5 bu/ac (3.05 t/ha) and the tilled treatment at 55.2 bu/ac (3.09 t/ha), which were statistically the same. This could be related to the uneven growth that occurred early in the season within the check area that had no residue management. When analyzing the chopper treatments separately and comparing them to the post-harvest treatments, the check treatment was significantly lower in yield in the AFT treatment areas, and the lowest (though statistically insignificant) yield in the OEM treatments.

There were no statistical differences when comparing the separate treatments in terms of chopper type and post-harvest treatment. After the data was analyzed by the one-way ANOVA, the test displayed that the yields were statistically the same.
In analyzing seed moisture across the treatments, the chopper type had no significant impact on seed moisture. There was significant difference across the post-harvest treatments. The seed moisture of the tilled treatment (9.50%) was significantly higher than the harrow treatment (9.00%) and the check (8.80%), which were statistically the same.

The environmental conditions this growing season greatly impacted the data from the dry spring to the wet late season/fall. This field was one of the last harvested by the producer due to the adverse conditions and uneven crop maturity.

4.3.3 Nipawin, Saskatchewan, Year 3

The Year 3 canola harvest results showed some differences across treatments. The yield averaged 51.0 bu/ac (2.86 t/ha) that was corrected to a 10.0% moisture content. The averaged moisture content of the grain samples was 12.0%.

The differences noted between the OEM and AFT chopper treatment was significant with the AFT chopper treatments yielding significantly higher than the OEM treatments. The AFT chopper treatment had an average across all treatments of 53.2 bu/ac (2.98 t/ha) and the OEM chopper treatments averaged at 48.7 bu/ac (2.73 t/ha).

There were no significant differences found when comparing the post-harvest treatment yields across the entire trial area. The tilled treatment trended the highest at 52.1 bu/ac (2.92 t/ha), followed by the check treatment with 51.7 bu/ac (2.90 t/ha) yield, and lastly the harrow treatment at 49.2 bu/ac (2.76 t/ha). When running the analysis on the post-harvest treatments per chopper type (i.e., AFT harrow vs. AFT check vs. AFT tilled, OEM harrow) there were no significant differences found within the chopper treatments. This was also the case when analyzing each chopper treatment yield per post-harvest treatment.

There was a significant difference when viewing the repetitions, which displayed that Repetition 1 (the pass along the north end of the field) had a significantly higher yield than the remaining three repetitions. This repetition had the same treatments applied as the rest of the field, with no other different management practice noted. This proves that spatial variability is reflected in the results.

Moisture content of the grain was determined by taking grain samples from each treatment to PAMI where a moisture test was conducted. The grain moisture percentage across chopper treatments did not show a significant difference, with the OEM treatments having a slightly higher moisture percent (12.2%) compared to the OEM treatments (11.8%). There were no significant differences found in the grain moisture across post-harvest treatments, with the harrow treatment trending higher at 12.5% seed moisture, followed by the check treatment at 12.0%, and the tilled treatment at 11.56%.

5. Conclusion and Recommendations

Implementing a residue management strategy on farm may provide benefits to the following year's canola crop. The AFT choppers throughout these trials provided a more even field finish than the poorly set OEM choppers. The AFT choppers (measured in Years 2 and 3) also provided smaller, fractioned residue than the OEM. The OEM chopper left the majority of the residue directly behind the chopper, which caused a strip pattern through the fields. This resulted in some bare ground as well as some that was covered in heavy residue.

The post-harvest treatments aided in spreading the OEM residue clumps and provided minimal (visual) differences in the AFT treatments. The heavy-harrow treatment facilitated some clumps to be evened out, as well as some of the finer residue pieces to be incorporated into the soil. The tillage treatment incorporated more of the residue and provided a blackening effect on the soil surface as it turned the soil.

When analyzing the canola emergence across the three treatment years, there were few significant differences found. The results varied by year between emergence inside and outside the chaff row. In Years 1 and 3, the emergence was higher outside the chaff row whereas in Year 2 the emergence was higher in the chaff row. This could be due to the very dry spring, resulting in moisture being the limiting factor, which was held in the residue and allowed for a better emergence. When comparing the emergence by chopper, there were few significant differences found that varied across year. Comparing the post-harvest treatments, the results varied each year with mostly the harrow or check treatment having the higher emergence count compared to the tillage. However, Year 3 did see a trend toward the harrow treatment experiencing the highest emergence across all treatments when comparing post-harvest treatments. This, however, was just a trend, and few significant differences were found in the data.

The yield data across the three years displayed that there was no significant difference in yield between choppers for Years 1 and 2; however, in Year 3, the AFT treatments yielded significantly higher than the OEM. When comparing the emergence to post-harvest treatments, there was only a significant difference found in Year 2, with the check treatment yielding lower than the harrowed and tilled, respectively, but no significant yield differences were found in Years 1 and 3 when analyzing post-harvest treatments. Lastly, when comparing each of the separate six treatments (OEM harrow, OEM tilled, OEM check, AFT harrow, etc.) there were no significant differences found between the yields between each year.

Though few significant differences found in the data were found, proper residue management on farm can provide benefits. Without an even residue distribution pattern, there are risks associated with both bare ground as well as clumping behind the chopper. Bare ground can lead to erosion problems and clumped residue that does not break down can lead to an increase in disease, such as Blackleg (Canola Council of Canada, 2021). Although the results did not show many significant differences in canola emergence across treatments, some differences were noted. Proper residue management is recommended on farm for a good plant stand, ease of in-field management, and a good canola harvest outcome. Future work on this topic may consider analyzing results based on longer crop rotations and tillage treatments, as well as other factors that may be affected by the treatments (i.e., soil microbial community, disease pathogen levels, etc.).

6. References

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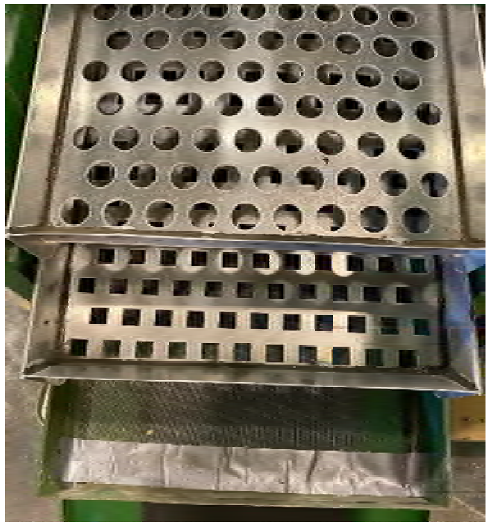
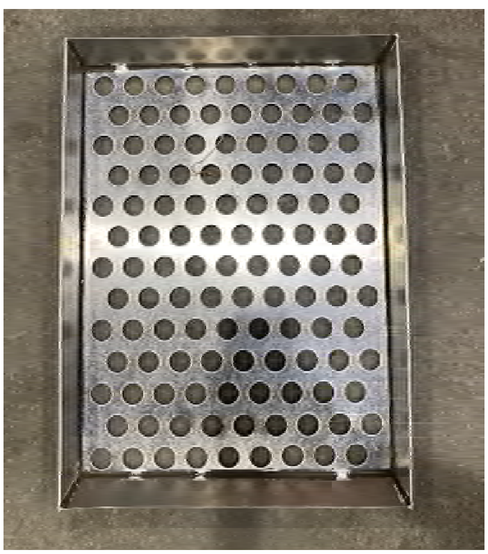
Appendix A

Procedure for Fractioning Straw Residue

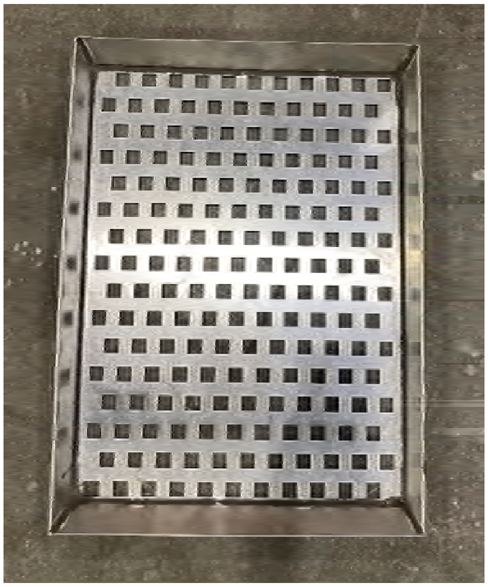
For Years 2 and 3 only, the material was separated by a particle separator, which includes an oscillating screen set. The residue from each tray were analyzed separately. Four different trays were used with different hole sizes to separate the material. Due to the top two trays being very similar, the weights of those trays were combined for the data analysis. The forage separator was run for 20 seconds per sample. The characteristics of the four trays used is listed below.

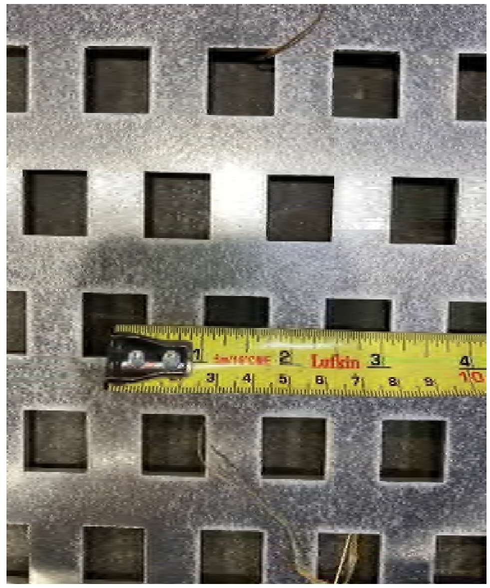


The top tray, with 1 1/8 in (2.9 cm) round holes:

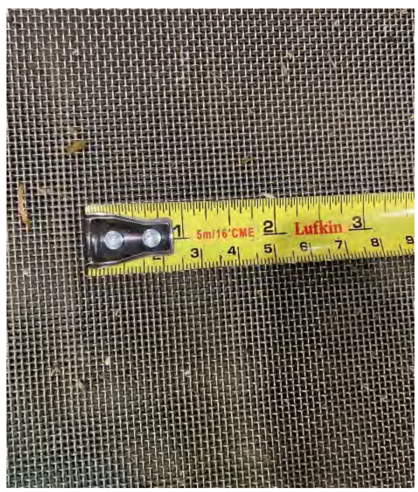


The second tray, with ¾ in (1.9 cm) square holes:

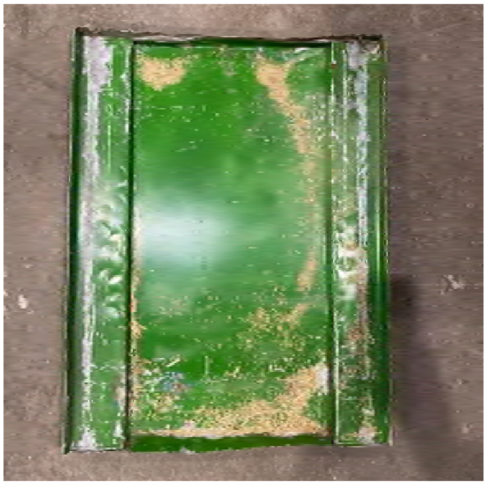




The third tray, with wire mesh on 1/16 in (0.16 cm) grid:



The fourth tray, with a solid bottom:



An example of the distribution of residue after using the particle seperator is shown below:


Appendix B

Emergence ANOVA Results

- All analysis used the Tukey method for grouping, at a 90% confidence interval
- Means that do not share the same letter are significantly different

Year 1

Emergence Chaff Row vs. Emergence Outside

Emergence Chaff Row, Emergence Outside, All Data

Factor	N	Mean	Grouping		P-Value= 0.107
Emergence Outside	52	4.018	A		
Emergence Chaff Row	52	3.388	A		

Emergence Chaff Row, Emergence Outside, Count 1

Factor	N	Mean	Grouping		P-Value= 0.008
Emergence Outside	26	2.191	A		
Emergence Chaff Row	26	1.6163		B	

Emergence Chaff Row, Emergence Outside, Count 2

Factor	N	Mean	Grouping		P-Value= 0.004
Emergence Outside	26	5.844	A		
Emergence Chaff Row	26	5.159		B	

Emergence vs. Chopper

Emergence Chaff Row vs Chopper, All Data

Chopper	N	Mean	Grouping		P-Value= 0.407
OEM	26	3.61	A		
AFTERMARKET	26	3.165	A		

Emergence Outside vs Chopper, All Data

Chopper	N	Mean	Grouping	P-Value= 0.512
OEM	26	4.206	A	
AFTERMARKET	26	3.83	A	

Emergence Chaff Row vs chopper, Count 1

Chopper	N	Mean	Grouping		P-Value= 0.016
OEM	13	1.848	A		
AFTERMARKET	13	1.385		B	

Emergence Outside vs Chopper, Count 1

Chopper	N	Mean	Grouping	P-Value= 0.101
OEM	13	2.494	A	
AFTERMARKET	13	1.888	A	

Emergence Chaff Row, vs. Chopper, Count 2

Chopper	N	Mean	Grouping	P-Value= 0.183
OEM	13	5.371	A	
AFTERMARKET	13	4.946	A	

Emergence Outside vs. Chopper, Count 2

Chopper	N	Mean	Grouping	P-Value= 0.660
OEM	13	5.917	A	
AFTERMARKET	13	5.771	A	

Emergence vs. Post-Harvest Treatment

Emergence Outside vs Post-Harvest, All Data

Post-Harvest	N	Mean	Grouping	P-Value= 0.618
Check	16	4.45	A	
Harrow	16	4.117	A	
Tilled	16	3.7	A	
Double Harrow	4	3.162	A	

Emergence Chaff Row vs Post-Harvest, All Data

Post-Harvest	N	Mean	Grouping	P-Value= 0.941
Harrow	16	3.594	A	
Tilled	16	3.411	A	
Double Harrow	4	3.38	A	
Check	16	3.161	A	

Emergence Outside vs Post-Harvest, Count 1

Post-Harvest	N	Mean	Grouping	P-Value= 0.457
Check	8	2.616	A	
Harrow	8	2.078	A	
Tilled	8	2.022	A	
Double Harrow	2	1.625	A	

Emergence Chaff Row vs. Post-Harvest, Count 1

Post-Harvest	N	Mean	Grouping	P-Value= 0.625
Tilled	8	1.769	A	
Harrow	8	1.662	A	
Double Harrow	2	1.563	A	
Check	8	1.431	A	

Emergence Outside vs Post-Harvest, Count 2

Post-Harvest	N	Mean	Grouping		P-Value= 0.010
Check	8	6.284	A		
Harrow	8	6.156	A	B	
Tilled	8	5.378		B	C
Double Harrow	2	4.7			C

Emergence Chaff Row vs. Post-Harvest, Count 2

Post-Harvest	N	Mean	Grouping	P-Value= 0.465
Harrow	8	5.525	A	
Double Harrow	2	5.188	A	
Tilled	8	5.053	A	
Check	8	4.891	A	

Year 2

Emergence Chaff Row vs. Emergence Outside

Emergence Chaff Row, Emergence Outside, All Data

Factor	N	Mean	Grouping		P-Value= 0.463
Emergence Chaff Row	48	1.949	A		
Emergence Outside	48	1.664	A		

Emergence Chaff Row, Emergence Outside, Count 1

Factor	N	Mean	Grouping		P-Value= 0.134
Emergence Outside	24	0.181	A		
Emergence Chaff Row	24	0.0882	A		

Emergence Chaff Row, Emergence Outside, Count 2

Factor	N	Mean	Grouping		P-Value= 0.057
Emergence Chaff Row	24	3.81	A		
Emergence Outside	24	3.148		B	

Emergence vs. Chopper

Emergence Chaff Row vs Chopper, All Data

Chopper	N	Mean	Grouping	P-Value= 0.875
AFTERMARKET	24	2.099	A	
OEM	16	1.849	A	
OEM 2	8	1.701	A	

Emergence Outside vs Chopper, All Data

Chopper	N	Mean	Grouping	P-Value= 0.969
OEM 2	8	1.788	A	
AFTERMARKET	24	1.666	A	
OEM	16	1.601	A	

Emergence Chaff Row vs Chopper, Count 1

Chopper	N	Mean	Grouping	P-Value= 0.609
OEM 2	4	0.1512	A	
AFTERMARKET	12	0.0831	A	
OEM	8	0.0643	A	

Emergence Outside vs Chopper, Count 1

Chopper	N	Mean	Grouping	P-Value= 0.974
OEM	8	0.195	A	
OEM 2	4	0.1912	A	
AFTERMARKET	12	0.1683	A	

Emergence Chaff Row vs. Chopper, Count 2

Chopper	N	Mean	Grouping	P-Value= 0.443
AFTERMARKET	12	4.115	A	
OEM	8	3.633	A	
OEM 2	4	3.251	A	

Emergence Outside vs Chopper, Count 2

Chopper	N	Mean	Grouping	P-Value= 0.865
OEM 2	4	3.386	A	
AFTERMARKET	12	3.163	A	
OEM	8	3.006	A	

Emergence vs. Post-Harvest Treatment

Emergence Outside vs Post-Harvest, All Data

Post-Harvest	N	Mean	Grouping	P-Value= 0.558
Harrow	16	1.957	A	
Check	16	1.729	A	
Tilled	16	1.309	A	

Emergence Chaff Row vs Post-Harvest, All Data

Post-Harvest	N	Mean	Grouping	P-Value= 0.498
Check	16	2.241	A	
Harrow	16	2.164	A	
Tilled	16	1.445	A	

Emergence Outside versus Post-Harvest, Count 1

Post-Harvest	N	Mean	Grouping	P-Value= 0.679
Check	8	0.249	A	
Harrow	8	0.1606	A	
Tilled	8	0.1338	A	

Emergence Chaff Row vs. Post-Harvest, Count 1

Post-Harvest	N	Mean	Grouping	P-Value= 0.459
Harrow	8	0.1399	A	
Tilled	8	0.0642	A	
Check	8	0.0605	A	

Emergence Outside versus Post-Harvest, Count 2

Post-Harvest	N	Mean	Grouping		P-Value= 0.065
Harrow	8	3.753	A		
Check	8	3.209	A	B	
Tilled	8	2.482		B	

Emergence Chaff Row vs. Post-Harvest, Count 2

Post-Harvest	N	Mean	Grouping		P-Value= 0.013
Check	8	4.421	A		
Harrow	8	4.184	A		
Tilled	8	2.826		B	

Year 3

Emergence Chaff Row vs. Emergence Outside

Emergence Chaff Row, Emergence Outside, All Data

Factor	N	Mean	Grouping		P-Value= 0.001
Emergence Outside	48	5.063	A		
Emergence Chaff Row	48	4.422		B	

Emergence Chaff Row, Emergence Outside, Count 1

Factor	N	Mean	Grouping		P-Value= 0.003
Emergence Outside	24	4.903	A		
Emergence Chaff Row	24	3.998		B	

Emergence Chaff Row, Emergence Outside, Count 2

Factor	N	Mean	Grouping		P-Value= 0.093
Emergence Outside	24	5.218	A		
Emergence Chaff Row	24	4.846		B	

Emergence vs. Chopper

Emergence Chaff Row vs Chopper, All Data

Chopper	N	Mean	Grouping	P-Value= 0.595
AFTERMARKET	24	4.491	A	
OEM	24	4.353	A	

Emergence Outside vs Chopper, All Data

Chopper	N	Mean	Grouping	P-Value= 0.187
OEM	24	5.249	A	
AFTERMARKET	24	4.874	A	

Emergence Chaff Row vs chopper, Count 1

Chopper	N	Mean	Grouping	P-Value= 0.294
AFTERMARKET	12	4.198	A	
OEM	12	3.798	A	

Emergence Outside vs Chopper, Count 1

Chopper	N	Mean	Grouping	P-Value= 0.750
OEM	12	4.98	A	
AFTERMARKET	12	4.835	A	

Emergence Chaff Row, vs. Chopper, Count 2

Chopper	N	Mean	Grouping	P-Value= 0.650
OEM	12	4.908	A	
AFTERMARKET	12	4.785	A	

Emergence Outside vs. Chopper, Count 2

Chopper	N	Mean	Grouping		P-Value= 0.081
OEM	12	5.518	A		
AFTERMARKET	12	4.918		B	

Emergence vs. Post-Harvest Treatment

Emergence Outside vs Post-Harvest, All Data

Post-Harvest	N	Mean	Grouping	P-Value= 0.759
Harrow	16	5.213	A	
Check	16	4.993	A	
Tilled	16	4.982	A	

Emergence Chaff Row vs Post-Harvest, All Data

Post-Harvest	N	Mean	Grouping	P-Value= 0.361
Harrow	16	4.673	A	
Tilled	16	4.363	A	
Check	16	4.23	A	

Emergence Outside versus Post-Harvest, Count 1

Post-Harvest	N	Mean	Grouping	P-Value= 0.717
Harrow	8	5.171	A	
Tilled	8	4.793	A	
Check	8	4.759	A	

Emergence Chaff Row vs. Post-Harvest, Count 1

Post-Harvest	N	Mean	Grouping	P-Value= 0.426
Harrow	8	4.346	A	
Tilled	8	3.874	A	
Check	8	3.773	A	

Emergence Outside versus Post-Harvest, Count 2

Post-Harvest	N	Mean	Grouping	P-Value= 0.982
Harrow	8	5.254	A	
Check	8	5.228	A	
Tilled	8	5.171	A	

Emergence Chaff Row vs. Post-Harvest, Count 2

Post-Harvest	N	Mean	Grouping	P-Value= 0.643
Harrow	8	4.999	A	
Tilled	8	4.853	A	
Check	8	4.688	A	

Appendix C

Leaf stage differences across treatments

Year 1

Leaf Stage Chaff Row, Leaf Stage Outside, All Data

Factor	N	Mean	Grouping		P-Value= 0.000
Leaf Stage Outside	26	1.9038	A		
Leaf Stage Chaff Row	26	1.6817		B	

Leaf Stage Chaff Row vs Chopper, count 2

Chopper	N	Mean	Grouping	P-Value= 0.581
OEM	13	1.7019	A	
AFTERMARKET	13	1.6615	A	

Leaf Stage Chaff Row vs Post-Harvest, Count 2

Post-Harvest	N	Mean	Grouping		P-Value= 0.065
Tilled	8	1.7469	A		
Harrow	8	1.7031	A		
Check	8	1.6719	A	B	
Double Harrow	2	1.375		B	

Leaf Stage Outside vs Chopper, Count 2

Chopper	N	Mean	Grouping	P-Value= 0.160
OEM	13	1.9615	A	
AFTERMARKET	13	1.8462	A	

Leaf Stage Outside vs Post-Harvest, Count 2

Post-Harvest	N	Mean	Grouping	P-Value= 0.198
Tilled	8	1.9531	A	
Check	8	1.9531	A	
Harrow	8	1.875	A	
Double Harrow	2	1.625	A	

Year 2

Leaf Stage Chaff Row, Leaf Stage Outside Count 2

Factor	N	Mean	Grouping	P-Value= 0.881
Leaf Stage Chaff Row	24	2.698	A	
Leaf Stage Outside	24	2.672	A	

Leaf Stage Chaff Row vs Chopper, Count 2

Chopper	N	Mean	Grouping	P-Value= 0.210
OEM 2	4	3	A	
AFTERMARKET	12	2.792	A	
OEM	8	2.406	A	

Leaf Stage Chaff Row vs Post-Harvest, Count 2

Post-Harvest	N	Mean	Grouping	P-Value= 0.467
Harrow	8	2.906	A	
Tilled	8	2.656	A	
Check	8	2.531	A	

Leaf Stage Outside vs Chopper, Count 2

Chopper	N	Mean	Grouping	P-Value= 0.825
AFTERMARKET	12	2.716	A	
OEM	8	2.688	A	
OEM 2	4	2.5	A	

Leaf Stage Outside vs Post-Harvest

Post-Harvest	N	Mean	Grouping	P-Value= 0.867
Harrow	8	2.766	A	
Check	8	2.641	A	
Tilled	8	2.609	A	

Year 3

Leaf Stage Chaff Row, Leaf Stage Outside Count 2				
				P-Value=
Factor	N	Mean	Grouping	0.350
Leaf Stage Outside	24	3.3021	A	
Leaf Stage Chaff Row	24	3.167	A	

Leaf Stage Chaff Row vs Chopper, Count 2				
				P-Value=
Chopper	N	Mean	Grouping	0.076
OEM	12	3.354	A	
AFTERMARKET	12	2.979		
				B

Leaf Stage Chaff Row vs Post-Harvest, Count 2				
				P-Value=
Post-Harvest	N	Mean	Grouping	0.501
Check	8	3.313	A	
Harrow	8	3.188	A	
Tilled	8	3	A	

Leaf Stage Outside vs Chopper, Count 2				
				P-Value=
Chopper	N	Mean	Grouping	0.600
OEM	12	3.354	A	
AFTERMARKET	12	3.25	A	

Leaf Stage Outside vs Post-Harvest				
				P-Value=
Post-Harvest	N	Mean	Grouping	0.763
Harrow	8	3.406	A	
Tilled	8	3.25	A	
Check	8	3.25	A	

Weed count differences across treatments

Year 1

Weed Count Chaff Row, Weed Count Outside, Count 2					
					P-Value=
Factor	N	Mean	Grouping		0.029
Weed Count Chaff Row	26	32.13	A		
Weed Count Outside	26	23.33		B	

Weed Count Chaff Row vs Chopper, Count 2				
				P-Value=
Chopper	N	Mean	Grouping	0.645
OEM	13	33.46	A	
AFTERMARKET	13	30.81	A	

Weed Count Chaff Row vs Post-Harvest, Count 2				
				P-Value=
Post-Harvest	N	Mean	Grouping	0.346
Check	8	34.19	A	
Tilled	8	33.5	A	
Harrow	8	33.19	A	
Double Harrow	2	14.25	A	

Weed Count Outside vs Post Harvest				
				P-Value=
Post-Harvest	N	Mean	Grouping	0.646
Tilled	8	25.69	A	
Harrow	8	25.69	A	
Check	8	21.25	A	
Double Harrow	2	12.75	A	

Weed Count Outside vs Chopper				
				P-Value=
Chopper	N	Mean	Grouping	0.609
OEM	13	24.77	A	
AFTERMARKET	13	21.88	A	

Year 2

Weed Count Chaff Row, Weed Count Outside, Count 2				
Factor	N	Mean	Grouping	P-Value= 0.049
Weed Count Chaff Row	24	17.19	A	
Weed Count Outside	24	10.58	B	

Weed Count Chaff Row vs Post-Harvest, Count 2				
Post-Harvest	N	Mean	Grouping	P-Value= 0.996
Harrow	8	17.5	A	
Check	8	17.13	A	
Tilled	8	16.94	A	

Weed Count Outside vs Post-Harvest, Count 2				
Post-Harvest	N	Mean	Grouping	P-Value= 0.405
Tilled	8	13.56	A	
Check	8	11.31	A	
Harrow	8	6.88	A	

Weed Count Chaff Row vs Chopper, Count 2				
Chopper	N	Mean	Grouping	P-Value= 0.000
OEM 2	4	36.5	A	
OEM	8	18.31	B	
AFTERMARKET	12	10	B	

Weed Count Outside vs Chopper, Count 2				
Chopper	N	Mean	Grouping	P-Value= 0.004
OEM 2	4	23.88	A	
OEM	8	10.06	B	
AFTERMARKET	12	6.5	B	

Year 3

Weed Count Chaff Row, Weed Count Outside, Count 2				
Factor	N	Mean	Grouping	P-Value= 0.143
Weed Count Chaff Row	24	5.083	A	
Weed Count Outside	24	3.667	A	

Weed Count Chaff Row vs Post-Harvest, Count 2				
Post-Harvest	N	Mean	Grouping	P-Value= 0.693
Check	8	5.63	A	
Tilled	8	5.438	A	
Harrow	8	4.19	A	

Weed Count Outside vs Chopper				
Chopper	N	Mean	Grouping	P-Value= 0.041
OEM	12	4.92	A	
AFTERMARKET	12	2.419	B	

Weed Count Chaff Row vs Chopper, Count 2				
Chopper	N	Mean	Grouping	P-Value= 0.135
OEM	12	6.167	A	
AFTERMARKET	12	4	A	

Weed Count Outside vs Post Harvest				
Post-Harvest	N	Mean	Grouping	P-Value= 0.639
Harrow	8	4.19	A	
Check	8	4	A	
Tilled	8	2.813	A	

Appendix D

Yield and Moisture ANOVA Results

- All analysis used the Tukey method for grouping, at a 90% confidence interval
- Means that do not share the same letter are significantly different

Year 1 Analysis

Moisture Corrected Yield vs. Chopper

Chopper	N	Mean	Grouping
OEM	13	64.312	A
Aftermarket	13	63.577	A

Moisture Corrected Yield vs. Treatment

Treatment	N	Mean	Grouping
Double Harrow	2	66.18	A
Check	8	64.573	A
Till	8	63.776	A
Harrow	8	62.926	A

Seed Moisture vs. Chopper

Chopper	N	Mean	Grouping
OEM	13	9.5846	A
Aftermarket	13	9.4385	A

Seed Moisture vs. Post-Harvest Treatment

Treatment	N	Mean	Grouping	
Till	8	9.6875	A	
Check	8	9.6	A	
Double Harrow	2	9.45	A	B
Harrow	8	9.2625		B

All Treatment Yield Comparison

Factor	N	Mean	Grouping
OEM Check	4	64.850	A
OEM Tilled	4	64.475	A
AFT Check	4	64.300	A
OEM Harrow	4	63.725	A
AFT Tilled	4	63.07	A
AFT Harrow	4	62.15	A

Year 2 Analysis

Moisture Yield vs. Chopper

Chopper	N	Mean	Grouping
OEM 2	4	54.795	A
Aftermarket	12	54.488	A
OEM	8	53.703	A

Yield vs. Treatment

Treatment	N	Mean	Grouping	
Tilled	8	55.196	A	
Harrow	8	54.534	A	
Check	8	53.102		B

Seed Moisture vs. Chopper

Chopper	N	Mean	Grouping
OEM	8	9.350	A
Aftermarket	12	8.975	A
OEM 2	4	8.950	A

Seed Moisture vs. Post-Harvest Treatment

Treatment	N	Mean	Grouping	
Tilled	8	9.525	A	
Harrow	8	8.975		B
Check	8	8.7875		B

All Treatment Yield Comparison

Factor	N	Mean	Grouping
AFT Tilled	4	55.203	A
OEM Tilled	4	55.189	A
AFT Harrow	4	55.096	A
OEM Harrow	4	53.97	A
AFT Check	4	53.165	A
OEM Check	4	53.039	A

Year 3 Analysis

Yield vs. Chopper

Chopper	N	Mean	Grouping	
Aftermarket	12	53.23	A	
OEM	12	48.72		B

Yield vs. Treatment

Treatment	N	Mean	Grouping
Tilled	8	52.05	A
Check	8	51.72	A
Harrow	8	49.15	A

Seed Moisture vs. Chopper

Chopper	N	Mean	Grouping
OEM	12	12.217	A
Aftermarket	12	11.817	A

Seed Moisture vs. Post-Harvest Treatment

Treatment	N	Mean	Grouping
Harrow	8	12.487	A
Check	8	12.000	A
Tilled	8	11.562	A

All Treatment Yield Comparison

Factor	N	Mean	Grouping
AFT Tilled	4	55.14	A
AFT Check	4	54.99	A
AFT Harrow	4	49.56	A
OEM Tilled	4	48.95	A
OEM Harrow	4	48.75	A
OEM Check	4	48.46	A

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