Project No. W18105
Date: December 7, 2018
Revised: December 10, 2018
Humboldt, Saskatchewan

Final Report

Air Seeder Distribution and Seed Damage Testing and Validation

For:
SeedMaster
Emerald Park, Saskatchewan

PAMI
Innovative Solutions
for Agriculture and Beyond

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Air Seeder Distribution and Seed Damage Testing and Validation

Amie Harrison, B.Sc.
Project Leader, Engineer-in-Training

Joel McDonald, P.Eng.
Program Manager
Agricultural Development Services

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1. Executive Summary

SeedMaster, the Client, contracted the Prairie Agricultural Machinery Institute (PAMI) to test and validate the distribution uniformity (coefficient of variation [CV]) and seed damage (germination and vigor) for their two air seeder configurations: Nova Cart and UltraPro II. The Nova Cart employs a traditional metering system with primary metering and distribution towers, while the UltraPro II utilizes individual meters for each seed run. Each of these configurations was paired with the same 70 ft (21 m) air seeder for testing.

Testing was completed between October 4 and October 16, 2018, at SeedMaster's location in Emerald Park, Saskatchewan. A representative from PAMI was onsite for the duration of testing and data collection. A total of 16 treatments, 3 repetitions per treatment, were simulated at 5 mph (8 km/h) with 12 in (0.30 m) opener spacing in a stationary setup. Eight treatments were completed per air seeder configuration using canola, wheat, soybeans, and peas. A selection of the Nova Cart treatments also included fertilizer, while the UltraPro II tests involved only seed. Tests were run for either 1 ac (0.4 ha) or 2 ac (0.81 ha), depending on seeding rate. For each treatment, samples were collected in polypropylene bags from the 70 individual openers and each sample was weighed and recorded after each repetition. For treatments with seed and fertilizer, for each opener, bags were placed on the outlet for seed and the outlet for fertilizer to collect the products separately. Seed samples were collected from 12 of the 16 treatments and grouped into left, centre, and right air seeder sections. Discovery Seed Labs conducted germination and vigor testing on these samples.

Uniformity was quantified by analyzing data to determine coefficient of variation (CV_2, CV_1), expressed as a percent. In a practical sense, CV_2 is a measure of seed/fertilizer rate uniformity across the width of the air seeder and CV_1 is a measure of seed/fertilizer rate uniformity in the direction of travel. CV_2 for seed ranged from 7.0% to 17.2% for the Nova cart, and 3.2% to 8.8% for the UltraPro II, with the highest variation occurring in canola for both air seeder configurations. CV_1 ranged from 1.2% to 11.7% for the Nova Cart, and 0.9% to 7.1% for the UltraPro II, with the highest variation occurring in canola for both air seeder configurations. **Table 1** summarizes the CV_2 and CV_1 values for each equipment configuration, seed type, and seed rate.

Table 1. A summary of CV_2 and CV_1.

Treatment	Equipment Type	Seed Type	Seed Rate lb/ac (kg/ha)	Fertilizer Rate lb/ac (kg/ha)	Seed CV_2 (%)	Fertilizer CV_2 (%)	Seed CV_1 (%)	Fertilizer CV_1 (%)
T1	Nova Cart	Wheat	95 (106)	N/A	7.0	N/A	1.2	N/A
T2	Nova Cart	Wheat	120 (135)	200 (224)	7.3	17.0	5.9	3.6
T3	Nova Cart	Canola	4.7 (5.3)	100 (112)	15.9	13.0	11.7	4.0
T4	Nova Cart	Canola	2.8 (3.1)	50 (56)	17.2	10.2	7.4	1.5
T5	Nova Cart	Canola	2.0 (2.2)	N/A	16.2	N/A	3.7	N/A
T6	Nova Cart	Soybeans	59 (66)	160 (179)	11.8	7.5	5.8	3.3
T7	Nova Cart	Peas	230 (258)	N/A	11.3	N/A	1.8	N/A
T8	Nova Cart	Peas	180 (202)	147 (165)	11.7	8.3	4.4	8.3
T9	UltraPro II	Wheat	95 (106)	N/A	3.2	N/A	0.9	N/A
T10	UltraPro II	Wheat	120 (135)	N/A	3.4	N/A	2.4	N/A
T11[a]	UltraPro II	Canola	2.8 (3.1)	N/A	5.6	N/A	1.5	N/A
T12	UltraPro II	Canola	4.7 (5.3)	N/A	7.9	N/A	2.6	N/A
T13	UltraPro II	Canola	2.0 (2.2)	N/A	8.8	N/A	7.1	N/A
T14	UltraPro II	Soybeans	59 (66)	N/A	5.8	N/A	1.5	N/A
T15	UltraPro II	Peas	230 (258)	N/A	5.7	N/A	1.5	N/A
T16	UltraPro II	Peas	180 (202)	N/A	4.8	N/A	1.1	N/A

[a] Only two repetitions completed for T11

Seed samples were collected from 12 of the 16 treatments for germination and vigor testing at Discovery Seed Labs. A one-way ANOVA was completed on this data, and it was determined that for all 12 samples there were no significant differences between the germination rates of the pre-test (control) samples and the test samples. This indicates that, as tested, the air seeder was found to have no significant effect on the seed germination rate, at a 95% confidence level. With respect to the vigor results, 8 of the 12 treatments had no significant differences between the pre-test (control) samples and the test samples. Although 4 of the 12 treatments showed a significant difference between at least one of the three air seeder sections (right, centre, and left) and the pre-test (control) samples, there was no obvious correlation between seeder configuration or seed type on reduction of vigor.

2. Background

The Client, SeedMaster, contracted Prairie Agricultural Machinery Institute (PAMI) to conduct tests on their two air seeder configurations, the Nova Cart and the UltraPro II, to determine and verify coefficient of variation of product distribution. Sixteen treatments, involving wheat, canola, soybeans, peas, and fertilizer were completed at common producer-used rates.

As technology and agronomic practices continue to evolve, the resolution of precision seed and fertilizer application becomes finer. Air seeder distribution and rate uniformity is of growing importance with the increasing adoption of variable rate prescription maps, used to increase input efficiencies and to maximize yield and/or profit. Research, technology, and experience provide recommendations for ideal application rates, but without machinery that can accurately apply the rates, the yield and profit potential may be reduced. Better air seeder distribution uniformity, expressed in terms of coefficient of variation, give producers and agronomists increased control to more accurately manage application rates and costs.

Any time a seed is handled with machinery, including air seeders, there is an opportunity for damage. With all crops, there are cost saving opportunities if seed damage can be minimized; especially with canola, where seed mortality can exceed 50% from seed bag to crop establishment and seed costs can exceed $75/ac ($185/ha). Samples were collected from the distribution treatments to test germination and vigor and investigate seed damage caused by the equipment.

3. Project Equipment and Methods

The purpose of this study was to determine the distribution uniformity and seed damage potential for two SeedMaster air seeder configurations, the Nova Cart and the UltraPro II. The Client provided the air seeder equipment, testing facility, seed (wheat, canola, soybeans, and peas), and fertilizer for the tests, while PAMI provided the test method/protocol and managed the testing operations.

3.1 Equipment

The Client's two air seeding systems, the Nova Cart (SN SNX181273) and the UltraPro II (SN SM181383), were tested during this project. The unit tested was equipped with both systems, a configuration common for SeedMaster. The Nova Cart (**Figure 1**) uses a traditional trailed cart with dual stream air delivery system: seed and fertilizer band. The UltraPro II system (**Figure 2**) uses a drill-frame mounted tank with individual meters and delivery hoses for each opener. In this configuration, each SeedMaster twin shank opener has three hoses delivering product to it. The UltraPro II has a single delivery tube connected to the rear, seed-placed shank on each opener. The Nova Cart has a delivery tube connected to both the rear, seed-placed shank and the forward, fertilizer side band shank, on each opener.

The Nova Cart distribution system features Tunable Towers with an adjustable cone that can be used to equalize product flow between outlets. Although the drill had Tunable Towers installed, all towers were set to a neutral/centred position and were not adjusted during testing. Each tower/manifold is connected to seven openers. Ten Tunable Towers are used to distribute seed and another 10 Tunable Towers are used to distribute fertilizer to the 70 openers.

Figure 1. The Nova Cart configuration.

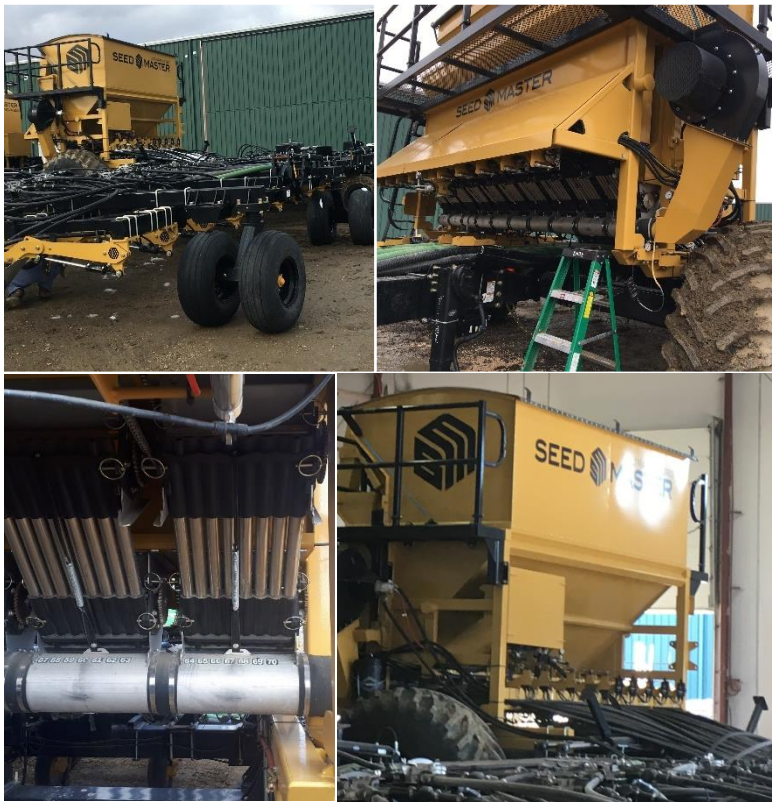


Figure 2. The UltraPro II configuration.

The above figure shows that the UltraPro II has the potential to distribute product to eight hoses per meter grouping. For the size and row spacing of the air seeder used for this project, only seven hoses per grouping were utilized.

Figure 3 shows the entire equipment setup that was used for testing. The air seeder with the UltraPro II system is mounted on the tillage tool frame directly behind the tractor. The Nova Cart is towed behind the tillage tool frame.

Figure 3. The test equipment setup.

Figure 4 and **Figure 5** show labeled air seeder schematics. **Figure 4** shows the physical location of the air seeder openers and **Figure 5** provides a representation of the openers and their corresponding manifolds/opener groupings and sections. The three sections illustrate how the samples were separated for the germination and vigor tests.

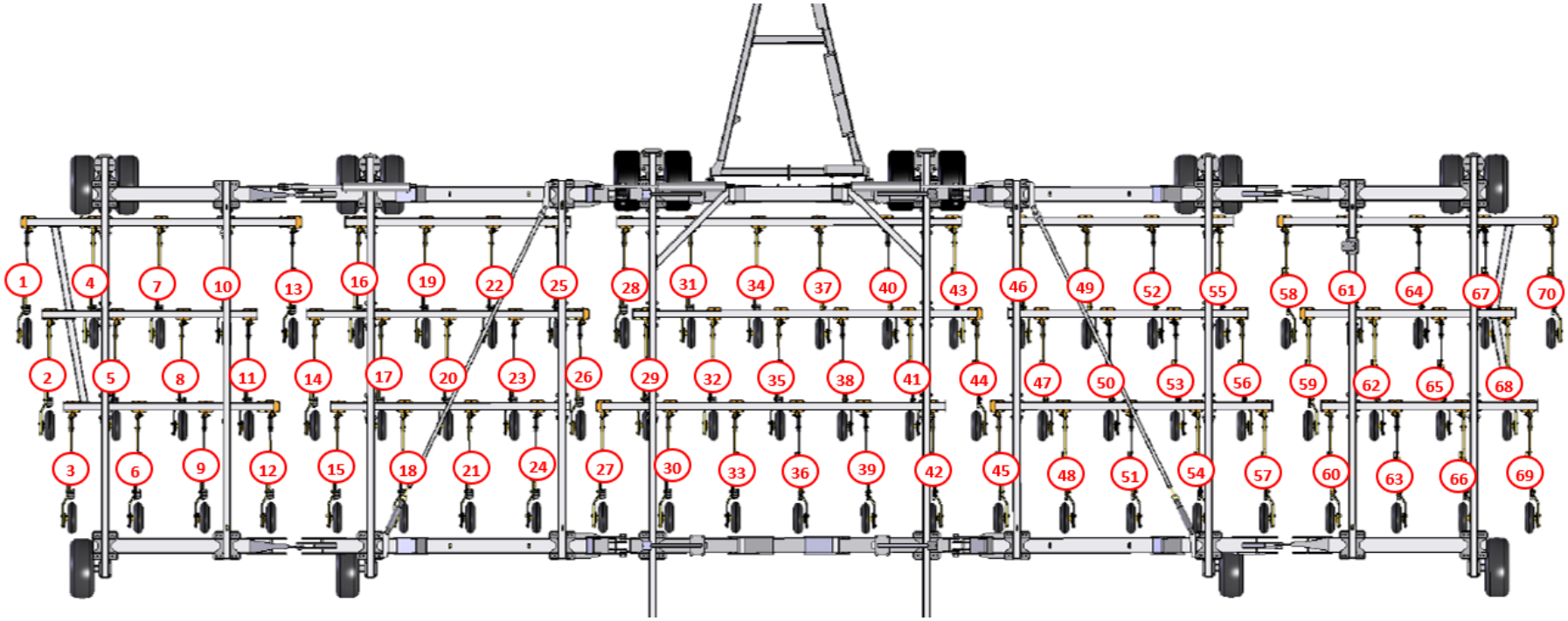


Figure 4. The labeled air seeder schematic.

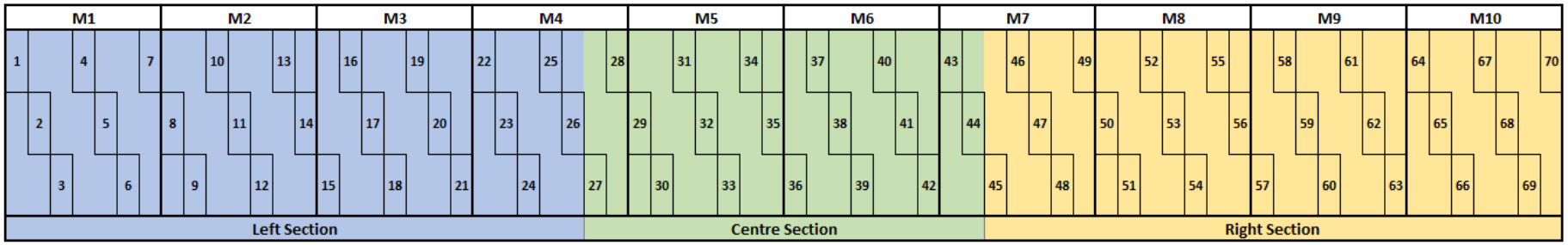


Figure 5. The air seeder opener diagram.

3.2 Testing Methods

Testing was completed between October 4 and October 16, 2018, at SeedMaster's location in Emerald Park, Saskatchewan. This section will outline the test procedure, test matrix and variables, and germination and vigor testing.

3.2.1 Test Procedure

The following procedure was used for each of the 16 treatments:

- Seed and/or fertilizer was loaded into the appropriate tank. Three samples of each seed type were collected and used as the pre-test (control) samples for germination and vigor testing. Two control sample sets were collected for canola as two different batches of seed were used - one for the Nova Cart and one for the UltraPro II.
- Calibration of seed and fertilizer rates was performed for each treatment as per the manufacturer's recommended procedure.
- Fan speed was set for each treatment as per the manufacturer's recommendation.
- Three air speeds were recorded prior to each treatment: opener 15 (left section), opener 33 (centre section), and opener 57 (right section). The air speed was measured with an anemometer below the tool opener where the seed and/or fertilizer exits the tool (**Figure 6**)**.**

Figure 6. Air speed measurement taken prior to treatment repetitions.

- Collection bags were placed over the seed and fertilizer openers (**Figure 7**). The sampling method utilized six sets of polypropylene bags (Set A, B, C, D, E, and F), each labelled from opener 1 through opener 70. This process allowed for all three repetitions to be completed back-to-back, with a reduced chance of error. The collection bag was fastened to the opener with a heavy-duty spring clamp and the top of the collection bag was left open to minimize resistance to air discharge.

Figure 7. A collection bag fastened to the rear seed opener with clamp.

- Fans were run for at least one minute to stabilize and remove any moisture from the air system prior to running seed or fertilizer through the air seeder.
- Ambient temperature and relative humidity readings were captured prior to each treatment.
- Static fan pressure measurements for each fan used (seed and fertilizer) were taken prior to running seed or fertilizer through the drill. Measurements were taken for each repetition.
- Static fan pressure measurements for each fan used were also taken during the test while seed or fertilizer travelled through the drill. Measurements were taken for each repetition (**Figure 8**).

Figure 8. Static pressure measurements were taken before and during tests.

- Seed meter run time was recorded using a stopwatch for each repetition.

- Fan rotation speed and seed/fertilizer rates were captured with a screen image recording from the tractor mounted control monitor for each repetition.
- After each repetition was completed, collection bags were removed and collected for product weighing.
- The product content of each collection bag was weighed and recorded. After weighing, the collected seed was segregated into three groups: left (openers 1 through 26), centre (openers 27 through 44), and right (openers 45 through 70). Samples from each group were collected for germination and vigor testing for each repetition.
- Any abnormal occurrences such as equipment malfunctions, hose blockage problems, improperly installed bags, etc., were recorded with the weight data.

3.2.2 Test Matrix and Variables

The Client requested eight treatments per air seeder configuration, using four different seed types (wheat, canola, soybeans, and peas). **Table 2** shows each of the 16 treatments with the corresponding seed type, seed rate, and fertilizer rate. Except where noted, three repetitions of each treatment were conducted. The Client selected rates based on common producer-used rates.

Table 2. The air seeder distribution test matrix.

Treatment	Equipment Type	Seed Type	Seed Rate lb/ac (kg/ha)	Fertilizer Rate lb/ac (kg/ha)
T1	Nova Cart	Wheat	95 (106)	N/A
T2	Nova Cart	Wheat	120 (135)	200 (224)
T3	Nova Cart	Canola	4.7 (5.3)	100 (112)
T4	Nova Cart	Canola	2.8 (3.1)	50 (56)
T5	Nova Cart	Canola	2.0 (2.2)	N/A
T6	Nova Cart	Soybeans	59 (66)	160 (179)
T7	Nova Cart	Peas	230 (258)	N/A
T8	Nova Cart	Peas	180 (202)	147 (165)
T9	UltraPro II	Wheat	95 (106)	N/A
T10	UltraPro II	Wheat	120 (135)	N/A
T11[a]	UltraPro II	Canola	2.8 (3.1)	N/A
T12	UltraPro II	Canola	4.7 (5.3)	N/A
T13	UltraPro II	Canola	2.0 (2.2)	N/A
T14	UltraPro II	Soybeans	59 (66)	N/A
T15	UltraPro II	Peas	230 (258)	N/A
T16	UltraPro II	Peas	180 (202)	N/A

[a] Only two repetitions completed for T11

Table 3 shows the thousand kernel weight (TKW) for the seed types used during testing.

Table 3. The thousand kernel weight (TKW).

Seed Type	**Thousand Kernel Weight (TKW),** lb (g)	Equipment Type
Canola	0.01094 (4.962)	Nova Cart
Canola	0.0095 (4.3)	UltraPro II
Wheat	0.09680 (43.91)	Nova Cart & UltraPro II
Soybeans	0.28742 (130.37)	Nova Cart & UltraPro II
Peas	0.42532 (192.92)	Nova Cart & UltraPro II

Figure 9 shows the seed types that were used during this project. Canola and soybeans were treated. Wheat and peas were untreated. A 25-10-10-5 fertilizer blend was used for the tests.

Figure 9. Seed types: canola-Nova Cart, canola-UltraPro II, wheat, soybeans, peas.

The following parameters were fixed during testing:

- Simulated ground speed: 5 mph (8 km/h)
- Opener spacing: 12 in (0.30 m)
- Air seeder width: 70 ft (21 m)
- Number of openers: 70

The following data was collected for each treatment:

- Test date
- Ambient temperature
- Relative humidity
- Air speed through opener 15 (left section), 33 (centre section), and 57 (right section)
- Fan speed
- Static pressure (before and during test)
- Run time of each repetition
- Weight of seed/fertilizer collected from each opener

Appendix B includes tabulated data for test dates, ambient temperature, relative humidity, opener air speed, fan speed, and static pressure.

T10, T15, and T16 were completed outdoors and the remaining 13 treatments were conducted indoors at the Client's facility. For the first treatment conducted with the Nova

Cart (T6), the fertilizer and seed primary hoses coupled to the Tunable Towers were interchanged for openers 22 through 28 (**Figure 5**); the fertilizer exited the air seeder through the seed openers, and the seed exited through the fertilizer openers. After T6 was completed, the primary hoses were rerouted, as per the manufacturer's specifications, for proper operation during the rest of the treatments in the test plan. In PAMI's opinion, it is unlikely that this affected the distribution uniformity of either the seed or the fertilizer.

3.2.3 Germination and Vigor Testing

Samples were taken from 12 of the treatments for germination and vigor testing. The test samples were collected from all three repetitions of these 12 treatments and were separated based on the air seeder section they were obtained from (left, centre, and right). The left section samples included seed collected from openers 1 through 26, the centre section included seed collected from openers 27 through 44, and the right section included seed collected from openers 45 through 70. **Table 4** shows the germination and vigor test matrix.

Table 4. The germination and vigor test matrix.

Treatment	Equipment Type	Seed Type	Seed Rate lb/ac (kg/ha)	Number of Samples
Control	UltraPro II	Canola	N/A	3
Control	Nova Cart	Canola	N/A	3
Control	Nova Cart & UltraPro II	Wheat	N/A	3
Control	Nova Cart & UltraPro II	Soybeans	N/A	3
Control	Nova Cart & UltraPro II	Peas	N/A	3
T2	Nova Cart	Wheat	120 (135)	8[a]
T3	Nova Cart	Canola	4.7 (5.3)	9
T4	Nova Cart	Canola	2.8 (3.1)	9
T5	Nova Cart	Canola	2.0 (2.2)	9
T6	Nova Cart	Soybeans	59 (66)	9
T7	Nova Cart	Peas	230 (258)	9
T10	UltraPro II	Wheat	120 (135)	9
T11	UltraPro II	Canola	2.8 (3.1)	6[b]
T12	UltraPro II	Canola	4.7 (5.3)	9
T13	UltraPro II	Canola	2.0 (2.2)	9
T14	UltraPro II	Soybeans	59 (66)	9
T15	UltraPro II	Peas	230 (258)	9

[a] Repetition 3 of T2 right section not available

[b] Only two repetitions completed for T11

3.3 Data Analysis

The raw data was first treated by removing outliers due to data collection issues or data points more than three standard deviations from the mean, unless a consistent trend was observed across repetitions and/or treatments. A few plugged runs occurred, in these cases, all data from that tower for that repetition were removed. The data was then normalized using both the actual run times and the desired run time for the test; this was calculated to be 85 seconds based on a 5 mph (8 km/h) simulated ground speed.

Coefficients of variation (CV) were calculated for each treatment. Both CV_2 and CV_1, were determined for the data and are explained in **Figure 10**.

CV_2 can be defined as the coefficient of variation over the entire width of the air seeder. For CV_2, for each repetition, the average sample weight and standard deviation are determined for all 70 openers, then the three CV_2 values for each repetition are averaged to give a final CV_2 for the treatment. In a practical sense, CV_2 is a measure of seed/fertilizer rate uniformity across the width of the air seeder.

CV_1 can be defined as the coefficient of variation of an individual opener, over multiple repetitions. The average weight and standard deviation over the three repetitions for one opener are used to calculate CV_1 for that single opener. In a practical sense, CV_1 is a measure of seed/fertilizer rate uniformity in the direction of travel.

Opener	Rep 1	Rep 2	Rep 3	Average (Avg.)	Standard Deviation (SD)		
1	x	x	x	Opener 1 Avg.	Opener 1 SD	**Opener 1 CV_1**	Averaged → **CV_1**
2	x	x	x	Opener 2 Avg.	Opener 2 SD	**Opener 2 CV_1**	
...	...	...	...	...	...	...	
70	x	x	x	Opener 70 Avg.	Opener 70 SD	**Opener 70 CV_1**	
	Rep 1 Avg.	Rep 2 Avg.	Rep 3 Avg.				
	Rep 1 SD	Rep 2 SD	Rep 3 SD				
	Rep 1 CV_2	**Rep 2 CV_2**	**Rep 3 CV_2**				
	Averaged → **CV_2**						

Figure 10. A visual representation of CV_2 and CV_1 for a treatment.

Box plots were created for each of the treatments to visually show the relationship between the distribution variation and the manifolds or opener groupings. **Figure 11** highlights the data that is communicated by a box plot.

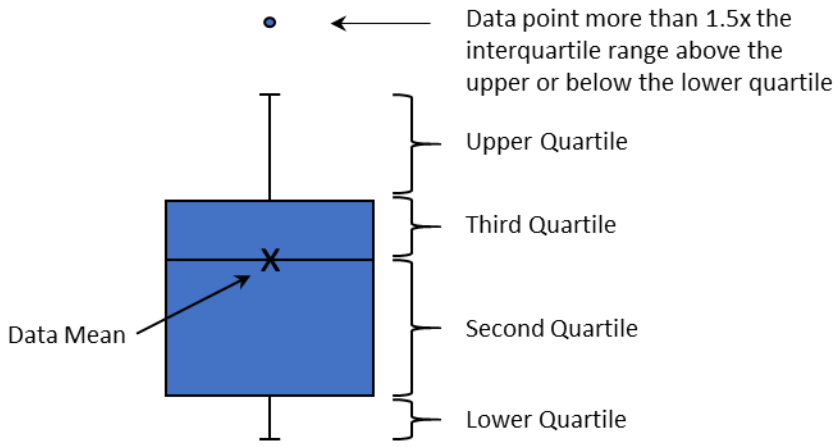


Figure 11. The box plot schematic.

A statistical analysis of the germination and vigor data was completed using Minitab 18. Statistical analysis helps to determine whether differences among treatments or groupings of data are due to the treatment itself or due to random variability. A statistically significant result means that the difference is highly likely to be due to the treatment itself.

An analyses of variance (ANOVA) was completed to determine the effect of air seeder section on germination and vigor. If there was a significant difference ($P<0.05$), then a Tukey means separation was conducted to determine which sections were different from the others. For the Tukey test, any sections that do not share common letters were determined to be significantly different. For all statistical analysis, a 95% confidence level was used.

4. Results and Discussion

This section includes an analysis of CV_2, CV_1 and distribution variation between manifolds/opener groupings as well as germination and vigor results.

4.1 Seed Distribution

CV_2 and CV_1 were determined for each of the 16 treatments. CV_2 represents the variation over the width of the air seeder, while CV_1, represents the variation over multiple repetitions of a single opener. Box plots for each of the treatments are below showing the distribution variation over the 10 manifolds/opener groupings.

4.1.1 Nova Cart

The Nova Cart CV_2 and CV_1 results are shown in **Table 5** and **Table 6**.

Table 5. The Nova Cart CV_2 results.

Treatment	**Seed Type**	**Seed Rate** lb/ac (kg/ha)	**CV_2 Seed** (%)	**Fertilizer Rate** lb/ac (kg/ha)	**CV_2 Fertilizer** (%)
T1	Wheat	95 (106)	7.0	N/A	N/A
T2	Wheat	120 (135)	7.3	200 (224)	17.0
T3	Canola	4.7 (5.3)	15.9	100 (112)	13.0
T4	Canola	2.8 (3.1)	17.2	50 (56)	10.2
T5	Canola	2.0 (2.2)	16.2	N/A	N/A
T6	Soybeans	59 (66)	11.8	160 (179)	7.5
T7	Peas	230 (258)	11.3	N/A	N/A
T8	Peas	180 (202)	11.7	147 (165)	8.3

Table 6 . The Nova Cart CV_1 results.

Treatment	**Seed Type**	**Seed Rate** lb/ac (kg/ha)	**CV_1 Seed** (%)	**Fertilizer Rate** lb/ac (kg/ha)	**CV_1 Fertilizer** (%)
T1	Wheat	95 (106)	1.2	N/A	N/A
T2	Wheat	120 (135)	5.9	200 (224)	3.6
T3	Canola	4.7 (5.3)	11.7	100 (112)	4.0
T4	Canola	2.8 (3.1)	7.4	50 (56)	1.5
T5	Canola	2.0 (2.2)	3.7	N/A	N/A
T6	Soybeans	59 (66)	5.8	160 (179)	3.3
T7	Peas	230 (258)	1.8	N/A	N/A
T8	Peas	180 (202)	4.4	147 (165)	8.3

For the Nova Cart seed treatments, CV_2 ranged from 7.0% to 17.2% and CV_1 ranged from 1.2% to 11.7%; the highest variation occurring in canola and the lowest variation occurring in wheat, for both CV_2 and CV_1. For the Nova Cart fertilizer treatments, CV_2 ranged from 7.5% up to 17.0% and CV_1 ranged from 1.5% to 8.3%, with no obvious trend between fertilizer rate and uniformity.

Figure 12 through **Figure 24** include seed and fertilizer distribution box plots. It is possible for a treatment to have a relatively good CV_2 and still show visual differences amongst manifolds on the box plots below. Before making conclusions from the box plots, it is important to consider the magnitude of the variation and the scale of the graphs. There were no obvious correlations between variability and seed type or manifold position.

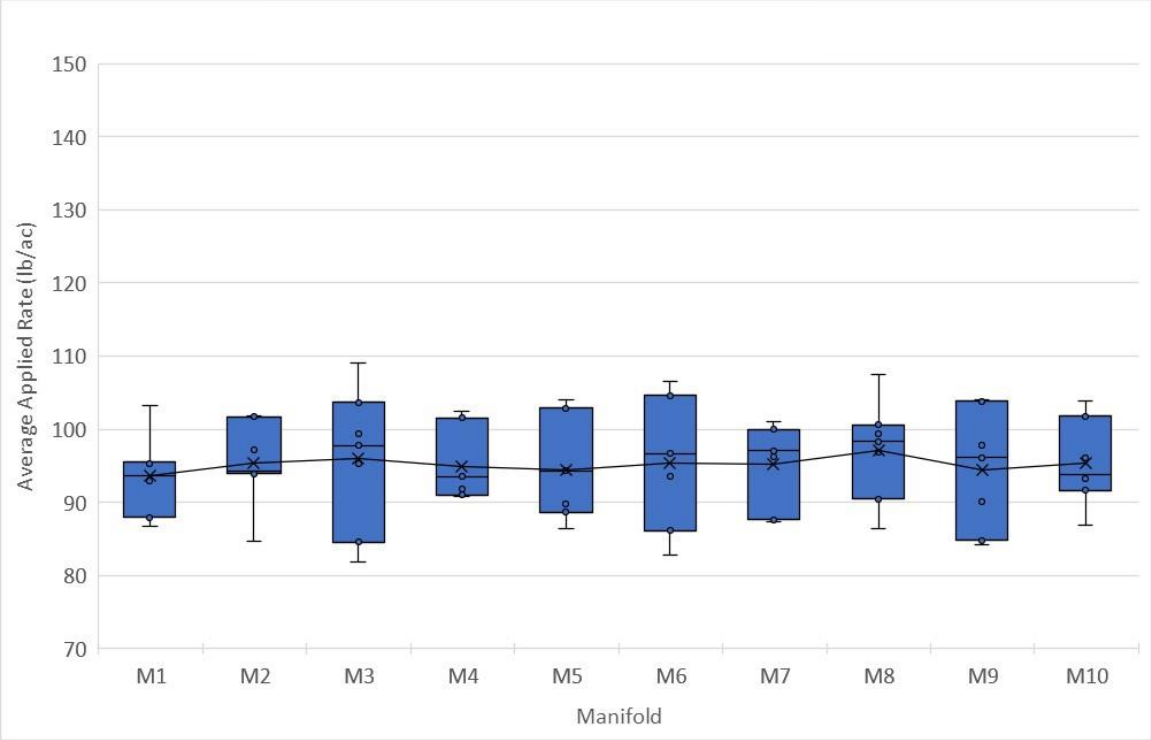


Figure 12. Nova Cart - Wheat 95 lb/ac (106 kg/ha) - Treatment 1.

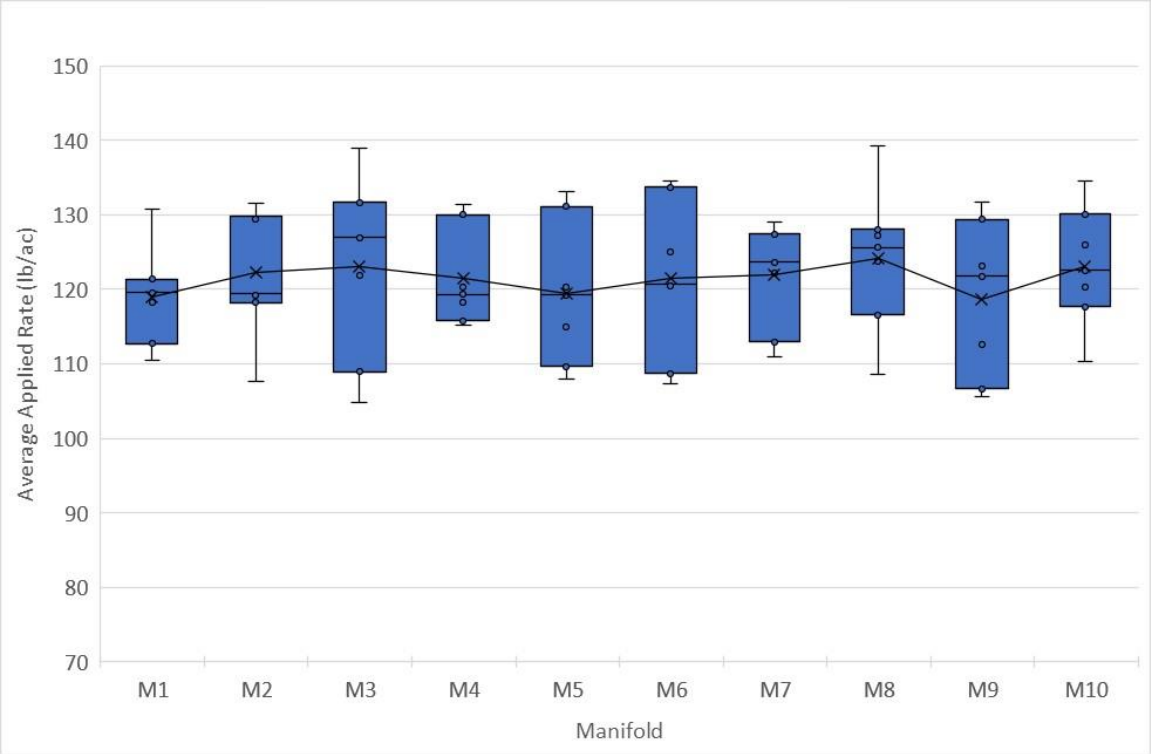


Figure 13. Nova Cart - Wheat 120 lb/ac (135 kg/h) – Treatment 2.

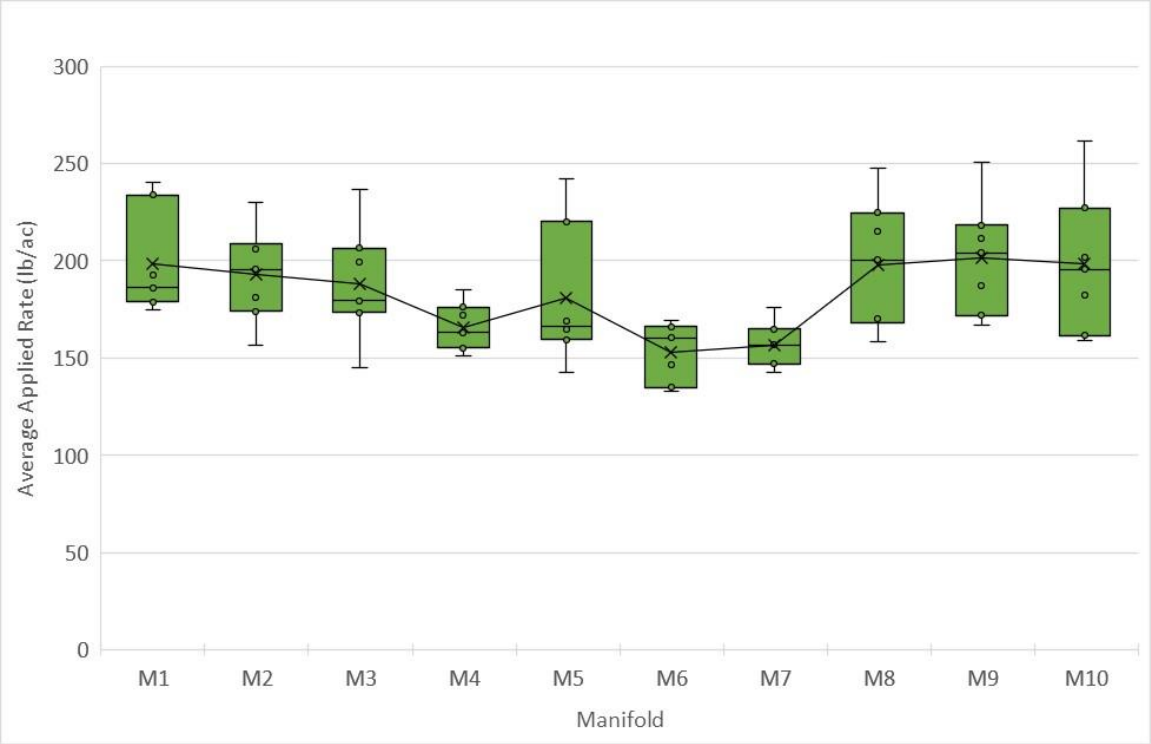


Figure 14. Nova Cart - Fertilizer 200 lb/ac (224 kg/ha) - Treatment 2.

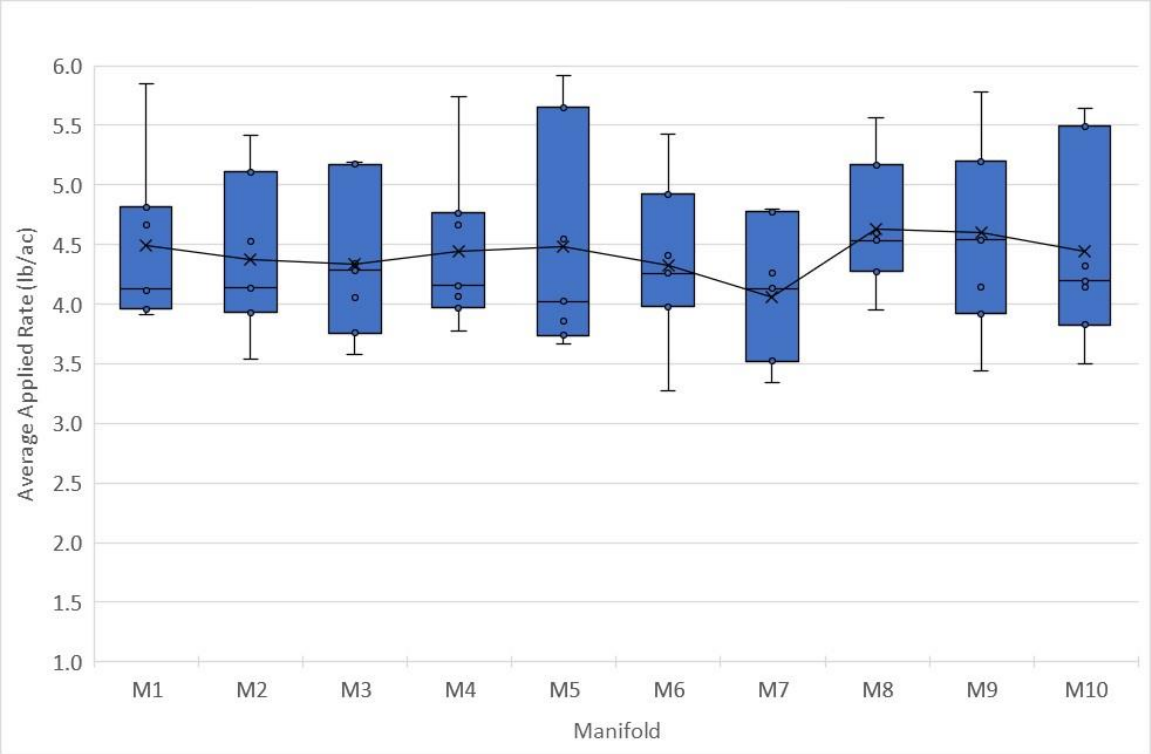


Figure 15. Nova Cart - Canola 4.7 lb/ac (5.3 kg/ha) - Treatment 3.

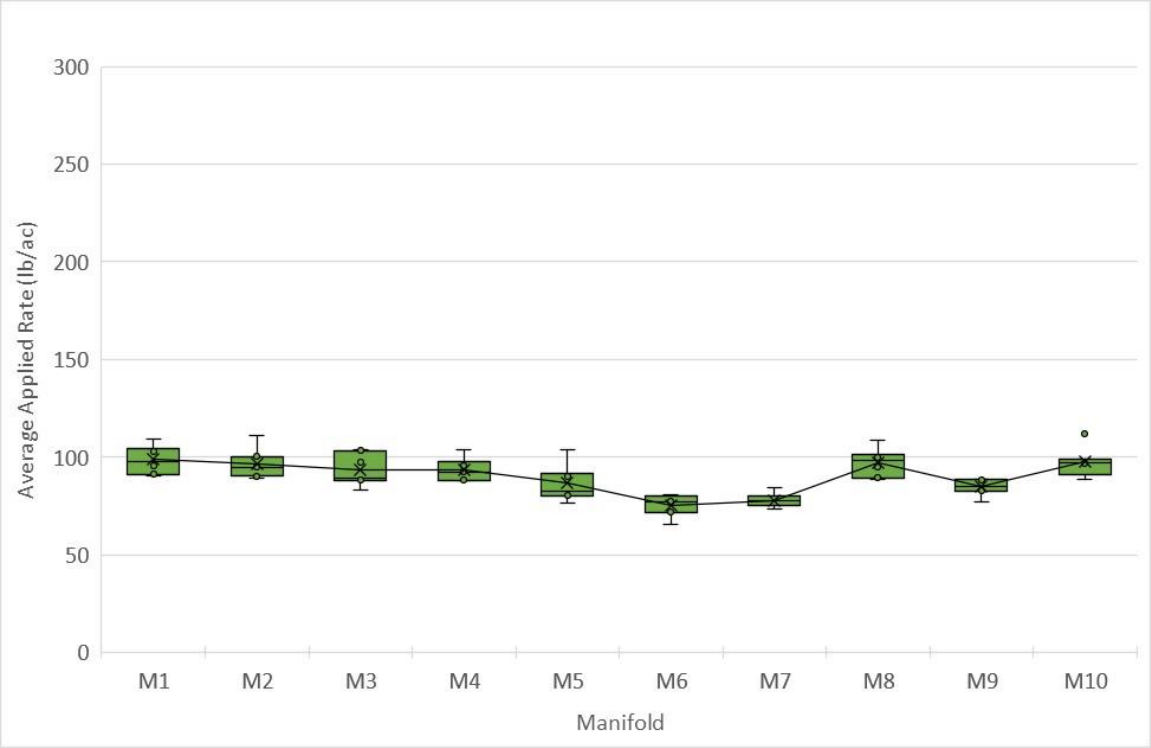


Figure 16. Nova Cart - Fertilizer 100 lb/ac (112 kg/ha) - Treatment 3.

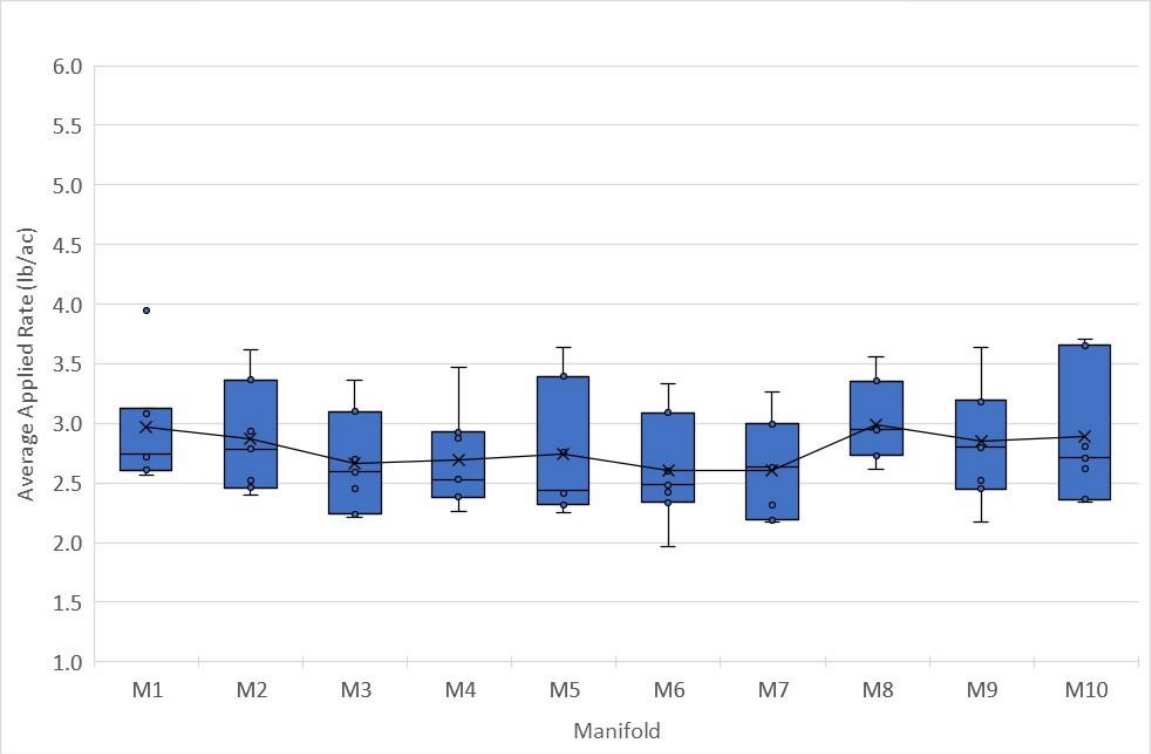


Figure 17. Nova Cart - Canola 2.8 lb/ac (3.1 kg/ha) - Treatment 4 (2 ac. test).

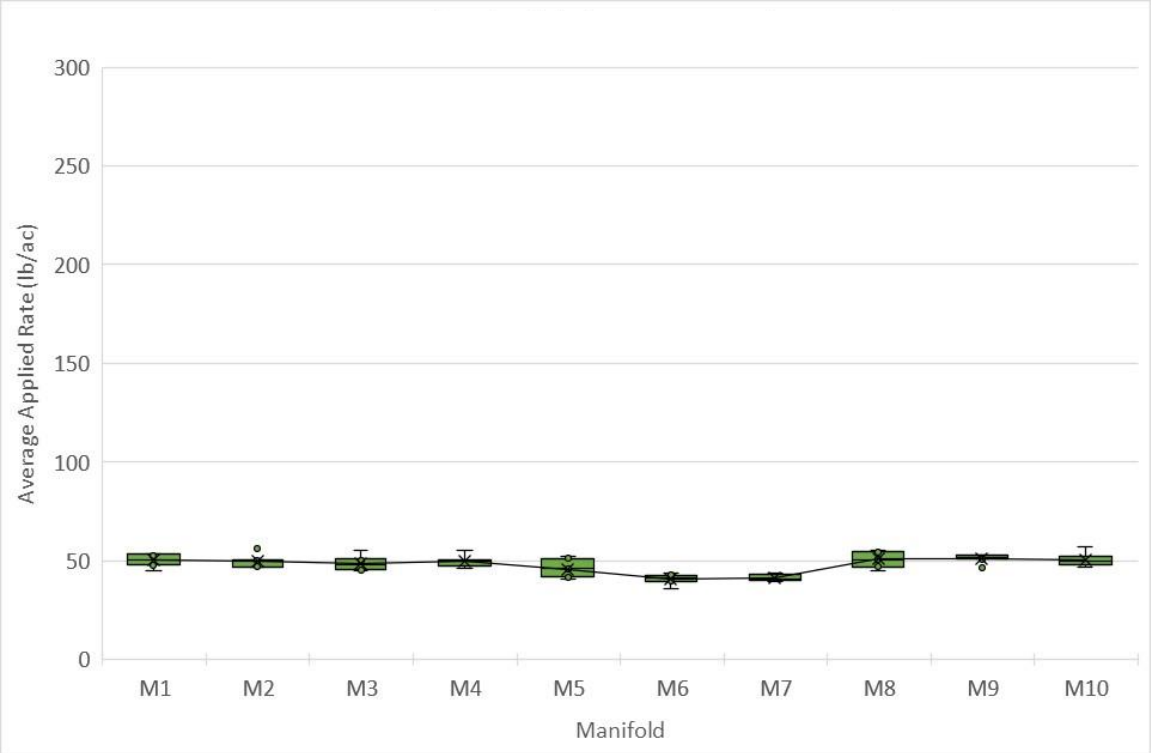


Figure 18. Nova Cart - Fertilizer 50 lb/ac (56 kg/ha) - Treatment 4 (2 ac. test).

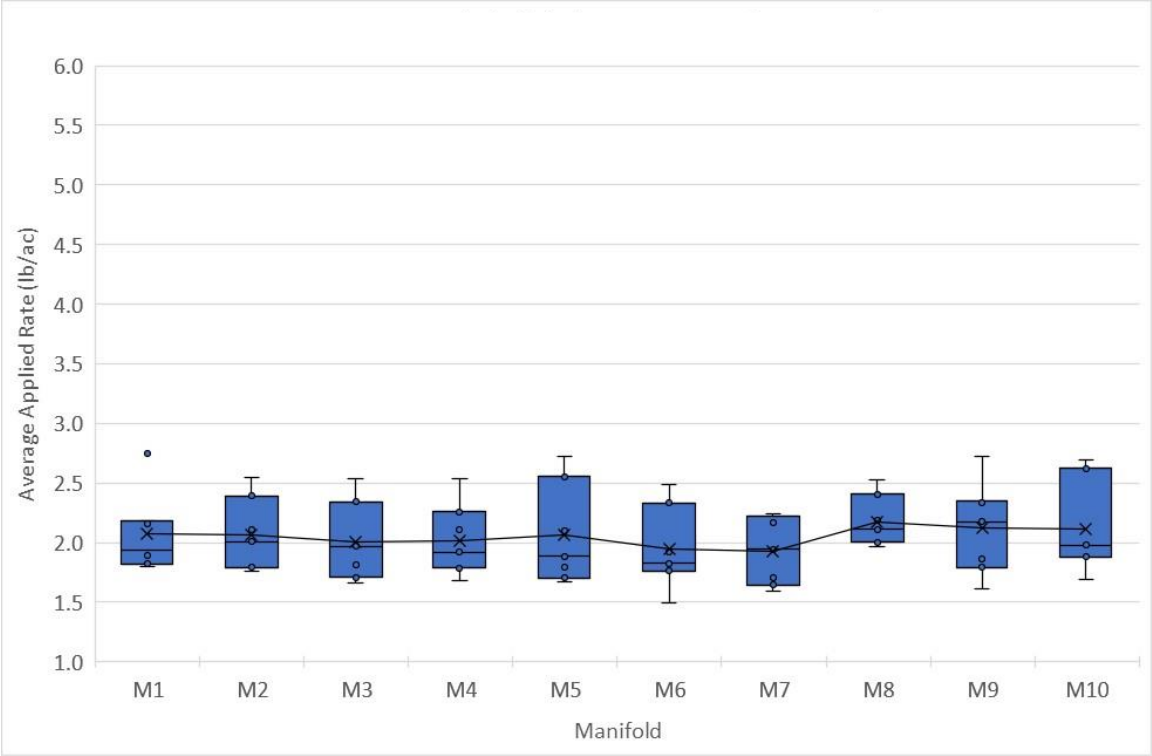


Figure 19. Nova Cart - Canola 2.0 lb/ac (2.2 kg/ha) - Treatment 5 (2 ac. test).

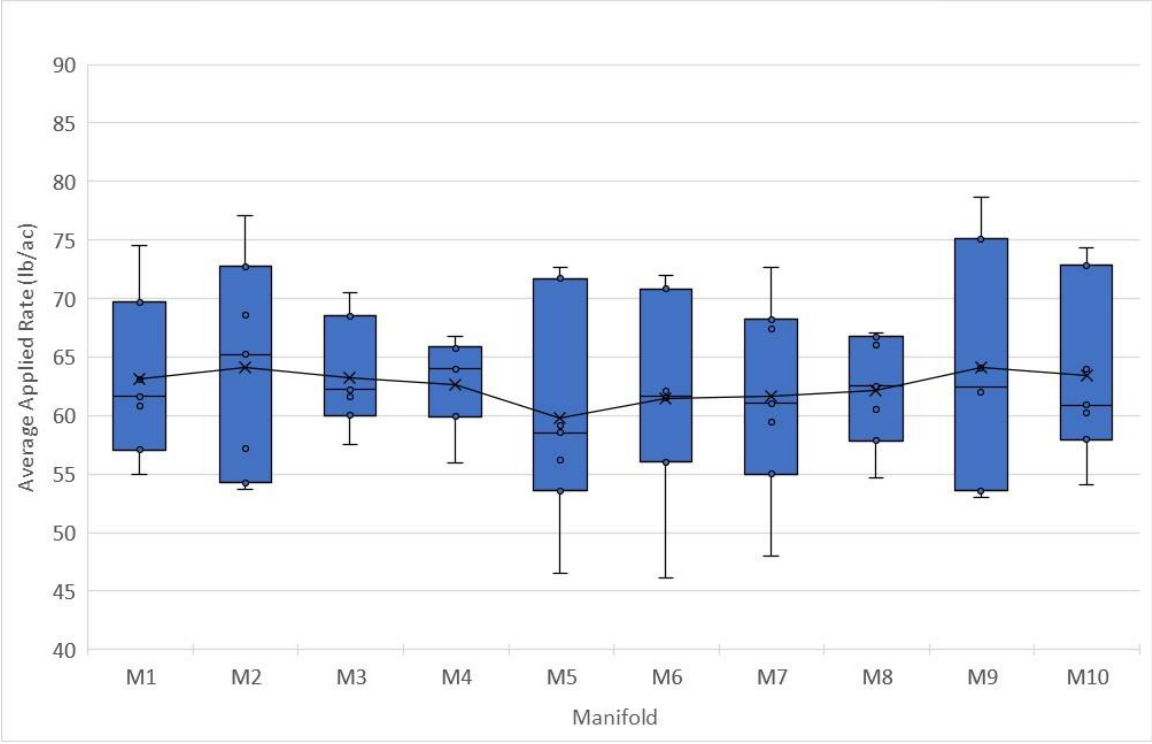


Figure 20. Nova Cart - Soybeans 59 lb/ac (66 kg/ha) - Treatment 6.

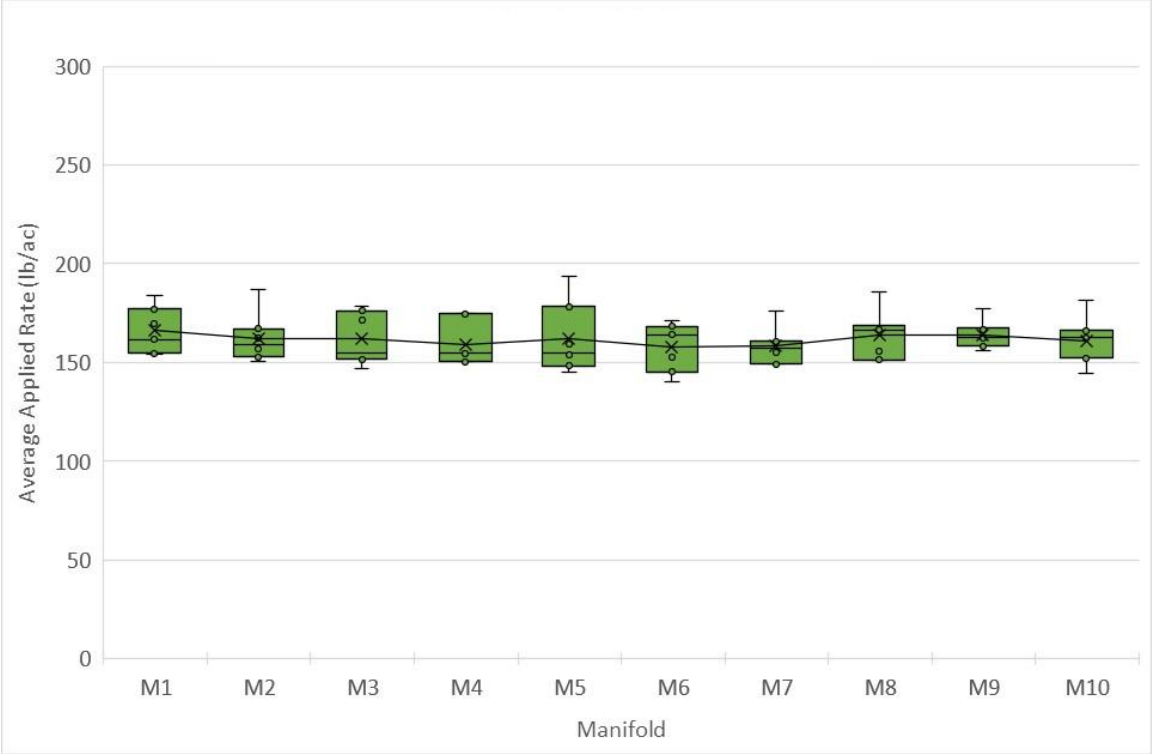


Figure 21. Nova Cart - Fertilizer 160 lb/ac (179 kg/ha) - Treatment 6.

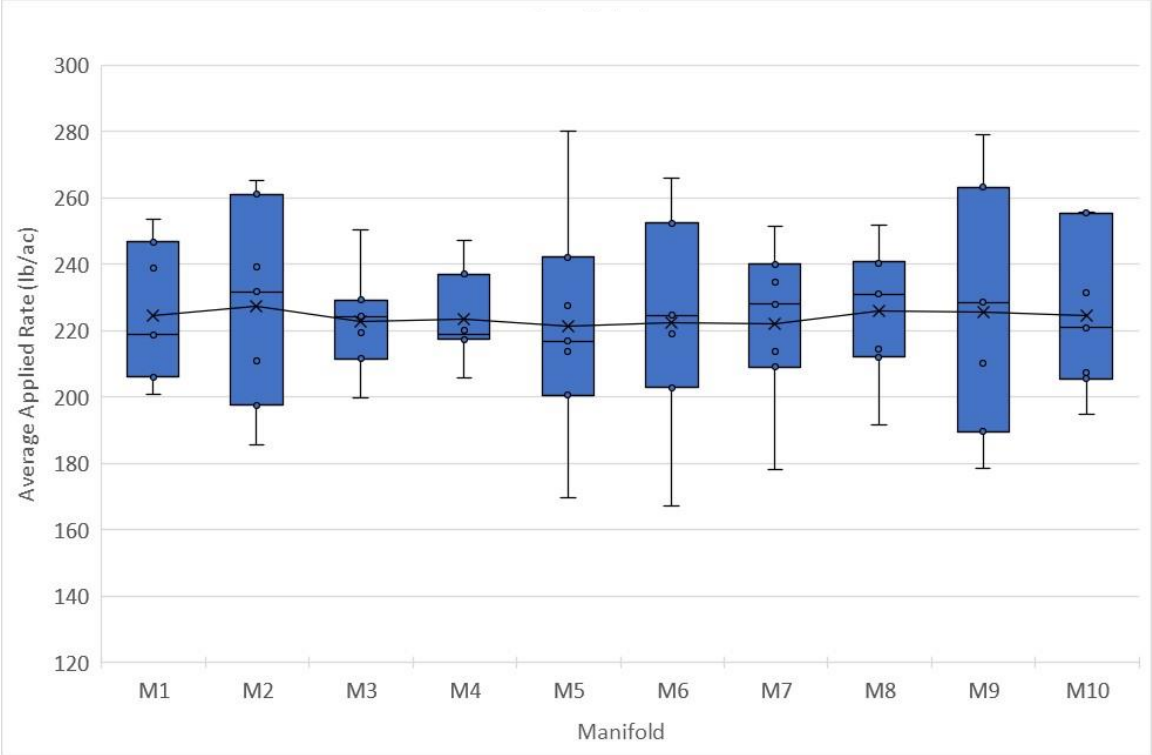


Figure 22. Nova Cart - Peas 230 lb/ac (258 kg/ha) - Treatment 7.

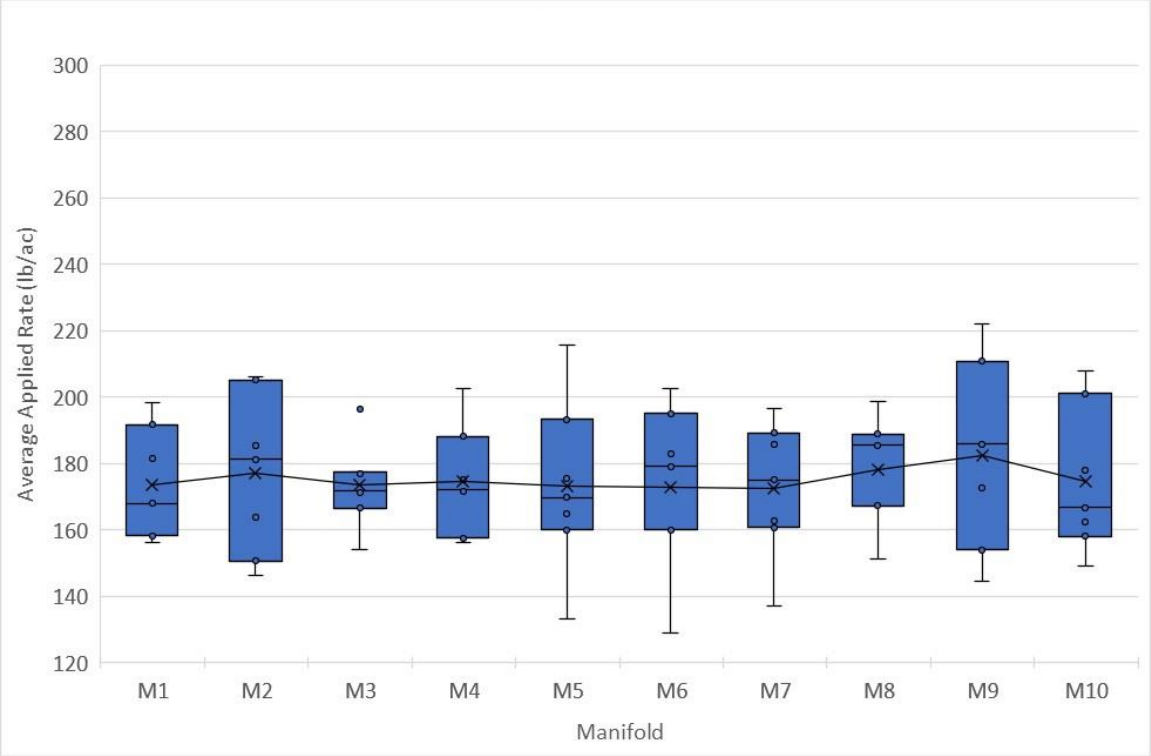


Figure 23. Nova Cart - Peas 180 lb/ac (202 kg/ha) - Treatment 8.

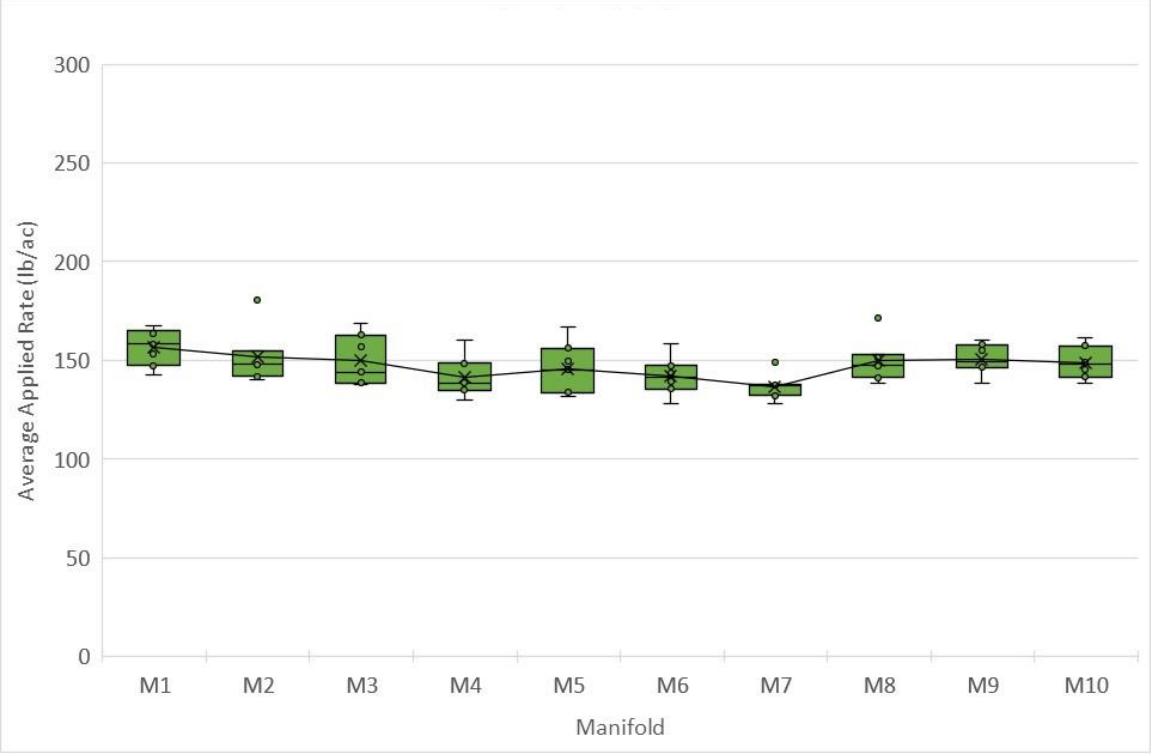


Figure 24. Nova Cart - Fertilizer 180 lb/ac (202 kg/ha) - Treatment 8.

4.1.2 UltraPro II

The UltraPro II has a meter and distribution hose for each opener. The meters are clustered into groups of eight, with seven of the lines being utilized for the air seeder configuration used during this project. **Table 7** shows the CV_2 and CV_1 results for each of the eight treatments conducted with the UltraPro II.

Table 7. The UltraPro II CV_2 and CV_1 results.

Treatment	**Seed Type**	**Seed Rate** lb/ac (kg/ha)	**CV_2 Seed** (%)	**CV_1 Seed** (%)
T9	Wheat	95 (106)	3.2	0.9
T10	Wheat	120 (135)	3.4	2.4
T11[a]	Canola	2.8 (3.1)	5.6	1.5
T12	Canola	4.7 (5.3)	7.9	2.6
T13	Canola	2.0 (2.2)	8.8	7.1
T14	Soybeans	59 (66)	5.8	1.5
T15	Peas	230 (258)	5.7	1.5
T16	Peas	180 (202)	4.8	1.1

[a] Only two repetitions completed for T11.

For the UltraPro II, seed CV_2 ranged from 3.2% to 8.8% and CV_1 ranged from 0.9% to 7.1%, with the highest variation occurring in canola and the lowest variation occurring in wheat, for both CV_2 and CV_1.

Figure 25 through **Figure 32** show the seed distribution between opener groupings for the UltraPro II treatments. It is possible for a treatment to have a relatively good CV_2 and still show visual differences amongst opener groupings on the box plots below. Before making conclusions from the box plots, it is important to consider the magnitude of the variation and the scale of the graphs. There was no obvious correlation between variability and seed type or opener grouping.

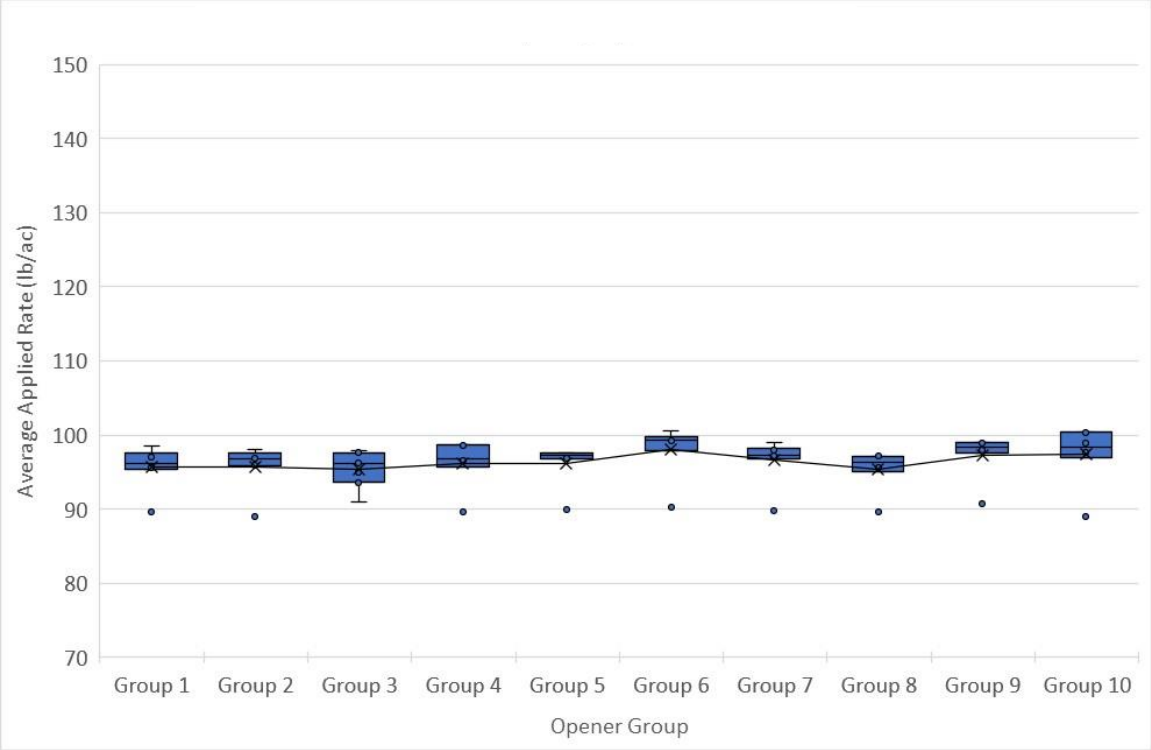


Figure 25. UltraPro II - Wheat 95 lb/ac (106 kg/ha) - Treatment 9.

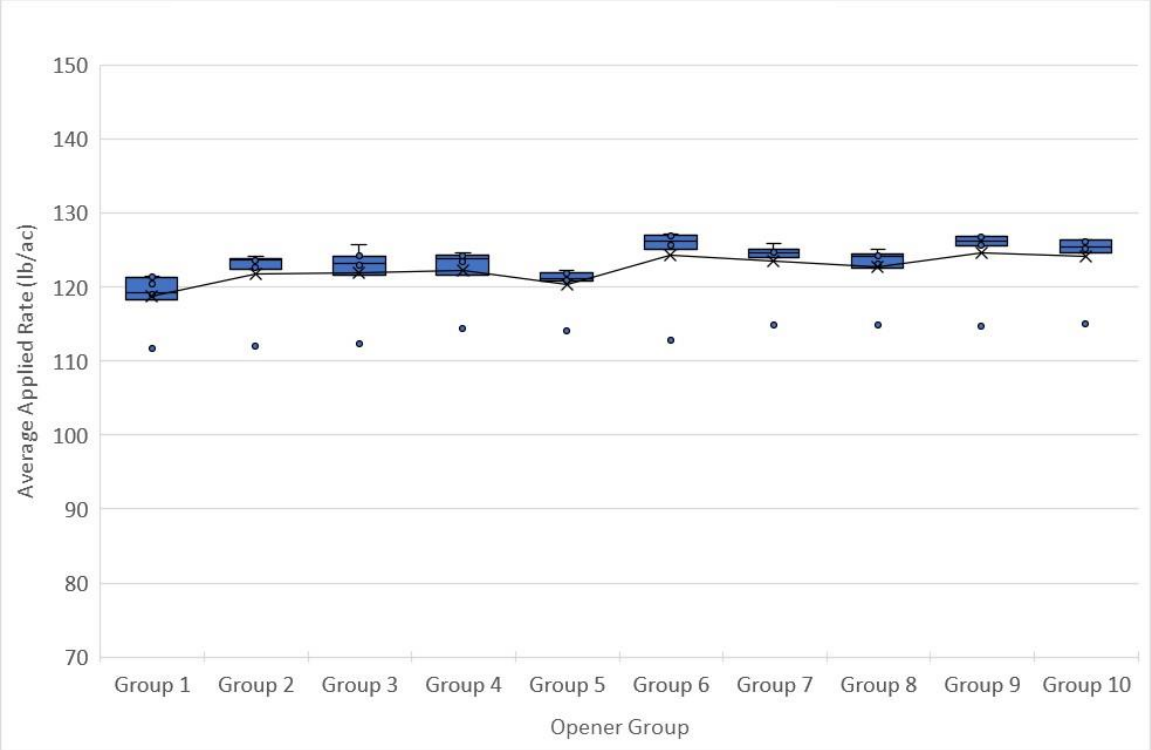


Figure 26. UltraPro II - Wheat 120 lb/ac (135 kg/ha) - Treatment 10.

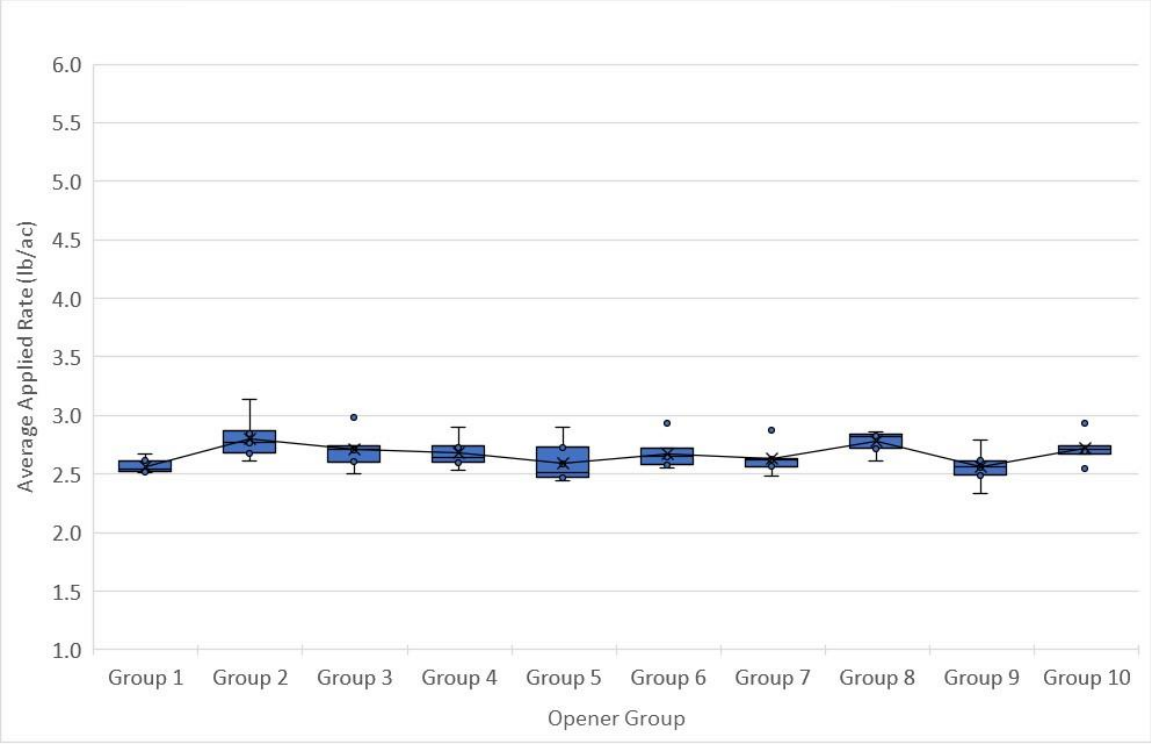


Figure 27. UltraPro II - Canola 2.8 lb/ac (3.1 kg/ha) - Treatment 11 (2 ac. test).

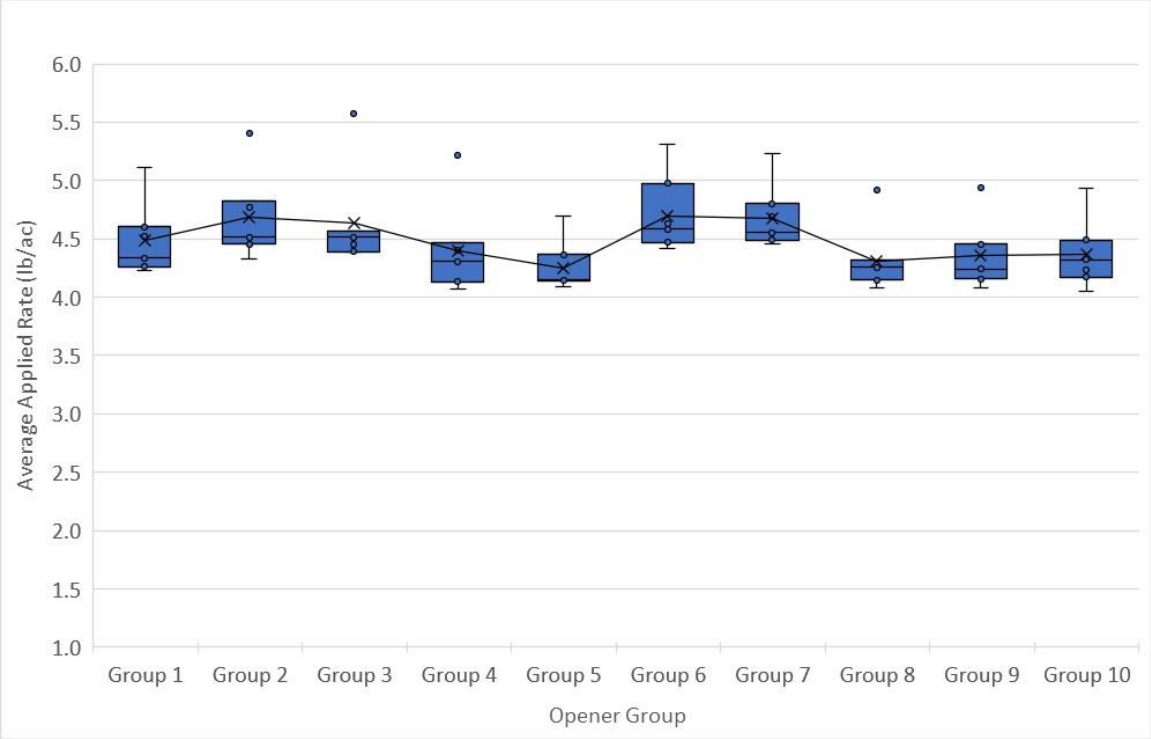


Figure 28. UltraPro II - Canola 4.7 lb/ac (5.3 kg/ha) - Treatment 12.

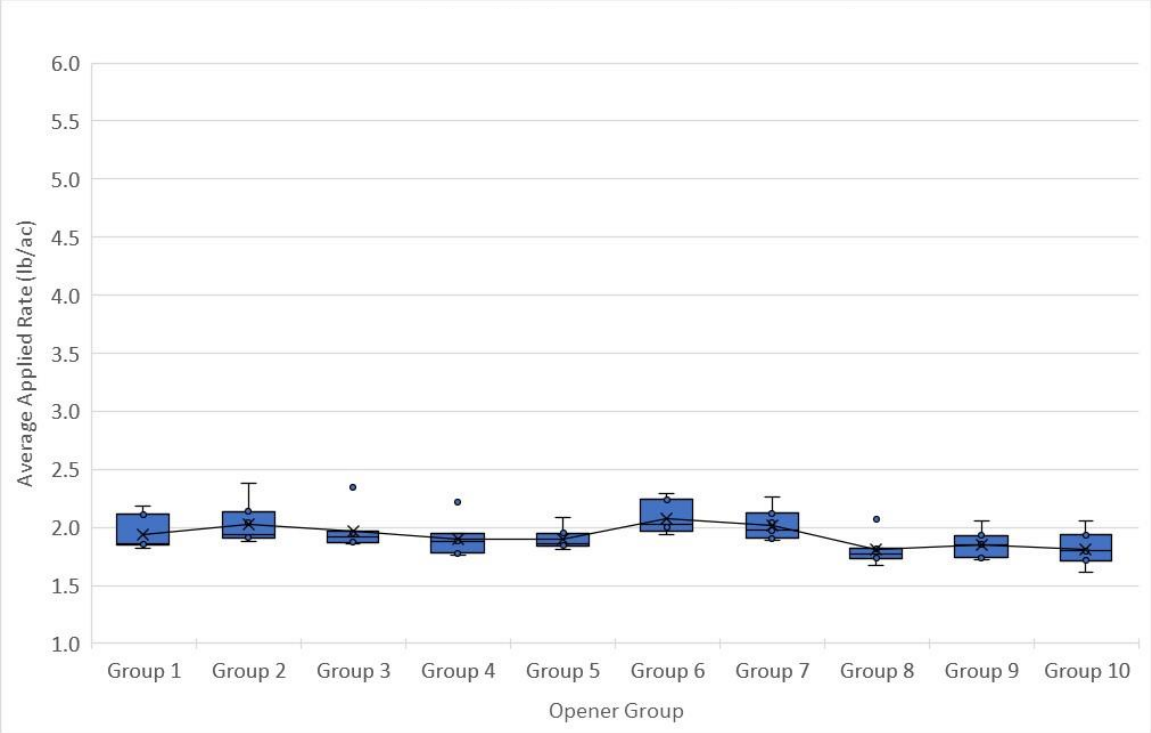


Figure 29. UltraPro II - Canola 2.0 lb/ac (2.2 kg/ha) - Treatment 13 (2 ac. test).

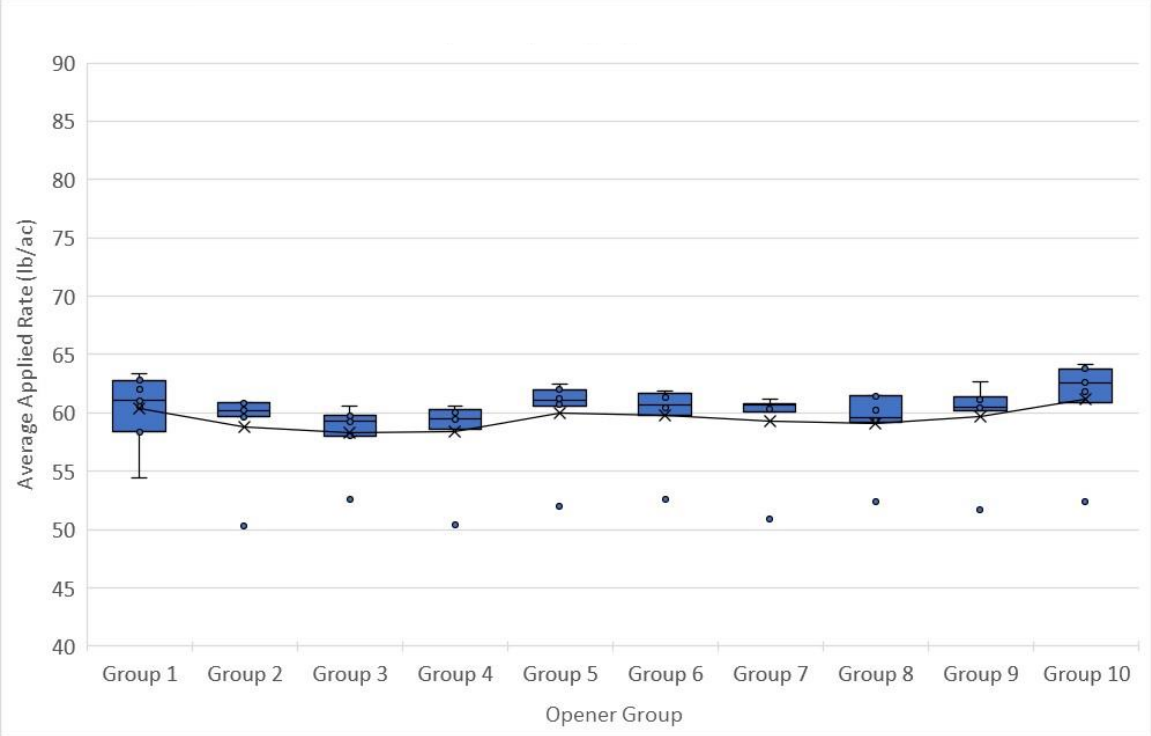


Figure 30. UltraPro II - Soybeans 59 lb/ac (66 kg/ha) - Treatment 14.

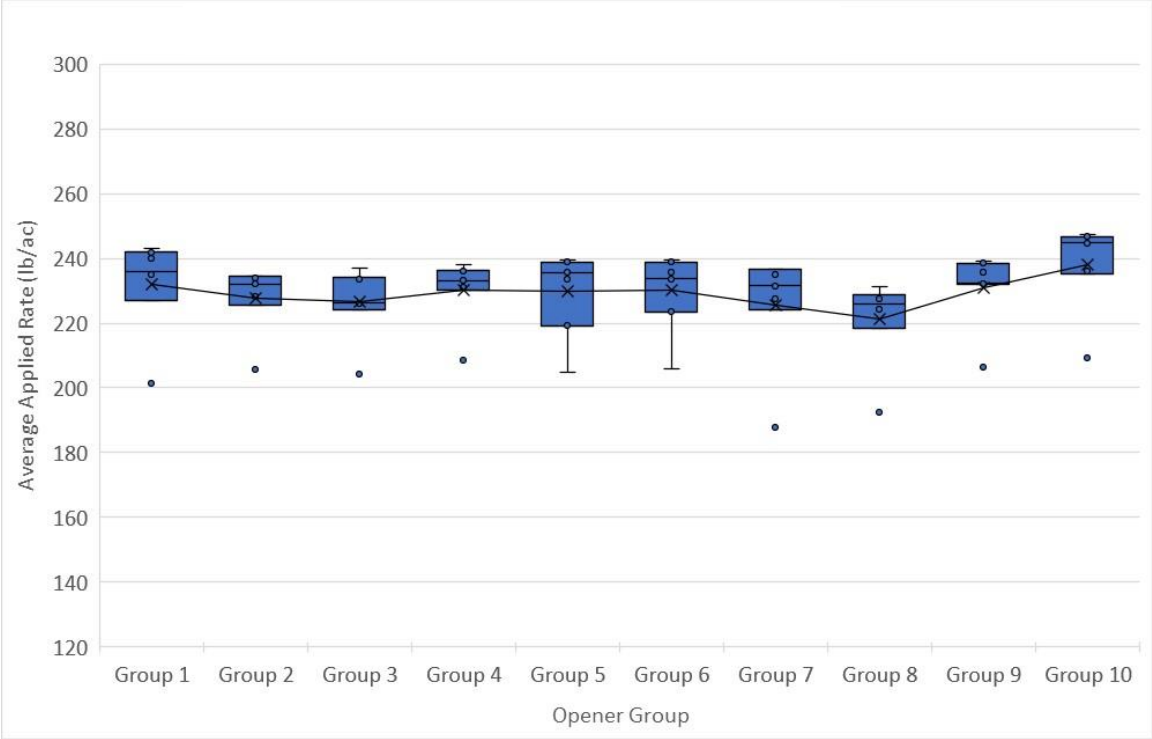


Figure 31. UltraPro II - Peas 230 lb/ac (258 kg/ha) - Treatment 15.

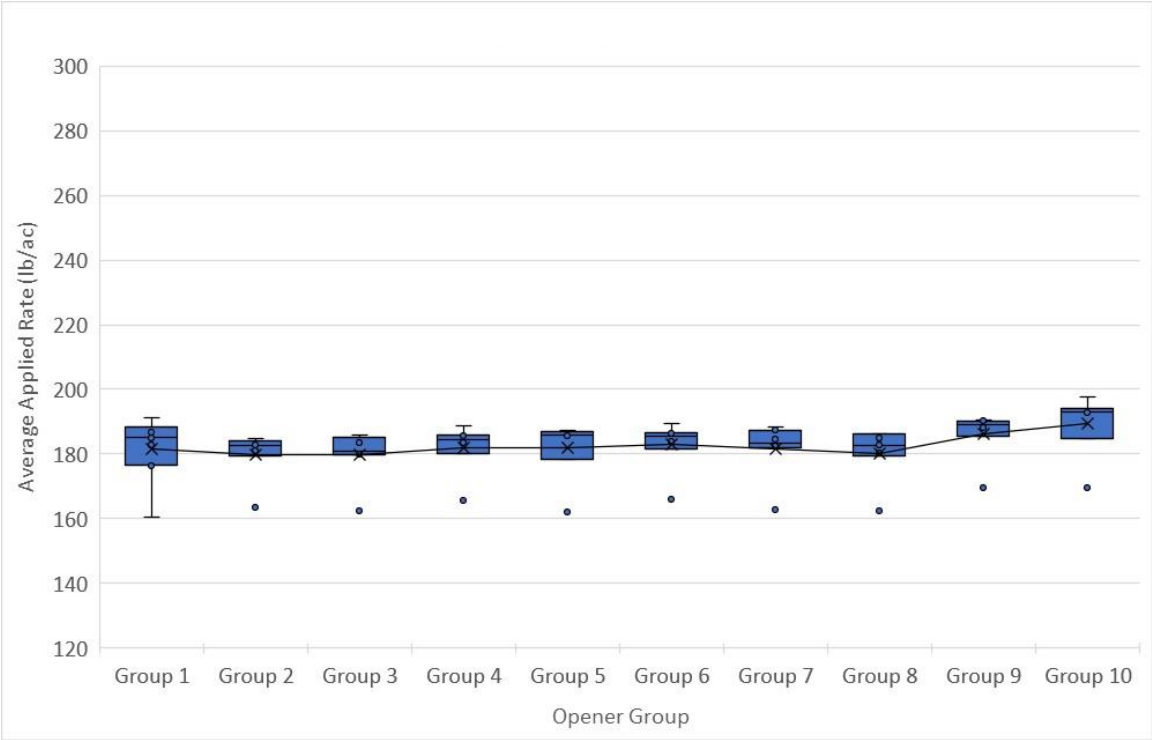


Figure 32. UltraPro II - Peas 180 lb/ac (202 kg/ha) - Treatment 16.

4.2 Seed Damage

Due to the schedule and timing of this project, high quality seed was not available for testing. This is important to note when viewing the low pre-test (control) germination and vigor results presented within this section, specifically peas and soybeans.

Germination and vigor tests were conducted on 12 of the 16 treatments, six per air seeder configuration. For each configuration, the treatments included one seed rate from wheat, peas, and soybeans, and all of the seed rates from canola. This section will review and discuss the results; **Appendix C** includes the full set of results received from Discovery Seed Labs.

It is important to note that air seeder metering and delivery systems, as tested during this project, are only one of many factors contributing to seed mortality from seed bag to established plants. Other factors not investigated in this project include soil conditions, fertility, moisture, and pests, all of which are important when determining seeding rates.

4.2.1 Nova Cart

For the Nova Cart, T2, T3, T4, T5, T6, and T7 were sampled and submitted to Discovery Seed Labs for germination and vigor tests. **Table 8** and **Table 9** display the resulting differences between pre-test (control) and post-test germination and vigor for each of the listed treatments. Any results found to have significant differences are accompanied by their Tukey grouping, highlighted in red, and discussed below. Values that do not share a common Tukey grouping letter exhibited a significant difference. To avoid overcrowding, the Tukey grouping was omitted for any results that did not exhibit a significant difference. The raw data is included in **Appendix C.**

Table 8. The Nova Cart average germination results.

Treatment	**Seed Type**	**Seed Rate** lb/ac (kg/ha)	**Pre-Test Germination (Control)** (%)	**Difference between Pre-Test and Post-Test Germination** (%)[b]		
				Left	**Centre**	**Right**
T2	Wheat	120 (135)	97	-1.7	+0.3	+0.8[a]
T3	Canola	4.7 (5.3)	95	+2.0	+2.7	+0.0
T4	Canola	2.8 (3.1)	95	+1.0	-2.0	-3.0
T5	Canola	2.0 (2.2)	95	+2.3	+2.3	-2.7
T6	Soybeans	59 (66)	80	-4.7	-1.3	-2.3
T7	Peas	230 (258)	44	+3.7	+1.3	-1.3

[a] Only two repetitions completed for the right section of T2

[b] Difference is determined by subtracting post-test result percentage from pre-test result percentage

Table 9. The Nova Cart average vigor results.

Treatment	Seed Type	Seed Rate lb/ac (kg/ha)	Pre-Test Germination (Control) (%)	Difference between Pre-Test and Post-Test Vigor (%)[b]		
				Left	Centre	Right
T2	Wheat	120 (135)	96 (A)	-8.7 (B)	0.0 (A)	-2.0 (A)[a]
T3	Canola	4.7 (5.3)	95	+1.0	+2.7	+0.7
T4	Canola	2.8 (3.1)	95	0.0	-1.7	-1.0
T5	Canola	2.0 (2.2)	95	+1.3	+0.3	+0.3
T6	Soybeans	59 (66)	60 (B)	+0.3 (B)	+3.7 (AB)	+7.3 (A)
T7	Peas	230 (258)	42	-2.3	-2.7	+0.7

[a] Only two repetitions completed for the right section of T2

[b] Difference is determined by subtracting post-test result percentage from pre-test result percentage

For the Nova Cart, the germination results for the individual air seeder sections were not significantly different from the pre-test (control) sample. In regards to vigor, the left sample from T2 (wheat) and the right sample from T6 (soybeans) exhibited a significant difference compared to the pre-test (control) samples. For all other treatments, the difference between pre-test (control) and post-test results can be attributed to random variability. Some of the results show an increase in germination or vigor from pre-test (control) to post-test, this can also be attributed to random variability within tests.
It should be noted that the low germination and vigor rates for soybeans and peas were visible in the pre-test (control) samples and are due to the low quality of available seed at the time of testing.

4.2.2 Ultra Pro II

For the UltraPro II, T10, T11, T12, T13, T14, and T15 were sampled and submitted to Discovery Seed Labs for germination and vigor tests. **Table 10** and **Table 11** display the resulting differences between pre-test (control) and post-test germination and vigor for each of the listed treatments. Any results found to have statistical significance are accompanied by their Tukey grouping, highlighted in red, and discussed below. Values that do not share a common Tukey grouping letter exhibited a significant difference. To avoid overcrowding, the Tukey grouping was omitted for any results that did not exhibit a significant difference. The raw data is included in **Appendix C.**

Table 10. The UltraPro II average germination results.

Treatment	Seed Type	Seed Rate lb/ac (kg/ha)	Pre-Test Germination (Control) (%)	Difference between Pre-Test and Post-Test Germination (%)[b]		
				Left	Centre	Right
T10	Wheat	120 (135)	97	+0.7	+0.0	+1.0
T11[a]	Canola	2.8 (3.1)	98	+0.8	+0.8	+0.8
T12	Canola	4.7 (5.3)	98	+0.7	0.0	-0.7
T13	Canola	2.0 (2.2)	98	-0.3	-4.3	-1.3
T14	Soybeans	59 (66)	80	-0.7	+1.3	+3.3
T15	Peas	230 (258)	44	+3.7	-1.0	+2.7

[a] Only two repetitions completed for T11

[b] Difference is determined by subtracting post-test result percentage from pre-test result percentage

Table 11. The UltraPro II average vigor results.

Treatment	Seed Type	Seed Rate lb/ac (kg/ha)	Pre-Test Vigor (Control) (%)	Difference between Pre-Test and Post-Test Vigor (%)[b]		
				Left	Centre	Right
T10	Wheat	120 (135)	96 (A)	-6.0 (B)	-6.0 (B)	-4.0 (B)
T11[a]	Canola	2.8 (3.1)	96	-5.2	-3.2	-3.7
T12	Canola	4.7 (5.3)	96	-2.0	+0.3	-1.0
T13	Canola	2.0 (2.2)	96 (A)	-7.3 (B)	-1.7 (AB)	-2.3 (AB)
T14	Soybeans	59 (66)	60	+4.3	+6.0	+4.7
T15	Peas	230 (258)	42	-3.0	+1.3	-2.3

[a] Only two repetitions completed for T11

[b] Difference is determined by subtracting post-test result percentage from pre-test result percentage

For the UltraPro II, the germination results for the individual air seeder sections were not significantly different from the pre-test (control) sample. In regards to vigor, it was determined that for T10 (wheat) all three sections were significantly different from the pre-test (control) sample, as shown by the Tukey groupings in **Table 11**. T13 (canola) results showed that the left section samples were significantly different from the pre-test (control) sample, as shown by the Tukey groupings in **Table 11**. For all other treatments, the difference between pre-test (control) and post-test results can be attributed to random variability. Some of the results show an increase in germination or vigor from pre-test (control) to post-test, this can also be attributed to random variability within tests. It should be noted that the low germination and vigor rates for soybeans and peas were visible in the control samples and are due to the low quality of available seed at the time of testing.

Although 4 of the 12 treatments exhibited a significant difference between at least one of the air seeder sections and the pre-test (control) samples, there was no obvious correlation between seed quality and cart type, seed type, and manifold/opener grouping.

5. Conclusion

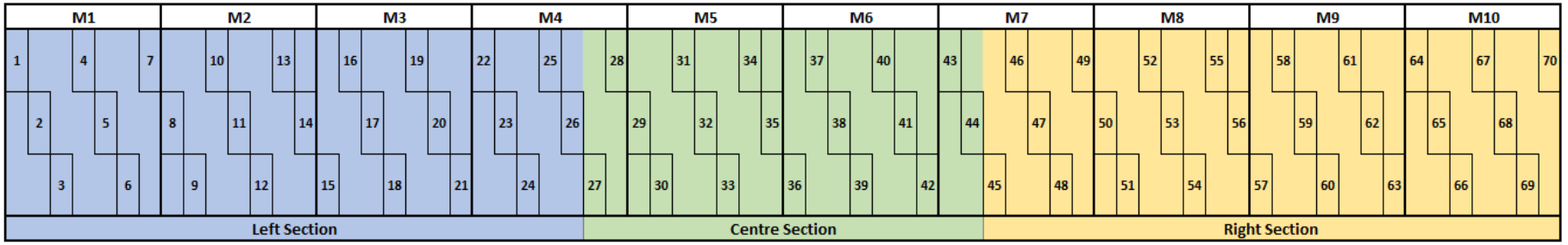
The purpose of this project was to test and validate the distribution uniformity and seed damage of two 70 ft (21 m) air seeder configurations manufactured by SeedMaster; the Nova Cart and the UltraPro II. A total of eight treatments per air seeder configuration were completed, with three repetitions per treatment. Treatments included varying rates of wheat, canola, soybeans, and peas, with some treatments also including fertilizer. Germination and vigor tests were conducted on 12 of the 16 treatments.

Two different coefficients of variation (CV_2 and CV_1) were calculated to determine the distribution variation of seed and fertilizer over the width of the air seeder as well as the variation over multiple repetitions of a single opener, respectively. CV_2 for seed distribution ranged from 7.0% to 17.2% for the Nova Cart, and 3.2% to 8.8% for the UltraPro II, with canola showing the highest variation and wheat showing the lowest, for both configurations. CV_1 ranged from 1.2% to 11.7% for the Nova Cart, and 0.9% to 7.1% for the UltraPro II, with the highest variation occurring in canola and the lowest in wheat, for both configurations. Box plots were created for each of the treatments to visually show the relationship between the distribution variation and the manifolds or opener groupings, however no obvious visual trends were observed amongst box plots.

For both the Nova Cart and UltraPro II, the germination results did not show a significant difference between any of the test samples and their corresponding pre-test (control) samples. Based on these results, the equipment was not the cause of any change in germination between pre-test (control) and post-test results, rather random variability caused these differences. In regards to vigor, four treatments, two per air seeder configuration, exhibited a significant difference between at least one of the air seeder sections and the pre-test (control) samples. In these four cases, no consistent trend was observed.

Appendix A

Equipment Map



Manifold	Openers
M1	1 - 7
M2	8 - 14
M3	15 - 21
M4	22 - 27
M5	28 - 35
M6	36 - 42
M7	43 - 47
M8	48 - 54
M9	55 - 63
M10	64 - 70

Section	Openers	Manifolds/Opener Groups
Left	1 - 26	M1, M2, M3, M4 (partial)
Centre	27 - 44	M4 (partial), M5, M6, M7 (partial)
Right	45 - 70	M7 (partial), M8, M9, M10

Appendix B

Test Conditions

Table B-1. The opener air speed, temperature, and relative humidity data.

Treatment	Equipment Type	Seed Type	Test Date	Fertilizer Opener Air Speed ft/min (m/s)			Seed Opener Air Speed ft/min (m/s)			Temperature °F (°C)	Relative Humidity (%)
				Opener 15	Opener 33	Opener 57	Opener 15	Opener 33	Opener 57		
T1	Nova Cart	Wheat	15-Oct	2800 (14.2)	2430 (12.3)	2750 (14)	2080 (10.6)	1690 (8.6)	2180 (11.1)	63.1 (17.3)	28.8
T2	Nova Cart	Wheat	12-Oct	3100 (15.7)	2800 (14.2)	3060 (15.5)	2180 (11.1)	1720 (8.7)	2440 (12.4)	65.3 (18.5)	30.1
T3	Nova Cart	Canola	15-Oct	2920 (14.8)	2930 (14.9)	2970 (15.1)	1700 (8.6)	1370 (7)	1720 (8.7)	63.7 (17.6)	34.5
T4	Nova Cart	Canola	16-Oct	2500 (12.7)	2400 (12.2)	2840 (14.4)	1710 (8.7)	1350 (6.9)	1820 (9.2)	62.6 (17)	26.4
T5	Nova Cart	Canola	15 & 16-Oct	N/A	N/A	N/A	1650 (8.4)	1200 (6.1)	1700 (8.6)	N/A	N/A
T6	Nova Cart	Soybeans	10 & 11-Oct	2220 (11.3)	2480 (12.6)	2270 (11.5)	2250 (11.4)	2030 (10.3)	2260 (11.5)	57.9 (14.4)	27.0
T7	Nova Cart	Peas	11-Oct	N/A	N/A	N/A	2360 (12)	1900 (9.7)	2590 (13.2)	58.8 (14.9)	22.3
T8	Nova Cart	Peas	11-Oct	2490 (12.6)	2520 (12.8)	2650 (13.5)	2350 (11.9)	1910 (9.7)	2580 (13.1)	56.7 (13.7)	24.4
T9	UltraPro II	Wheat	9-Oct	N/A	N/A	N/A	2400 (12.2)	2260 (11.5)	2170 (11)	32.5 (0.3)	51.9
T10	UltraPro II	Wheat	5-Oct	N/A	N/A	N/A	2360 (12)	2260 (11.5)	2310 (11.7)	43.2 (6.2)	52.4
T11	UltraPro II	Canola	10-Oct	N/A	N/A	N/A	2010 (10.2)	2020 (10.3)	2030 (10.3)	61.7 (16.5)	27.1
T12	UltraPro II	Canola	12-Oct	N/A	N/A	N/A	1830 (9.3)	1930 (9.8)	1880 (9.6)	57.9 (14.4)	32.6
T13	UltraPro II	Canola	12-Oct	N/A	N/A	N/A	1950 (9.9)	1920 (9.8)	1870 (9.5)	66.7 (19.3)	25.9
T14	UltraPro II	Soybeans	9-Oct	N/A	N/A	N/A	2490 (12.6)	2350 (11.9)	2420 (12.3)	40.1 (4.5)	31.7
T15	UltraPro II	Peas	4 & 5-Oct	N/A	N/A	N/A	N/A	N/A	N/A	44.8 (7.1)	47.7
T16	UltraPro II	Peas	5-Oct	N/A	N/A	N/A	2320 (11.8)	2160 (11)	2370 (12)	N/A	N/A

Table B-2. The treatment fan speed and static pressure data.

Treatment	Repetition	Fan 1 (Seed)			Fan 2 (Fertilizer)		
		Speed RPM (Hz)	**Static Pressure Empty** psi (kPa)	**Static Pressure Full** psi (kPa)	**Speed** RPM (Hz)	**Static Pressure Empty** psi (kPa)	**Static Pressure Full** psi (kPa)
T1	1	3604 (60)	0.8 (5.54)	0.83 (5.72)	3836 (64)	0.73 (5.02)	0.67 (4.65)
	2	3452 (58)	0.75 (5.15)	0.77 (5.31)	3705 (62)	0.65 (4.5)	0.62 (4.28)
	3	3495 (58)	0.88 (6.09)	0.86 (5.93)	3965 (66)	0.69 (4.73)	0.67 (4.63)
T2	1	3848 (64)	0.83 (5.75)	0.73 (5.04)	3863 (64)	0.83 (5.73)	0.76 (5.22)
	2	3897 (65)	0.82 (5.63)	0.85 (5.84)	3893 (65)	0.81 (5.59)	0.82 (5.66)
	3	3844 (64)	0.89 (6.11)	0.87 (6.02)	3840 (64)	0.89 (6.15)	0.91 (6.26)
T3	1	3757 (63)	0.53 (3.64)	0.52 (3.58)	3073 (51)	0.79 (5.42)	0.74 (5.1)
	2	3686 (61)	0.48 (3.34)	0.48 (3.3)	3083 (51)	0.75 (5.19)	0.77 (5.34)
	3	3809 (63)	0.53 (3.64)	0.51 (3.54)	2994 (50)	0.78 (5.36)	0.82 (5.62)
T4	1	3480 (58)	0.54 (3.75)	0.51 (3.51)	3049 (51)	0.69 (4.76)	0.69 (4.79)
	2	3491 (58)	0.52 (3.59)	0.53 (3.67)	3035 (51)	0.74 (5.1)	0.77 (5.28)
	3	3491 (58)	0.55 (3.79)	0.57 (3.93)	3017 (50)	0.75 (5.19)	0.78 (5.36)
T5	1	2941 (49)	0.48 (3.3)	N/A	N/A	N/A	N/A
	2	3035 (51)	N/A	0.53 (3.67)	N/A	N/A	N/A
	3	3139 (52)	0.5 (3.42)	0.52 (3.58)	N/A	N/A	N/A
T6	1	4370 (73)	N/A	1.16 (7.98)	4357 (73)	(NR)	1.21 (8.32)
	2	4264 (71)	1.01 (6.98)	1.09 (7.51)	4247 (71)	1 (6.89)	1.08 (7.45)
	3	4311 (72)	1.03 (7.13)	1.09 (7.52)	4302 (72)	1.03 (7.12)	1.19 (8.23)
T7	1	4374 (73)	1.09 (7.54)	1.26 (8.72)	N/A	N/A	N/A
	2	4239 (71)	1.06 (7.33)	1.25 (8.61)	N/A	N/A	N/A
	3	4365 (73)	1.09 (7.51)	1.28 (8.8)	N/A	N/A	N/A
T8	1	4370 (73)	1.07 (7.41)	1.23 (8.49)	4352 (73)	1.09 (7.52)	1.24 (8.55)
	2	4374 (73)	1.08 (7.48)	1.23 (8.47)	4352 (73)	1.11 (7.62)	1.25 (8.62)
	3	4383 (73)	1.07 (7.38)	1.22 (8.44)	4357 (73)	1.09 (7.53)	1.25 (8.62)
T9	1	4871 (81)	1.37 (9.44)	1.36 (9.39)	N/A	N/A	N/A
	2	4818 (80)	1.36 (9.35)	1.36 (9.37)	N/A	N/A	N/A
	3	4800 (80)	1.33 (9.18)	1.34 (9.25)	N/A	N/A	N/A
T10	1	4814 (80)	1.38 (9.5) [a]	1.38 (9.5) [a]	N/A	N/A	N/A
	2	4814 (80)	1.45 (10) [a]	1.45 (10) [a]	N/A	N/A	N/A
	3	4800 (80)	1.38 (9.5) [a]	1.38 (9.5) [a]	N/A	N/A	N/A
T11	1	3761 (63)	0.78 (5.39)	0.77 (5.31)	N/A	N/A	N/A
	2	3813 (64)	0.8 (5.52)	0.8 (5.49)	N/A	N/A	N/A
	3 [b]	N/A	N/A	N/A	N/A	N/A	N/A

[a] Visual estimate from undamped pressure gauge

[b] Only two repetitions completed for T11

Table B-2 (continued). The treatment fan speed and static pressure data.

Treatment	Repetition	Fan 1 (Seed)			Fan 2 (Fertilizer)		
		Speed RPM (Hz)	**Static Pressure Empty** psi (kPa)	**Static Pressure Full** psi (kPa)	**Speed** RPM (Hz)	**Static Pressure Empty** psi (kPa)	**Static Pressure Full** psi (kPa)
T12	1	3874 (65)	0.83 (5.74)	0.83 (5.69)	N/A	N/A	N/A
	2	3848 (64)	0.79 (5.45)	0.8 (5.49)	N/A	N/A	N/A
	3	3944 (66)	0.78 (5.39)	0.79 (5.47)	N/A	N/A	N/A
T13	1	3852 (64)	0.8 (5.49)	0.79 (5.43)	N/A	N/A	N/A
	2	3960 (66)	0.85 (5.88)	0.84 (5.82)	N/A	N/A	N/A
	3	3836 (64)	0.86 (5.92)	0.87 (5.98)	N/A	N/A	N/A
T14	1	4885 (81)	1.39 (9.56)	1.39 (9.58)	N/A	N/A	N/A
	2	4847 (81)	1.34 (9.26)	1.36 (9.38)	N/A	N/A	N/A
	3	4856 (81)	1.37 (9.46)	1.38 (9.5)	N/A	N/A	N/A
T15	1	4890 (82)	1.45 (10) [a]	1.45 (10) [a]	N/A	N/A	N/A
	2	4823 (80)	1.31 (9) [a]	1.38 (9.5) [a]	N/A	N/A	N/A
	3	4823 (80)	1.38 (9.5) [a]	1.38 (9.5) [a]	N/A	N/A	N/A
T16	1	4856 (81)	1.45 (10) [a]	1.45 (10) [a]	N/A	N/A	N/A
	2	4852 (81)	1.45 (10) [a]	1.45 (10) [a]	N/A	N/A	N/A
	3	4856 (81)	1.38 (9.5) [a]	1.38 (9.5) [a]	N/A	N/A	N/A

[a] Visual estimate from undamped pressure gauge

[b] Only two repetitions completed for T11

Appendix C

Germination and Vigor Results

Table C-1. The Nova Cart germination and vigor results.

Seed Type	Treatment	Section	Repetition	Germination	Vigor
Wheat	Control	Control	1	98%	97%
			2	95%	96%
			3	97%	95%
	T2	Left	1	95%	89%
			2	94%	89%
			3	96%	84%
		Centre	1	97%	95%
			2	97%	97%
			3	97%	96%
		Right	1	99%	93%
			2	96%	95%
Canola	Control	Control	1	89%	94%
			2	98%	97%
			3	98%	95%
	T3	Left	1	96%	97%
			2	97%	95%
			3	98%	97%
		Centre	1	95%	98%
			2	99%	98%
			3	99%	98%
		Right	1	96%	96%
			2	95%	95%
			3	94%	97%
	T4	Left	1	93%	96%
			2	99%	97%
			3	96%	93%
		Centre	1	95%	94%
			2	93%	92%
			3	91%	95%
		Right	1	91%	94%
			2	90%	96%
			3	95%	93%
	T5	Left	1	97%	99%
			2	99%	98%
			3	96%	93%
		Centre	1	98%	94%
			2	98%	95%
			3	96%	98%
		Right	1	91%	96%
			2	94%	97%
			3	92%	94%

Table C-1 (continued). The Nova Cart germination and vigor results.

Seed Type	Treatment	Section	Repetition	Germination	Vigor
Soybeans	Control	Control	1	83%	57%
			2	81%	62%
			3	76%	62%
	T6	Left	1	74%	61%
			2	70%	58%
			3	82%	63%
		Centre	1	77%	65%
			2	78%	62%
			3	81%	65%
		Right	1	79%	69%
			2	77%	65%
			3	77%	69%
Peas	Control	Control	1	43%	43%
			2	43%	44%
			3	47%	39%
	T7	Left	1	47%	39%
			2	44%	38%
			3	53%	42%
		Centre	1	47%	33%
			2	44%	39%
			3	46%	46%
		Right	1	42%	43%
			2	44%	44%
			3	43%	41%

Table C-2. The UltraPro II germination and vigor results.

Seed Type	Treatment	Section	Repetition	Germination	Vigor
Wheat	Control	Control	1	98%	97%
			2	95%	96%
			3	97%	95%
	T10	Left	1	97%	91%
			2	97%	91%
			3	98%	88%
		Centre	1	97%	90%
			2	96%	90%
			3	97%	90%
		Right	1	96%	91%
			2	98%	92%
			3	99%	93%
Canola	Control	Control	1	99%	94%
			2	97%	96%
			3	97%	97%
	T11	Left	1	98%	92%
			2	99%	89%
		Centre	1	99%	90%
			2	98%	95%
		Right	1	99%	91%
			2	98%	93%
	T12	Left	1	98%	91%
			2	99%	95%
			3	98%	95%
		Centre	1	99%	96%
			2	96%	95%
			3	98%	97%
		Right	1	97%	95%
			2	96%	93%
			3	98%	96%
	T13	Left	1	99%	86%
			2	99%	89%
			3	94%	90%
		Centre	1	92%	90%
			2	94%	96%
			3	94%	96%
		Right	1	95%	95%
			2	96%	92%
			3	98%	93%

Table C-2 (continued). The UltraPro II germination and vigor results.

Seed Type	Treatment	Section	Repetition	Germination	Vigor
Soybeans	Control	Control	1	83%	57%
			2	81%	62%
			3	76%	62%
	T14	Left	1	77%	64%
			2	80%	69%
			3	81%	61%
		Centre	1	78%	67%
			2	84%	65%
			3	82%	67%
		Right	1	80%	63%
			2	84%	67%
			3	86%	65%
Peas	Control	Control	1	43%	43%
			2	43%	44%
			3	47%	39%
	T15	Left	1	49%	44%
			2	46%	34%
			3	49%	39%
		Centre	1	45%	43%
			2	44%	37%
			3	41%	50%
		Right	1	47%	37%
			2	46%	40%
			3	48%	42%

For further information regarding to this report, please contact:
pami@pami.ca

Saskatchewan Operations
Box 1150
2215 – 8th Avenue
Humboldt, SK S0K 2A0
1-800-567-7264

Manitoba Operations
Box 1060
390 River Road
Portage la Prairie, MB R1N 3C5
1-800-561-8378

Corporate Services
Box 1150
2215 – 8th Avenue
Humboldt, SK S0K 2A0
1-800-567-7264