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Portage la Prairie, MB

Final Report

Research Report

Air Seeder Distribution and Seed Damage for Wheat, Canola, and Soybeans

For:
MB Pulse and Soybean Growers, MB Wheat and Barley Growers, MB Canola Council

Innovative Solutions for Agriculture and Beyond

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Project Manager
Agricultural R & D

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Table of Contents

1. Executive Summary

The purpose of this study was to evaluate the consistency of distribution in large air seeders (60’ in width) and effect of fan speed on distribution and seed damage for small (canola), medium (wheat), and large (soybeans) seeds. In addition, soybean moisture content (8%, 10%, and 13%) at the time of seeding was evaluated for its effect on seed damage. Two configurations of 60’ seeders (Bourgault and John Deere) were chosen for analysis due to their popularity in Manitoba. Both air seeders were owned by local producers and used over six-seven seeding seasons. Some modifications to the air seeder distribution system and hoses were made by the owners over time. Because the systems tested were used, new equipment may produce different results.

Seeding set-ups (used machines) were provided by cooperating producers and tests were performed in producer’s yard sites. All equipment was assessed for quality and function prior to testing, and parts showing excessive wear were replaced. Three fan speeds were tested for each seed type: the lowest recommended by the manufacturer, as well as 15% and up to 30% higher RPM. Seeding was simulated in a stationary set-up with the openers in an up position and with product rates as recommended by local commodity groups. Seed was collected from individual openers after each repetition and its location recorded. Trials with wheat and canola included fertilizer rates suggested by their respective commodity groups. Each seeder underwent 45 tests (three fan speeds, five seed sets, three replications of each).

Variation was measured by coefficient of variation (CV_2), expressed as a percent. The CV_2 was between 11%-20% for all trials with the highest variation occurring in canola. Results suggest that the position of the manifold could affect product distribution, as manifolds closer to the center were more likely to receive larger volumes of product compared to manifolds near the extremes. However, no clear pattern in seed distribution was established. Manifold position was shown to have no significant effect on germination for wheat, and canola, or soybeans.

Lower fan speeds increased soybean germination in the Bourgault trials, but had no effect in the John Deere seeder. The overall effect of moisture content was more pronounced. The highest germination rates occurred when seeds had higher moisture and were seeded at lower fan speeds. Soybeans at 8% moisture had a lower rates of germination compared to 13% moisture soybeans by 4.6% and 3.0% in the Bourgault and John Deere trials, respectively.

Variation among openers in the same trial (CV_2) averaged 13.4% on the Bourgault seeder and 16.9% on the John Deere seeder with canola trials having the highest variability. On any single opener, variation in delivered product between successive trials was relatively low (average of 4.9% over both seeders). A summary of variation in product distribution is given in **Table 1**. From this information, higher fan speeds may increase variation for seeding soybeans, but may reduce variation with higher volumes of product such as with wheat and canola.

Table 1. Variation in product distribution, as denoted by CV_2 (%).

	CV_2 (%)							
	Bourgault				**John Deere**			
Fan Speed	***LS***	***MS***	***HS***	***Average***	***LS***	***MS***	***HS***	**Average**
Soybean	11	12	12.6	**11.9**	16.7	17.1	17.8	**17.2**
Canola	15.2	16.1	15.1	**15.5**	19	18.1	17	**18**
Wheat	11.6	12.2	11.5	**11.8**	17.7	14.2	15.8	**15.9**

Fan speed did not have an effect on germination in the John Deere trials, but lower fan speed resulted in higher germination in the Bourgault trials for soybeans. Fan speed had no effect on germination for canola or wheat. Combining results on all trials, higher moisture soybeans were shown to have higher germination than lower moisture soybeans. This indicates that in practice, lower fan speeds and higher moisture soybeans should be used where possible to reduce seed damage.

2. Background

Farm machinery is rapidly becoming larger as greater efficiency is sought. As air seeders grow in width, there is some concern over the possible variation of product distribution among openers, particularly at different airflows. Uniform distribution of product across the implement is vital for consistent germination and provides the best start possible for crop growth and development.

Excessive airflow may cause seed damage or bounce but is more likely to prevent plugging. An air speed that is too low may cause plugging but is more likely to prevent damage and seed bounce. Application rates also have an effect on the required air speed to ensure uniform application rates. As the distance to push product increases on larger implements, the required air speed to transport the product increases as well.

Manitoba producers, represented by the Wheat and Barley Growers (WBG), Manitoba Pulse and Soybean Growers (MPSG), and Manitoba Canola Growers (MCG), desire a better understanding of how product distribution and seed damage are affected by airflow on a large seeder (60'), and varying this air flow above what is recommended by the manufacturer. Understanding this effect on small (canola), medium (wheat), and large (soybeans) seed will aid producers in improving their seeding operations and begin the season with better chances of profitability.

Soybeans present an additional challenge due to their sensitivity to damage. Seed moisture at the time of seeding can have an effect on damage during handling, and therefore germination. Planters, which are gentler on seeds, are generally used for planting soybeans. Manitoba producers more commonly use air seeders as an adaptation to minimize investment in another seeding tool. There is very little research conducted in understanding how seed damage occurs in air seeders with soybeans. Therefore, there is a knowledge gap on the extent to which moisture content affects seed damage and germination, particularly in air seeders.

The two most common air seeders in Manitoba are Bourgault and John Deere, as shown by preliminary market research. Each has a unique distribution system and results gained from one cannot be extrapolated to another. In order to have the largest impact for the maximum number of producers and increase the audience for test results, it was desired that both of these distribution systems were used in this project. Used air seeders were selected for this study as they represent a typical operating condition of many units currently in use in Manitoba.

3. Project Description

The purpose of this study is to evaluate the effect of fan speed on seed damage and distribution in large air seeders. Understanding how fan speed affects distribution of seeds will aid farmers in optimizing their seeding operation to begin the season with a uniform and even plant stand. A second purpose is to evaluate the effect of soybean moisture content on seed damage and germination. Two 60’ air seeders were selected for testing based on their popularity in the province of Manitoba: a Bourgault 6550 and a John Deere 1910. Canola (small), wheat (medium), and soybeans (large) seeds were used to investigate the effects of fan speed on product distribution and damage.

3.1 Methods and Equipment

Trials with both seeders followed nearly identical testing methods. Adaptations were made where differences in operation of the seeder required a change, and any differences in operation will be outlined in the report where applicable.

Seed and fertilizer rates used were based on recommendations from each respective commodity group to reflect common practices amongst growers. Fertilizer was included in this trial to represent an accurate volume of material flowing through the machine, and to realistically represent actual particle interaction during the seeding operation.

All trials were stationary. Motors for the fan control and metering system were driven hydraulically. All distribution trials were run for the equivalent of one seeded acre to minimize the effects of start-up/shut-down. Additional germination trials were run for the equivalent of ½ an acre. Each opener was equipped with a collection container to collect all product from the trial. After the trial was complete, each sample was collected, labelled, and stored for later weighing and sub-sampling for germination. Three different fan speeds, low speed (LS), medium speed (MS), and high speed (HS) were run during the test.

3.1.1 Air seeder equipment

The air seeder set-up consisted of an air cart with an attached 60’ tool[1]. Both set-ups were provided by a cooperating producer and had been used by the producer for seeding earlier in the season. Both set-ups were examined to ensure proper functioning. The metering augers on the Bourgault cart were replaced. The air pressure and seals in the John Deere cart were verified by a John Deere technician, and several metering auger manifolds were replaced.

[1] John Deere models: 1910 (cart, 2012), 1890 (tool)
Bourgault models: 6550 (cart, 2011), 3710 (tool)

A main tractor was used to provide hydraulic flow to the fan of the air cart, and a secondary tractor was used to provide hydraulic flow to metering system. The metering mechanism at the bottom of each tank was used to ration the seeds/ fertilizer into the air stream at the desired rate representative of field operations.

Both air seeders were 60 feet wide, but the openers were spaced 10-inch and 7.5-inch apart in the Bourgault and John Deere, respectively. This resulted in 72 openers from 6 secondary manifolds on the Bourgault set-up, and 96 openers from 8 secondary manifolds on the John Deere setup. During trials with soybeans, the entire front row was blocked off for both tools to simulate the wider spacing used by producers. For these trials, seed was collected from 36 openers on the Bourgault, and 48 openers on the John Deere. The set-up of each unit is shown in **Figure 1** and **Figure 2**, with the location of the secondary manifolds indicated.

Figure 1. Bourgault set-up with locations of secondary manifolds.

Figure 2. John Deere set-up with locations of secondary manifolds.

Metering mechanisms for both units were calibrated according to the manufacturer's directions to deliver seeds and fertilizer at a desired rate (**Figure 3**). The target simulated ground speed for each trial was 5 mph. Bourgault trials were simulated at 5.0-5.2 mph. John Deere trials were simulated at 4.4-4.5 mph, due to limitations in speed of the calibration motor. Soybeans were calibrated at 13% moisture content and the metering mechanisms were not re-calibrated for other soybean moisture contents. **Table 2** presents the seed and fertilizer feed rates during the field evaluation. It should be noted that though inoculant is often applied with soybeans during seeding, it was not included in this study due to the relatively small amount used, making it very unlikely to have an effect on distribution or damage. Only fertilizer that would directly interact with the seed was used in this trial (not total fertilizer amounts).

Figure 3. Calibration procedure for John Deere (left) and Bourgault (right) air cart.

Table 2. Seed and fertilizer rates as recommended from producer groups.

Commodity	Fertilizer rate (lb/ac)	Seed rate (lb/ac)	Total rate (lb/ac)
Wheat	30	120	150
Canola	100	4.7	105
Soybeans	0	72	72

3.1.2 Fan speed

The fan speed was controlled hydraulically by the main tractor, and was measured by RPM from the cart controller. The lowest fan speed tested was determined using the lowest manufacturer recommended speed for the desired volume of product, and medium and high speeds were 15%, and up to 30% faster, respectively. The Bourgault manual used a fan curve to recommend the lowest allowable rpm, and the John Deere manual gave a range of recommended fan rpm. It should be noted that the high speed for canola and soybeans are 140 rpm faster than the fastest recommended speed for these volumes. However, there was a desire to maintain consistency between units and ensure that “high speed” indicated 30% faster than the lowest recommended speed.

The fan speeds used for this evaluation are presented in **Table 3**.

Table 3. Fan speeds (RPM) used based on manufacturers recommendations.

Commodity	Unit	Low Speed (LS)	Medium Speed (MS)	High Speed (HS)
Wheat	Bourgault	3800	4370	4830
	John Deere	3500	4025	4550
Canola	Bourgault	3350	3850	4355
	John Deere	2800	3220	3640
Soybeans	Bourgault	3000	3450	3900
	John Deere	2800	3220	3640

3.1.3 Static air pressure

Static air pressure in the air system was monitored with a calibrated manometer during every trial near the fan outlet to ensure that the fan performance remained consistent between repetitions. Two static pressure readings were taken for every trial: one when the fan was at a stabilized speed with no product in the lines (no load), and one after product metering had begun and static pressure had stabilized (with load). This monitoring ensured consistency between replications in fan speed and was a visual cue for changes to the air stream with the introduction of product. Any changes in pressure between repetitions would indicate a change in the system, and therefore void the trial. The static pressure monitoring system for each setup is shown in **Figure 4** and **Figure 5**.

Figure 4. Static pressure monitoring on the John Deere set-up near the fan.

Figure 5. Static pressuring monitoring on the Bourgault set-up near the fan.

3.1.4 Seeding area

To avoid external factors such as undulating land, or loss of product during the testing, all repetitions were simulated with the setup remaining stationary. Based on the simulated ground speed of the metering system, a run-time was calculated to simulate one acre[2] of seeding with a 60’ tool. All repetitions were normalized to ensure consistency.

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[2] Trials that were run strictly for germination tests and not distribution tests (8% and 10% soybeans) were run for the equivalent of a ½ acre.

3.1.5 Collecting seeds – openers

Openers and their corresponding manifolds on the Bourgault and John Deere tools were assigned a number to locate the position of the opener, shown in **Figure 7**. A schematic diagram of each unit is provided in **Figure 6** and **Appendix A.** This identity remained with the opener/manifold throughout the trial to ensure consistency. The manifold from which each opener originated from was recorded so that openers were grouped by manifold for the distribution analysis. This allows for an analysis of distribution of product in each furrow, and also of any variance in distribution based on distance away from the primary manifold. Trials were run with the openers in the up position, which may affect distribution results.

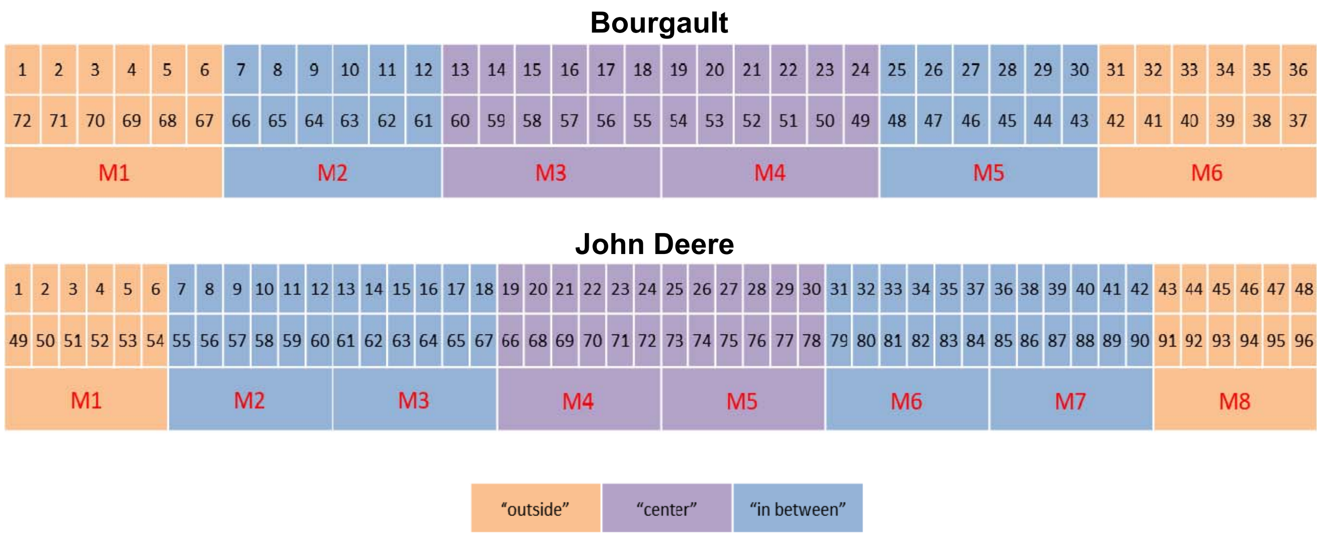

Figure 6. Schematic layout of opener and manifold numbers and locations.

Heavy-duty contractor bags were used to collect product from the openers, as shown in **Figure 8**[3]. Bags were secured to the openers so that air flowed freely from the top of the bag to prevent any back-pressure in the product lines. At the conclusion of every trial, product from each opener was collected and labelled. Three replicates of each treatment were performed to ensure enough data for statistical analysis was collected. A representative sample of seeds for each commodity was collected prior to running the trial to set a benchmark for pre-seeding damage.

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[3] Plastic pails were used originally in the Bourgault wheat trials and losses due to seed bounce were monitored. At high speeds, seed loss neared 3% and bags were then utilized for the rest of the trials to avoid all chances of seed bounce/loss.

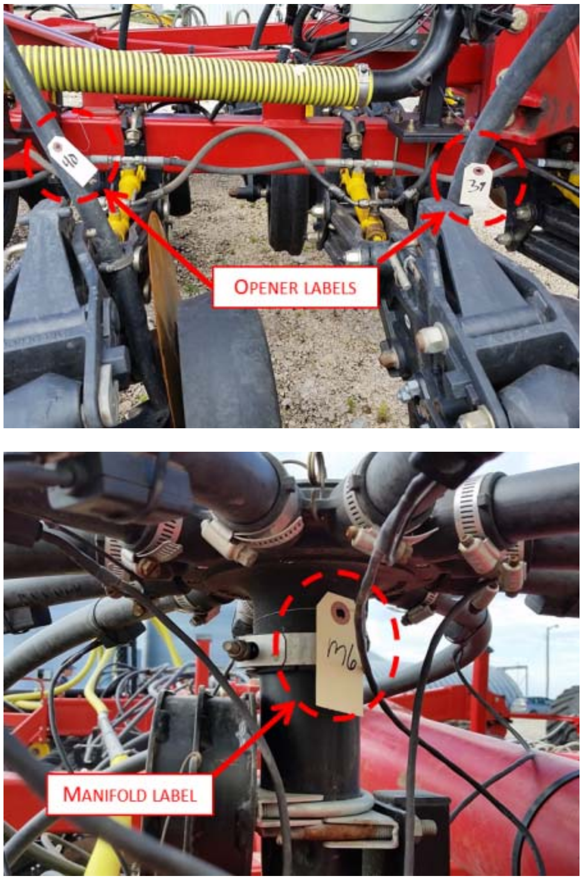


Figure 7. All openers were assigned a number (top) and all secondary manifolds were assigned an identity (bottom).

Figure 8. Bags were place around each opener to collect product during each repetition.

Though all openers on each seeder were used for trials with canola and wheat, only the rear openers were used for trials with soybeans to simulate the desired row spacing for this crop (15” for the John Deere and 20” for the Bourgault). The front openers were sealed with caps or plugs as provided by the manufacturer.

3.1.6 Seed sample analysis

Samples collected from each opener were weighed for a quantitative analysis. Weighed samples were then separated into three groups based on the position of the secondary manifold. The groups represented manifolds closest to the primary manifold (“center”), furthest from the primary manifold (“outside”) and those “in between” (**Appendix A**). Once all samples and replicates from a certain trial (i.e. reps 1, 2, and 3 from the low speed wheat trial) were weighed and sorted by manifold, the manifold-separated product was sub-sampled using a seed separator, shown in **Figure 9**. This representative sample was sent away for germination testing at a third-party laboratory. A total of 9 germination samples were sent away for analysis for each of the wheat and canola trials for each unit.

Figure 9. Weighing each sample (left) and sub-sampling for germination tests (right).

To accommodate additional germination testing for soybeans and moisture content, the various replications were not combined and each was sub-sampled for analysis. A total of 81 soybean samples were sent away per unit for a germination analysis. A breakdown of how sub-sampling occurred is given in **Appendix B**.

3.1.7 Effect of soybean moisture content on germination

Additional testing was undertaken to determine the effect soybean moisture content had on germination under various fan speeds. Soybeans were conditioned to three different moisture contents: 8%, 10%, and 13%. In order to dry without incurring any seed damage, the soybeans were dried passively in a hot room for a number of days until the appropriate moisture content was reached (**Figure 10**). Soybeans that required additional moisture were wet with an appropriate amount of water, mixed and sealed into plastic bags for the moisture content to normalize for up to one week. These processes were continued until all soybeans were at the desired moisture content (verified by three moisture samples), and then sealed until use.

Figure 10. Passive soybean drying in a hot room (left) and in the sun (right).

Three repetitions (LS, MS, and HS) were run on soybeans of the test outlined above. These tests were run with 8%, 10% and 13% moisture[4]. These samples were subsampled based on manifold position, and germination testing performed at a third-party lab. Tests run at 8% and 10% moisture ran for the equivalent of ½ an acre, as this provided sufficient time to negate the effects of starting and stopping the unit for the purposes of germination. Replications were <u>not</u> combined for soybean samples in order to have a larger data set to draw conclusions from. Eighty-one soybean samples from each unit were sent away for germination analysis. A breakdown of samples is given in **Table 4**.

[4] Only one set of samples (13%) were weighed for the distribution analysis as seed moisture is not expected to affect distribution.

Table 4. Germination samples for each trial.

Sample Description	**Number of germination samples**		
	LS	***MS***	***HS***
Canola (R1, R2, R3 combined)	3	3	3
Wheat (R1, R2, R3 combined)	3	3	3
8% Soybeans (R1, R2, R3 separated)	9	9	9
10% Soybeans (R1, R2, R3 separated)	9	9	9
13% Soybeans (R1, R2, R3 separated)	9	9	9

4. Results & Discussion

Tests on both seeders were completed in the summer/fall of 2017. In this report, the term “statistically significant” represents a statistical difference in results for the samples tested. The data was analyzed to determine if differences among factors (moisture content, fan speed, etc.) were due to natural variability or due to the applied treatment. For this report, a confidence level of 95% was selected, so a difference that is “statistically significant” is very likely to be due to the applied treatment rather than natural variability. These results indicate a difference between treatments *statistically*, but this does not necessarily mean that this difference is *significant* from a production point of view. A significant difference from a production point of view is best interpreted by the producer based on knowledge of their particular operation. Statistical analysis was performed using Minitab software.

4.1 Seed Damage

Seed damage sustained during the seeding simulation from the seed tank was evaluated using a warm germination test carried out by a third-party laboratory. Minitab software was used for statistical analysis. The results of the germination test were analyzed using two-way ANOVA **without** replication, for canola and wheat trials (as replicates were combined). Soybean damage was analysed using two way ANOVA **with** replication for all three (8, 10, and 13%) tested moisture contents. Overall results using only one variable were analyzed with one-way ANOVA. If the data was not normally distributed, all ANOVA results were validated by running an additional non-parametric analysis (Kruskal-Wallis).Graphs showing the interactive effects of moisture content and manifold position and fan speed for both units can be found in **Appendix C**.

4.1.1 Bourgault Air Seeder

There was no statistically significant effect of fan speed or manifold position on the germination of wheat, canola, or 8% soybeans. However, at 10% and 13% moisture, soybean germination was significantly reduced at certain speeds. Soybeans at 10% moisture suffered statistically lower germination rates at high fan speeds compared to medium and low fan speeds. Soybeans at 13% moisture experienced a small, but statistically significant, decrease in germination at medium speeds compared to high or low fan speeds.

When all soybean data was pooled and separated only by moisture content, 13% moisture content beans had significantly higher germination compared to 10% or 8% moisture soybeans. When data was separated only by fan speed, samples taken at low and medium fan speeds had significantly higher germination than high fan speeds.

Table 5. Effect of fan speed and moisture content on germination for soybenas. Means that do not share a letter are significantly different.

Moisture Content	Grouping	Fan Speed	Grouping	13%	Grouping	10%	Grouping	8%	Grouping
13%	A	HS	B	HS	A	HS	B	HS	A
10%	B	MS	A	MS	B	MS	A	MS	A
8%	B	LS	A	LS	A	LS	A	LS	A

The results also indicate that there is no connection between manifold position and seed germination. Manifold position had no statistically significant effect on germination for soybeans at any moisture content. The highest germination rates occurred when seed moisture was high and fan speed was low. Results for the average actual rate of germination for all conditions are given in **Table** .

Table 6. Average rate of germination for all seed types based on fan speed and manifold position.

Commodity Tested	Pre-seeding Germ. (%)	Average Rate of Germination (%)							
		Fan Speed				*Manifold Position*			
		LS	MS	HS	**Average**	Center	Outside	In Between	**Average**
Canola		96.0	96.0	95.0	**95.7**	95.0	95.7	96.3	**95.7**
Wheat	96.0	93.7	91.3	90.7	**91.9**	91.3	93.3	91.0	**91.9**
8% Soybeans	98.5	96.2	95.2	95.4	**95.6**	96.1	95.7	95.1	**95.6**
10% Soybeans	96.5	97.6	97.4	92.6	**95.9**	96.0	96.0	95.6	**95.9**
13% Soybeans	95.0	98.7	98	98.7	**98.5**	98.6	98.2	98.6	**98.5**
Average		**96.4**	**95.6**	**94.5**	**-**	**95.4**	**95.8**	**95.3**	-

4.1.2 John Deere Air Seeder

Fan speed had no effect on germination for either canola or wheat. Manifold position had no effect on germination for any trials.

If only fan speed is analyzed and all other variables are ignored, fan speed had no overall effect on germination. When moisture content is analyzed and all other variables are ignored, 8% moisture soybeans had significantly lower germination than 10% or 13% moisture content.

If fan speed is analyzed for each individual moisture content, fan speed affected the germination of soybeans for all moisture contents. For 13% soybeans, HS showed less damage than MS or LS. At 10% moisture, HS cause more damage than LS (no significant difference for MS). At 8% moisture, MS caused more damage than LS (no significant difference for HS). Results are summarized in **Table** . Categories that do not share letters are significantly different.

Table 7. Effect of fan speed and moisture content on germination of soybeans. Means that do not share a letter are significantly different.

Moisture Content	Grouping	Fan Speed	Grouping	13%	Grouping	10%	Grouping	8%	Grouping
13%	A	HS	A	HS	B	HS	B	HS	AB
10%	A	MS	A	MS	A	MS	AB	MS	B
8%	B	LS	A	LS	A	LS	A	LS	A

Table shows the average rate of germination based on fan speed and manifold position for the John Deere air seeder.

Table 8. Average rate of germination for all seed types based on fan speed and manifold position.

Commodity Tested	**Pre-seeding Germ. (%)**	**Average Rate of Germination (%)**							
		Fan Speed				***Manifold Position***			
		LS	MS	HS	***Average***	Center	Outside	In Between	***Average***
Canola		96.7	96.0	95.3	**96.0**	95.3	96.7	96.0	**96.0**
Wheat	96.0	97.0	96.3	95.3	**96.2**	96.3	96.7	95.7	**96.2**
8% Soybeans	98.5	92.7	88.2	92.5	**91.1**	93.1	91.6	88.8	**91.2**
10% Soybeans	96.5	96.0	94.1	92.1	**94.1**	94.8	94.0	93.4	**94.1**
13% Soybeans	95.0	94.4	94.9	96.8	**95.4**	95.0	95.2	95.9	**95.4**
Average		**95.4**	**93.9**	**94.4**	**-**	**94.9**	**94.8**	**94.0**	**-**

4.2 Seed Distribution

Consistency of product distribution is critical for establishing a uniform plant density. In this study, product distribution was evaluated in two ways using the coefficient of variation (CV), expressed as a percentage. First, CV was calculated for each opener based on the weight of each sample from three replicates, and the average of those replicates. This CV (CV_1) gives an indication of the consistency and repeatability of performance in each individual opener. The distribution of product across the tool was also evaluated (CV_2). This involves comparing the average output of each opener to every other opener during a single repetition. A higher CV in either case represents greater variability and less consistency. A visual representation of CV_1 and CV_2 is provided in **Figure 11**.

CV_2

Opener	Repetition 1	Repetition 2	Repetition 3	Average
1	x	x	x	X
2	x	x	x	X
…	…	…	…	…
95	x	x	x	X
96	x	x	x	X

CV_1

Figure 11. Visual representation of CV_1 and CV_2.

Box plots have been used to represent product distribution and associated statistics. **Figure 12** provides an interpretation of the symbols found in the box plot. The range of sample values is represented by a line going through the box and the intersection of green and purple sections of the box represent the data median. The 'x' represents the data mean while blue circles show data outliers. The letter designation shows the grouping of the treatment to denote statistical differences between treatments.

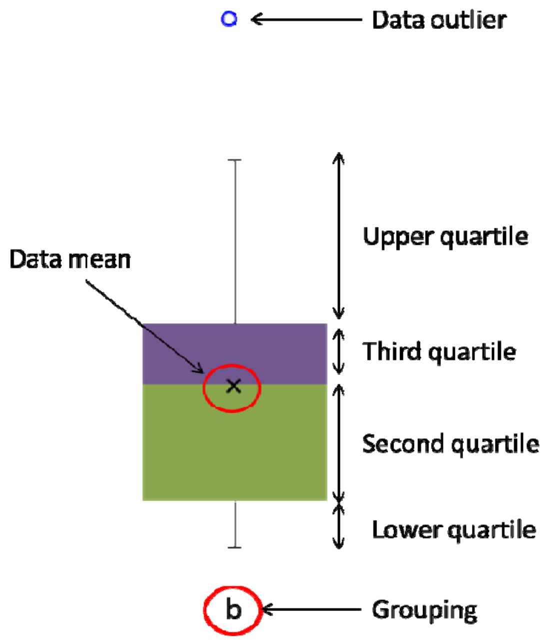


Figure 12. Interpretation of box plots.

4.2.1 Bourgault Air Seeder

In this trial, a unit with black tertiary hoses were used. These hoses can be sensitive to temperature/direct sunlight and have been known to have issues with plugging. These hoses have been upgraded by Bourgault on newer units to more reliable hoses. Time constraints and machinery availability restricted this unit to black tertiary hoses.

The weight of each sample from each opener was used to calculate the average differences in distribution along the tool bar. To ensure an accurate comparison between repetitions, product weights were normalized based on the simulated distance travelled. A higher CV represents greater variability in distribution [1].

For the Bourgault system, CV_1 was relatively low with the average variation for each opener being 3.88% and a range from 1.19%-10.2% The highest variation was seen in the wheat trials. The CV_1 for an individual opener could be quite high, but these were not in a great enough proportion to affect the overall average. The lowest variation was seen in the soybean trials with the exception of the MS trials in which the highest CV_1 was recorded. Reasons for high variability are unclear in this particular trial, as variability at HS and LS were nearly a magnitude lower, and there is no clear explanation as to what may have caused this variation. **Table** gives the results for CV_1.

Table 9. Average CV values for the consistency distribution for individual openers between repetitions.

Fan Speed	CV_1 (%)			
	LS	***MS***	***HS***	***Average***
Soybeans	1.19	10.2	1.72	4.37
Canola - overall	2.59	2.34	2.61	2.51
Canola – front	2.93	2.48	2.23	2.55
Canola – rear	2.23	2.51	3.00	2.58
Wheat - overall	3.89	4.03	6.32	4.75
Wheat – front	3.80	3.75	6.62	4.72
Wheat - rear	3.78	4.32	6.11	4.74

The CV_2 values for soybean and wheat seeds were below 15%. The distribution of canola was not above 15% at any of the three fan speeds. CV_2 values are presented in **Table** below.

Table 10. Average CV_2 values for distribution between openers.

	CV_2 (%)			
Fan Speed	***LS***	***MS***	***HS***	***Average***
Soybean	11.04	11.99	12.60	11.88
Canola - overall	15.17	16.10	15.12	15.46
Canola - front	16.82	17.07	15.99	16.63
Canola – rear	13.46	15.26	14.40	14.37
Wheat - overall	11.59	12.23	11.45	11.76
Wheat – front	12.51	12.97	11.67	12.38
Wheat – rear	10.74	11.62	11.39	11.25

Impact of variables

Two-way ANOVA was used to analyse the effects of different fan speeds and manifold positions on product distribution. A Post hoc analysis was used where necessary to gain more information about the effects of each variable. The box plots in this section detail how each variable (manifold position, fan speed) differs from the rest (95% confidence level). Items with the same letter are not statistically different from each other. Likewise, items with different letters are significantly different from each other.

Manifold position and fan speed were shown to have a significant effect on distribution for all three seed types. Manifolds were labelled incrementally from left to right. Manifold orientation is shown in **Figure 13**.

Figure 13. Manifold orientation on the Bourgault air seeder.

In the wheat trials (**Figure 14**), paired manifolds at the same distance on the either side of the centerline of the tool behaved similarly (not statistically significant at a 95% confidence level). Weight of wheat collected from the center manifolds (3 and 4) and on the outside positions (1 and 6) was not significantly different. However, openers originating from the manifolds in between (M2, and M5) showed significantly higher weights than that of other manifolds.

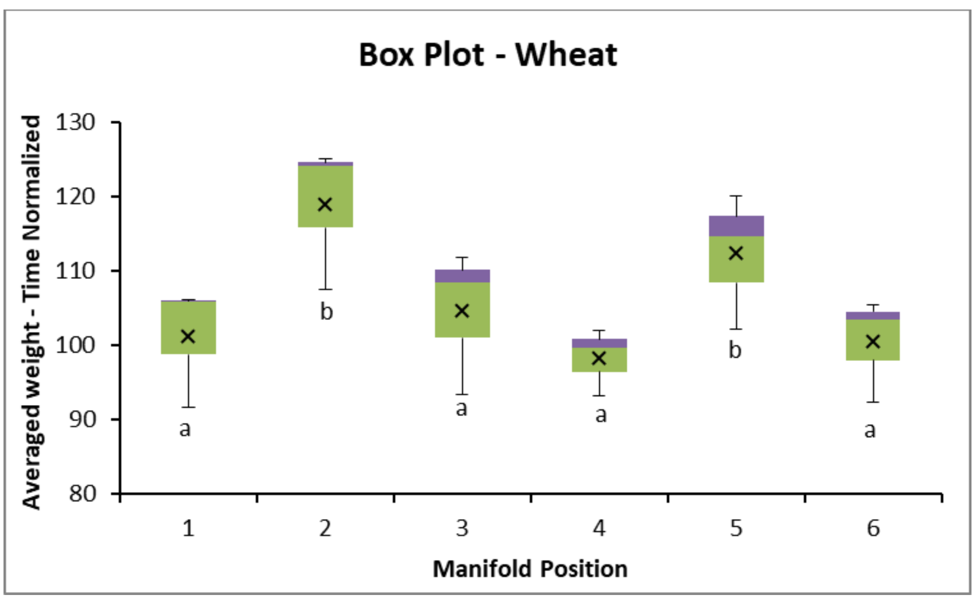


Figure 14. Product distribution for wheat trials**.**

A similar pattern was observed in canola trials. The manifolds in between (M2 & M5) received significantly higher weights of product compared to the center or outside manifolds, which received fairly even distribution of product. One difference was that M2 had significantly higher weights than M5. Trials at medium speeds delivered more seed than trials at high or low speed. **Figure 15** presents the information related to the canola seed distribution in the Bourgault seeder.

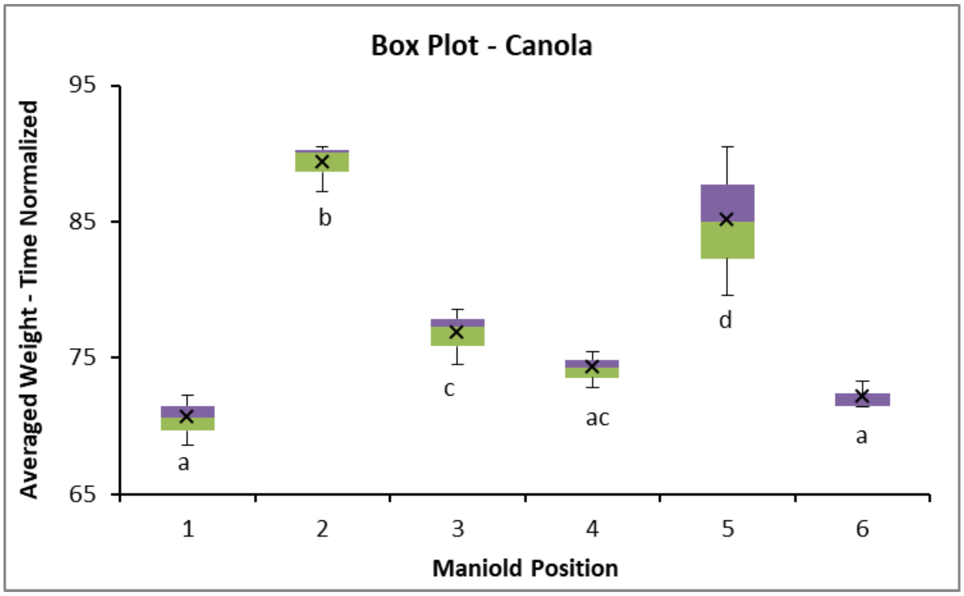


Figure 15. Product distribution for canola trials.

In the soybean trials, manifolds near the centerline of tool (M3 & M4) received significantly higher amount of seeds, as can be seen in **Figure 16**. Sample weights collected from remaining manifolds were not significantly different. Trials at low speeds delivered significantly more product than at medium speeds.

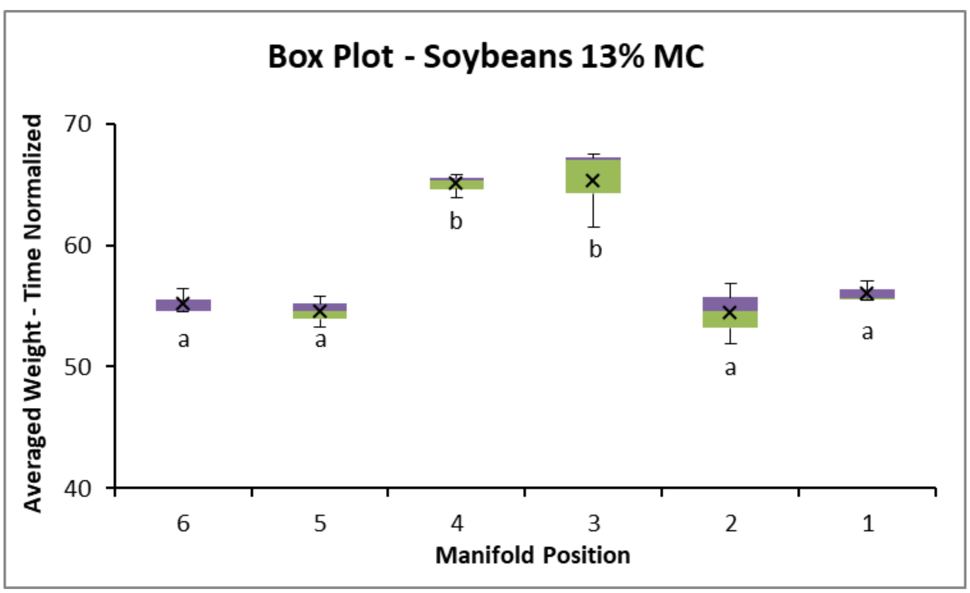


Figure 16. Product distribution for soybean trials.

Figure 17, **Figure 18**, and **Figure 19** present the effect of fan speeds on the product distribution for each trial. In each trial, box plots with different letter labels are significantly different (confidence level of 95%). The graphs help observe if a particular fan speed significantly affects the amount of product delivered. For example, if we examine the box plots for canola and soybeans in **Figure 18** and **Figure 19**, we can see that medium and low speed have been assigned different letters (b and a, respectively). This means that in these trials, running the fan at medium speed produces different results from running the fan at low speed. However, high speed was assigned both letters. This means that running the fan at high speed did not produce different results from medium or low speed. However in **Figure 17** for wheat, the letter classifications show us that medium and low speed did not produce different results, but high speed produced results different from both other fan speeds. Blue dots represent outliers in the data.

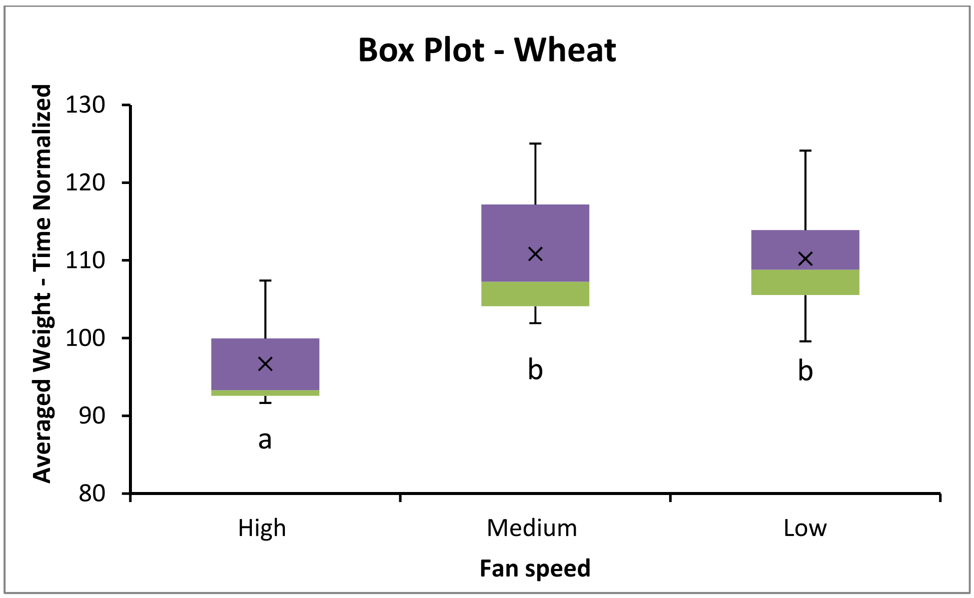


Figure 17. Effect of fan speed on product distribution of wheat (Bourgault).

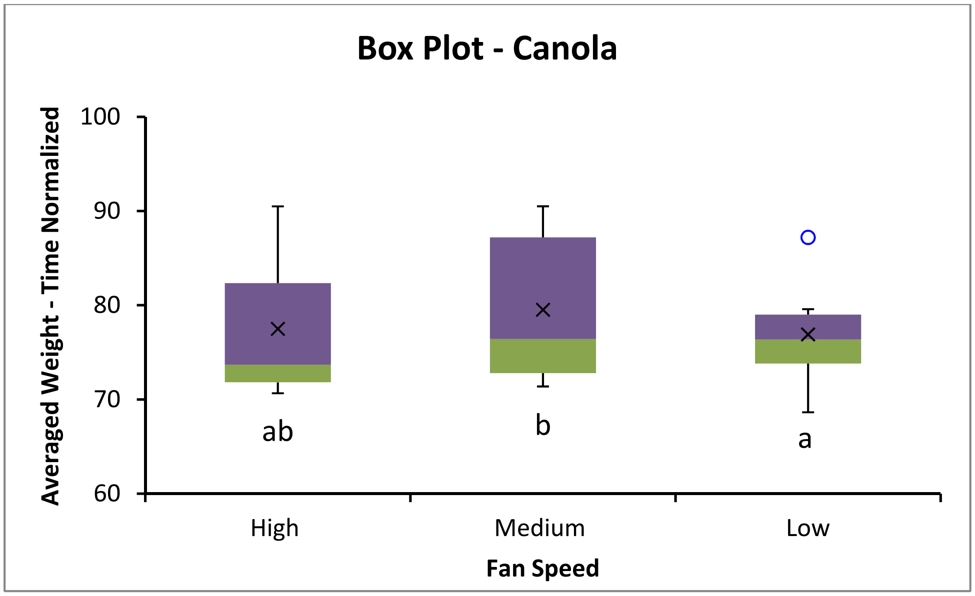


Figure 18. Effect of fan speed on product distribution of canola (Bourgault).

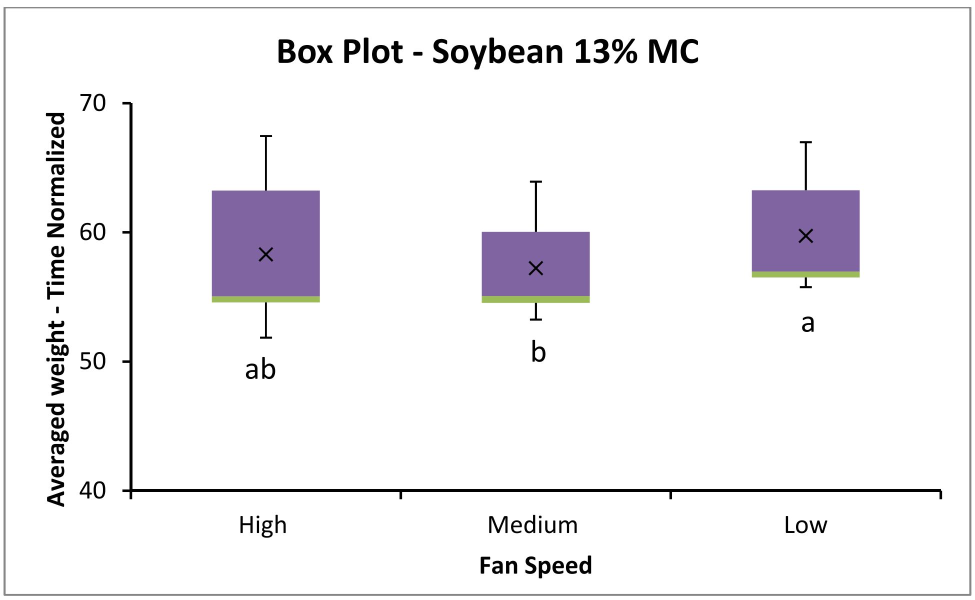


Figure 19. Effect of fan speed on product distribution of soybeans (Bourgault).

4.2.2 John Deere Air Seeder

CV_1 here illustrates the variation of one opener between different repetitions. On the John Deere set-up, individual opener variation ranged from 1.63% to 12.51%. The average variation for one opener was 6.00% with the highest CV_1 occurring for wheat trials and the lowest for soybeans. **Table** gives the average CV_1 values for the John Deere set-up.

Table 11. Average CV_1 values for the consistency distribution for individual openers between repetitions.

Fan Speed	**CV_1 (%)**			
	LS	***MS***	***HS***	***Average***
Soybeans	1.63	1.99	4.74	2.79
Canola - overall	4.53	3.46	8.23	5.41
Canola – front	3.93	2.74	6.89	4.52
Canola – rear	5.13	4.18	9.56	6.29
Wheat - overall	4.63	9.25	9.15	7.68
Wheat – front	4.29	6.39	5.82	5.50
Wheat - rear	4.97	12.04	12.51	9.84

During the evaluation of variation between openers (CV_2), the John Deere performance was less than 15% only during the evaluation of wheat at medium fan speed. In all other instance, the variation in product weight between openers averaged above 15%.

Product distribution for wheat, canola, and soybeans over the width of the seeder was significantly affected by the fan speed *and* position of the manifold. **Table 4** gives the average CV_2 values for variation along the seeder.

Table 4. Average CV_2 values for distribution between openers.

	CV_2 (%)			
Fan Speed	***LS***	***MS***	***HS***	**Average**
Soybean	16.70	17.08	17.79	17.19
Canola	18.96	18.10	16.96	18.01
Canola – front rack	19.88	18.15	18.09	18.71
Canola – rear rack	17.66	17.78	15.63	17.02
Wheat	17.72	14.15	15.77	15.88
Wheat – front rack	16.96	14.53	17.52	16.34
Wheat – rear rack	18.06	13.27	13.33	14.89

From **Figure 20**, the distribution of soybeans was only significantly different between manifolds M6 and M7. M6 delivered significantly higher volumes of product than other manifolds, whereas M7 delivered significantly less. This was not reflected on equivalent manifolds on the opposite side of the seeder (M2 and M3). Trials at high speed delivered less product than trials at medium or low speed.

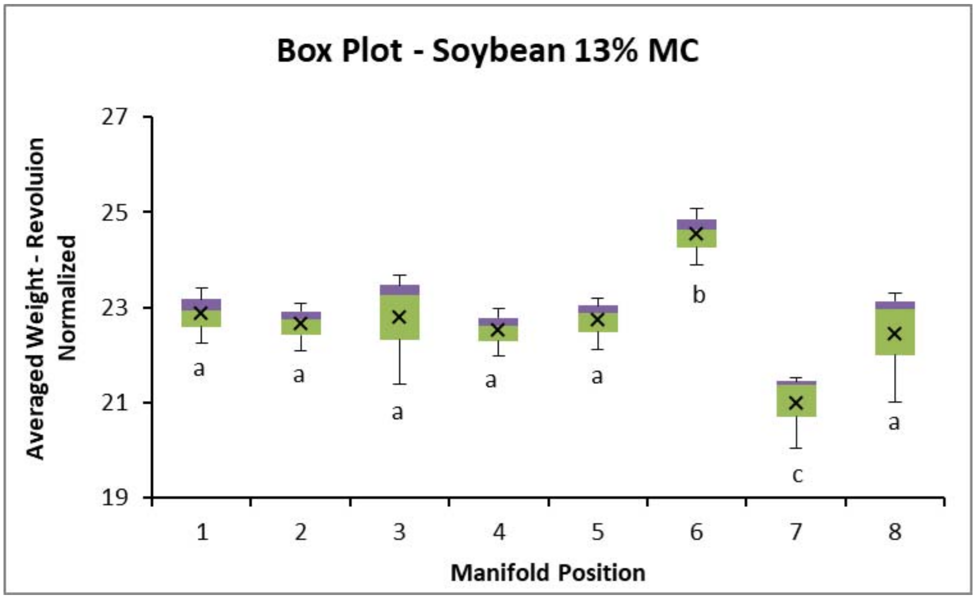


Figure 20. Product distribution for soybean trials.

Product distribution for canola trials followed a different pattern, with manifolds in the center delivering more product than that of M1 (outside). From **Figure 21**, the amount of product delivered by the manifolds decreased from central ones towards the outside ones. Trials at medium speed delivered more product than those at high or low speed.

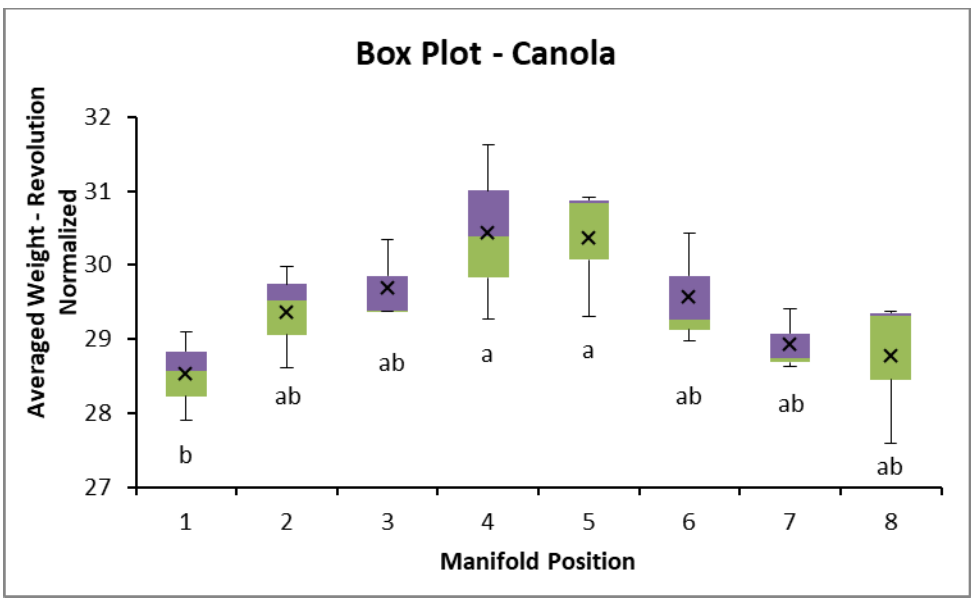


Figure 21. Product distribution for canola trials.

Wheat distribution in the John Deere was similar in all the manifolds over the width of the tool. There was no significant difference in product delivered among the manifolds. Quantitatively, center manifolds received higher amount of product as shown in **Figure 22**, though not enough to be considered significant. Trials at high speed delivered more product than at low speed.

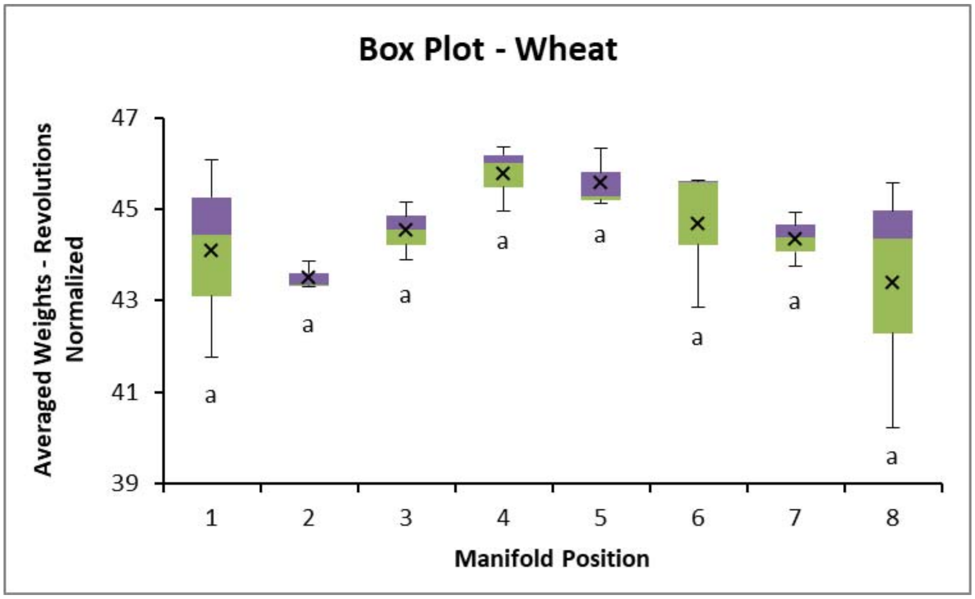


Figure 22. Product distribution for wheat trials.

Figure 23, **Figure 24**, and **Figure 25** compare the effects of fan speed on the passage of canola, wheat, and soybean during John Deere trial. In each trial, box plots with different letter labels are significantly different. The graphs help observe the effect of a particular speed is significantly higher or lower. For example, in **Figure 23**, high speed and low speed are assigned different letters. This indicates that results produce when running at high and low speed are statistically different. Medium speed was assigned both letter. This indicates that results produced at medium speed are not different than running at high or low speed. Blue dots represent outliers in the data.

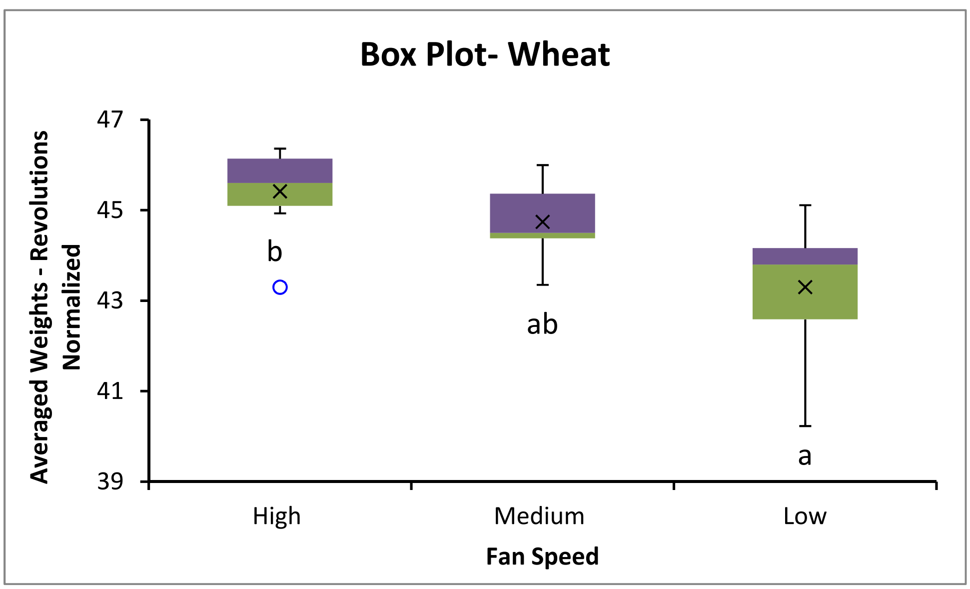


Figure 23. Effect of fan speed on product distribution of wheat (John Deere).

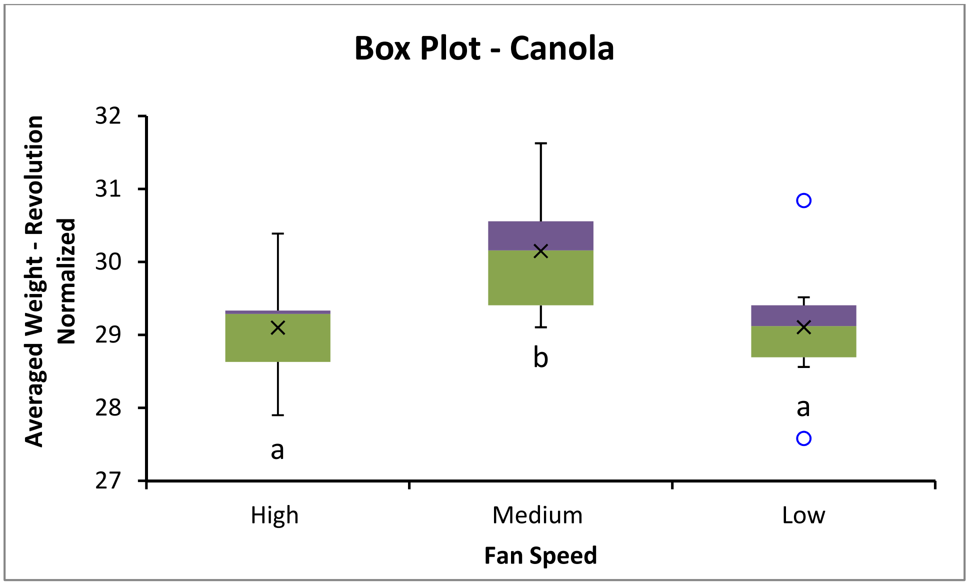


Figure 24. Effect of fan speed on product distribution of canola (John Deere).

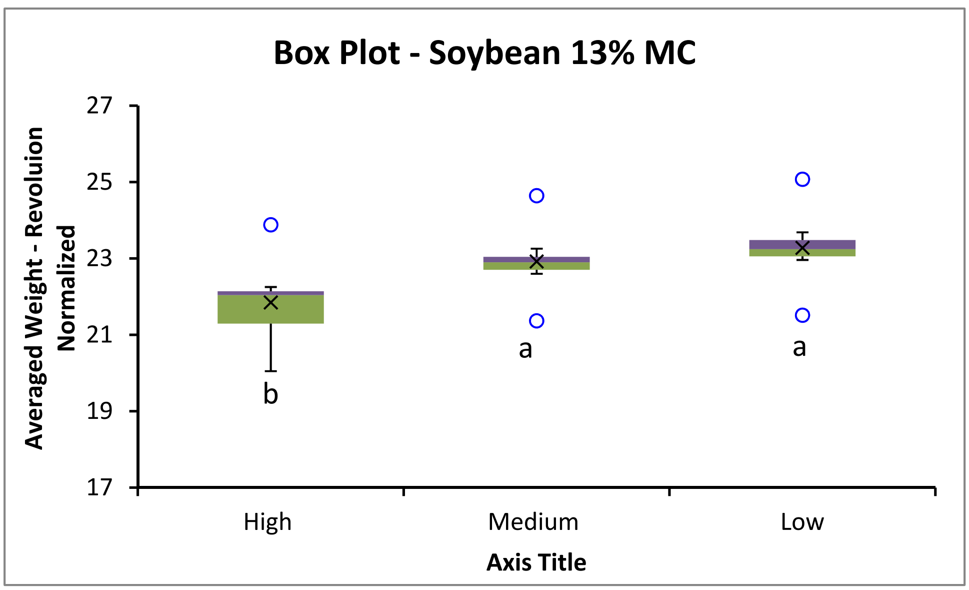


Figure 25. Effect of fan speed on product distribution of soybeans (John Deere).

5. Conclusion

In this study, two used 60’ seeders (Bourgault and John Deere) were examined for accuracy and repeatability of product distribution as well as seed damage at high, medium and low fan speeds for three different seed types: canola, wheat, and soybeans. Three moisture contents of soybeans tested were: 8%, 10%, and 13%. The seeders tested were owned by producers, and had been used for seeding in the spring prior to testing.

The Coefficient of Variation (CV_2) was used to determine difference in product distribution and represented the comparative difference in product delivery between openers in a single trial. Overall, a variation in product distribution for the trials was between 11%-20% with the highest variation seen in canola. Variation among openers in the same repetition (CV_2) averaged 13.4% on the Bourgault seeder and 16.9% on the John Deere seeder. On any single opener, variation in delivered product between successive repetitions (CV_1) was relatively low and all variation between individual openers averaged 4.9%.

Higher fan speeds produced better distribution results in canola, while low fan speeds generally produced better results in soybeans. There was no clear pattern for wheat. Results showed that the position of the manifold could affect product distribution, as manifolds closer to the center were more likely to receive more product compared to manifolds on the extreme outer edges. Though this pattern was true for both seeders, it is not consistent enough to make any conclusions about how manifold position affects distribution on a general basis. Manifold position was shown to have no significant effect on germination for wheat and canola, or soybeans.

Fan speed was shown to affect seed distribution in both seeders, though there was no specific pattern (i.e. one speed does not produce a more consistent distribution). Fan speed had some effect on germination. The overall effect of moisture content was much greater. The best germination rates occurred when seeds were higher moisture and at lower speeds. In the Bourgault trials, 8% moisture soybeans had an average rate of germination 4.3% lower than 13% soybeans. In the John Deere trials, 8% moisture soybeans had an average rate of germination 2.9% lower than 13% soybeans.

6. References

[1] Alberta Farm Machinery Research Centre; Prairie Agricultural Machinery Institute, "Evaluation Report 735," Alberta Farm Machinery Research Centre, Lethbridge, Alberta, 1998.

Appendix A

Map of each unit

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37
M1						M2						M3						M4						M5						M6					

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	37	36	38	39	40	41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	67	66	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
M1						M2						M3						M4						M5						M6						M7						M8					

"outside"	"center"	"in between"

Figure A- 1. Schematic representation of opener and manifold numbering for Bourgault (upper) and John Deere (lower) air seeders. The colour scheme indicates grouping of manifolds for germination samples.

Appendix B

Germination Sample Table

Table B- 1. Schematic of sub-sample tested for germination.

	HS_1			**HS_2**			**HS_3**			**MS_1**			**MS_2**			**MS_3**			**LS_1**			**LS_2**			**LS_3**		
Wheat	R_1, R_2, R_3			R_1, R_2, R_3			R_1, R_2, R_3			R_1, R_2, R_3			R_1, R_2, R_3			R_1, R_2, R_3			R_1, R_2, R_3			R_1, R_2, R_3			R_1, R_2, R_3		
Canola	R_1, R_2, R_3			R_1, R_2, R_3			R_1, R_2, R_3			R_1, R_2, R_3			R_1, R_2, R_3			R_1, R_2, R_3			R_1, R_2, R_3			R_1, R_2, R_3			R_1, R_2, R_3		
8% Soybeans	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
10% Soybeans	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
13% Soybeans	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3

Appendix C

Interaction between variables

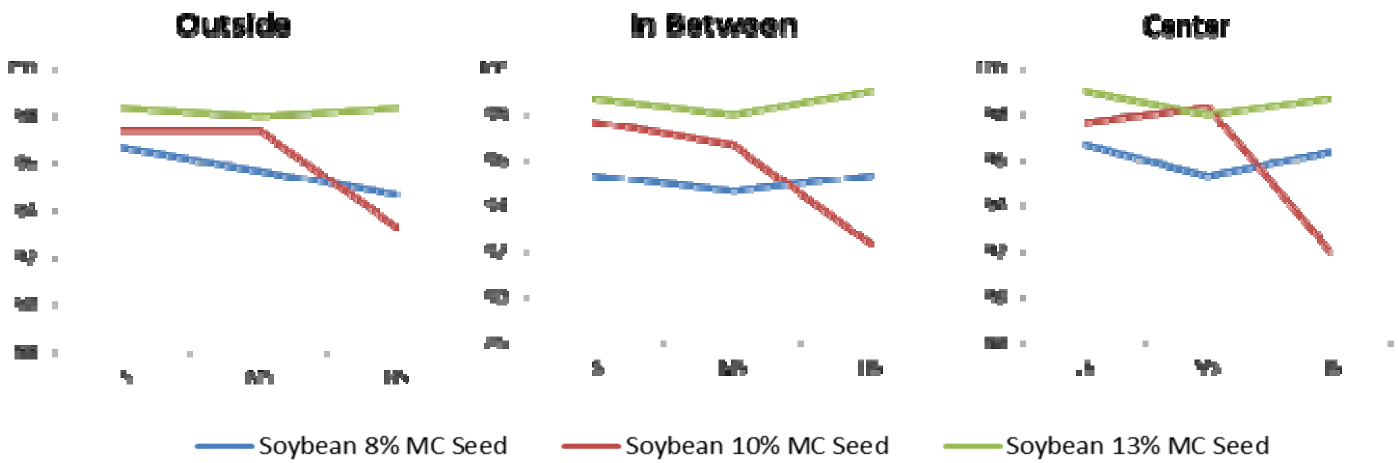


Figure C- 1. Interaction between fan speed and moisture content for germination rates (Bourgault).

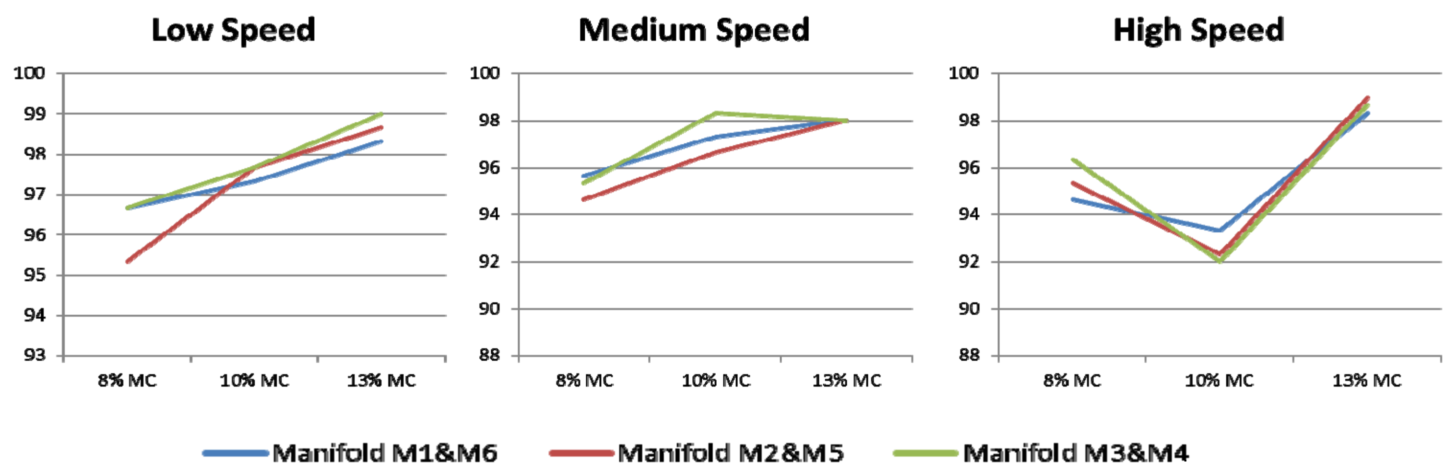


Figure C- 2. Interaction between manifold position and moisture content for germination rates (Bourgault).

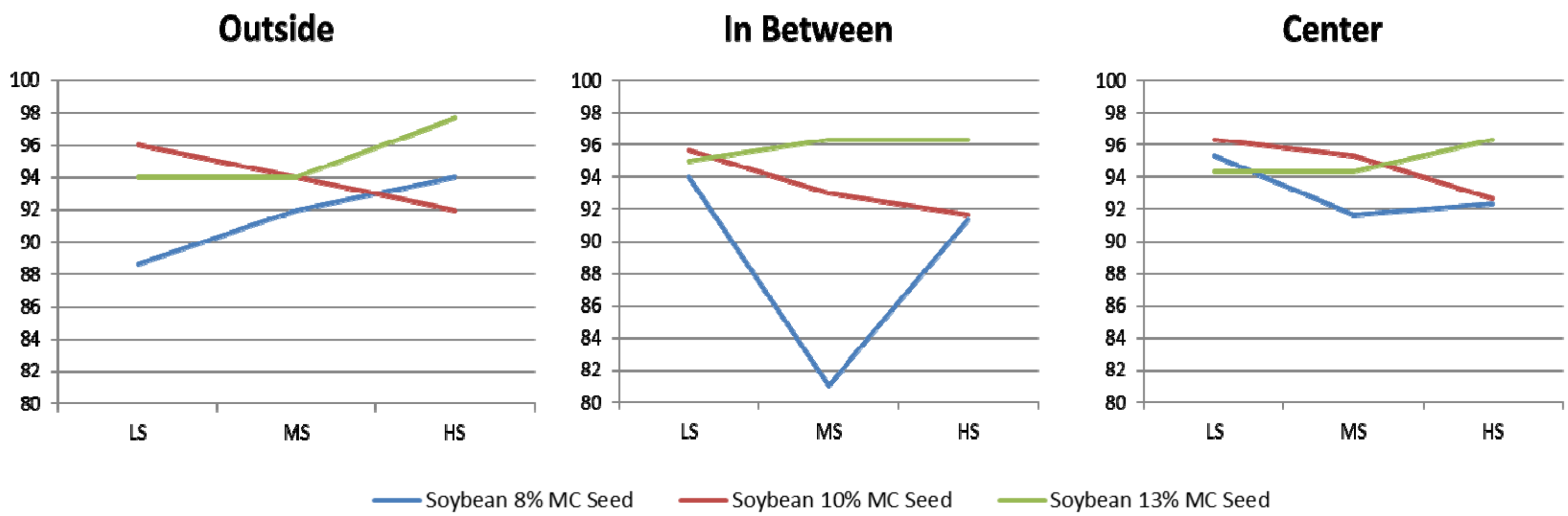


Figure C- 3. Interaction between moisture content and fan speed for germination rates (John Deere).

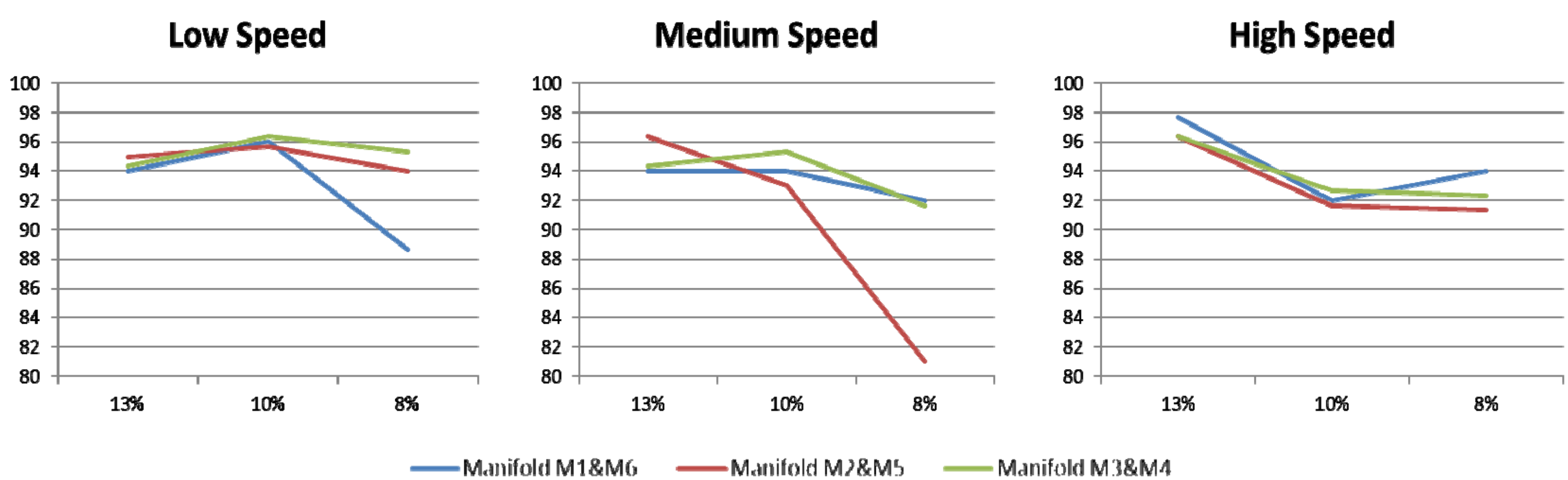
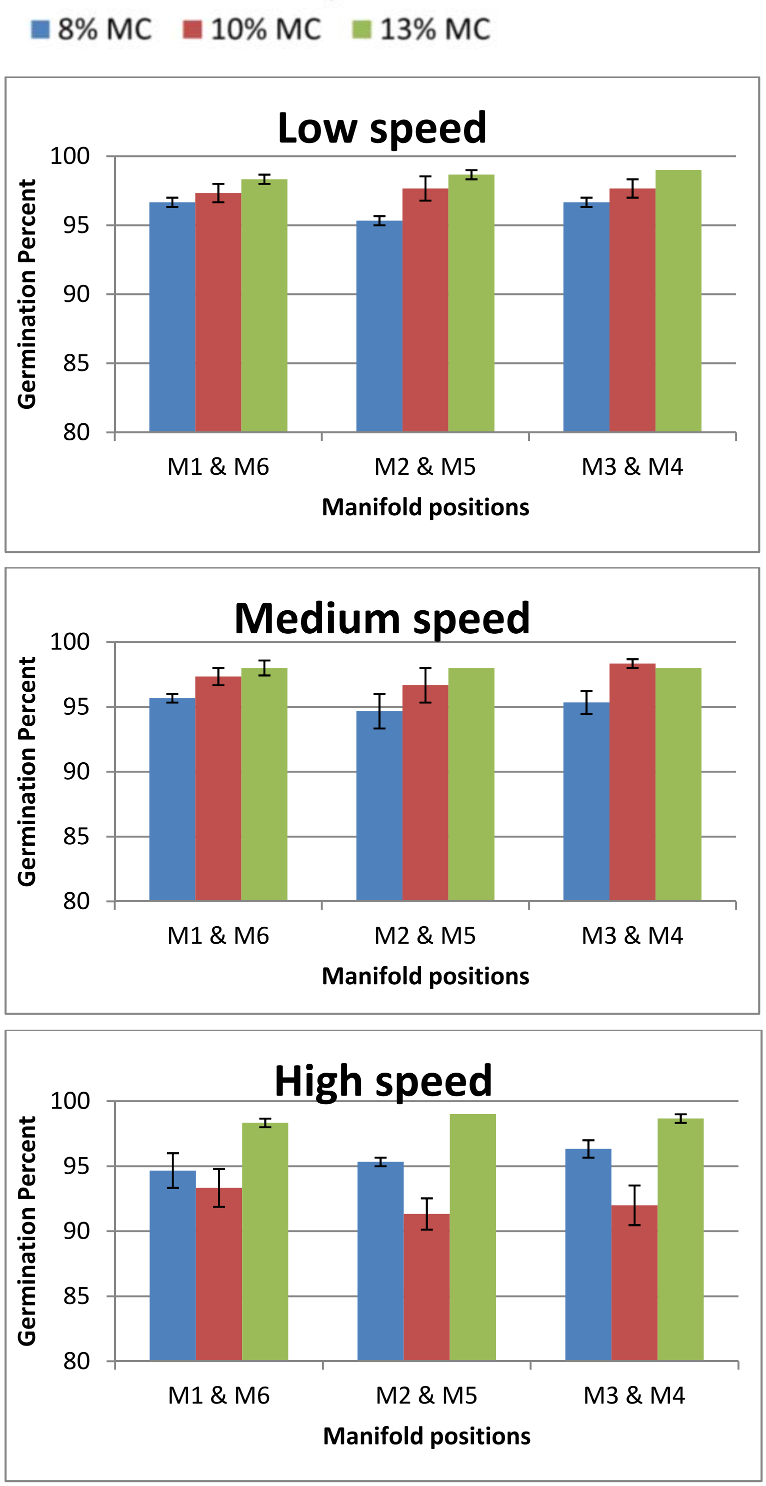


Figure C- 4. Interaction between manifold position and moisture content for germination rates (John Deere).

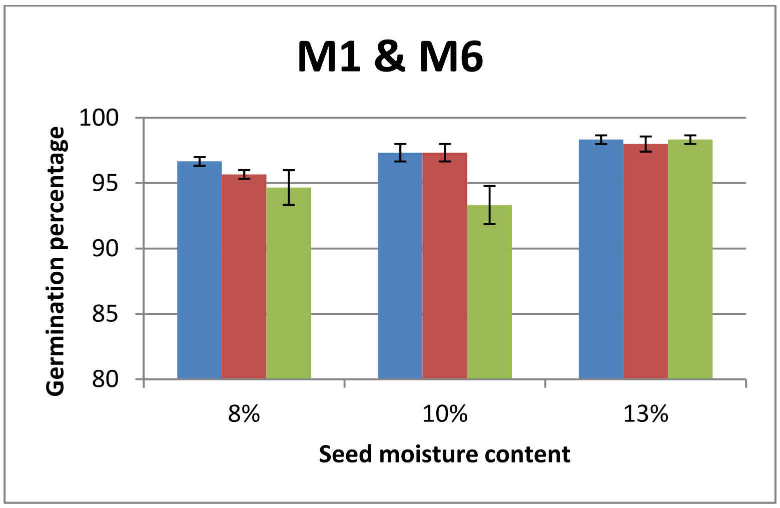
Soybean Germination Reports – Bourgault

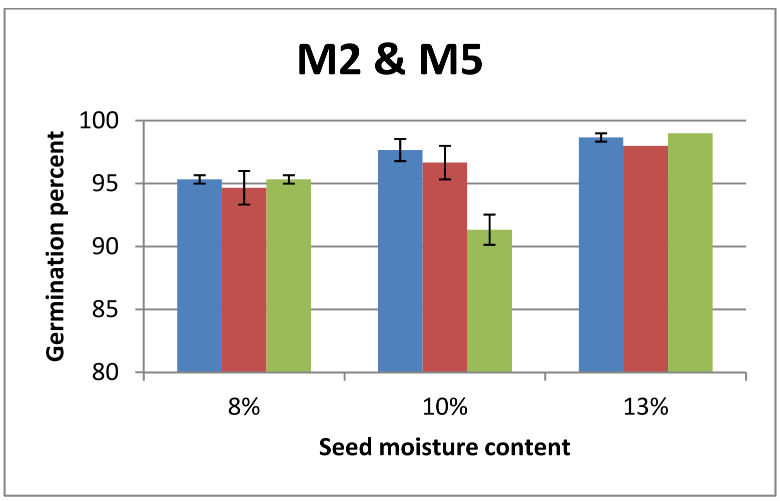
By Fan Speed

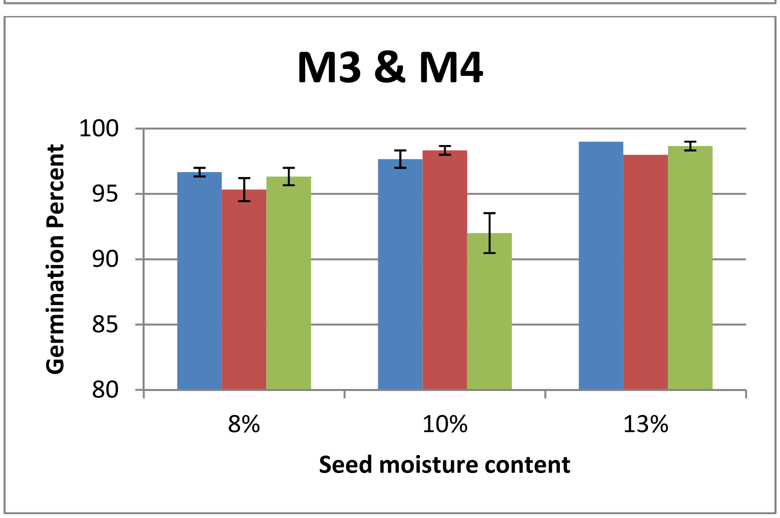


By Manifold Position

Low speed   Medium speed   High speed

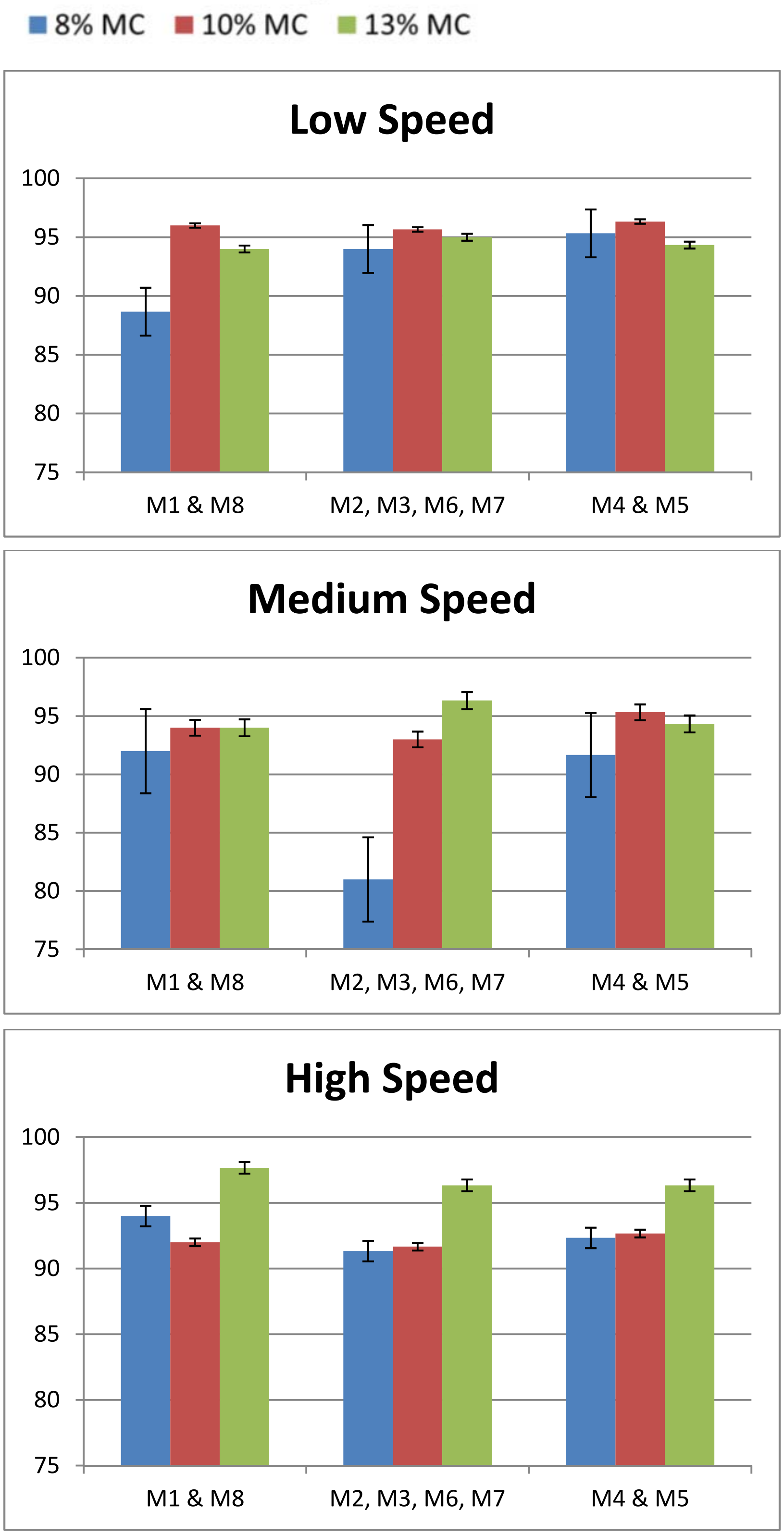




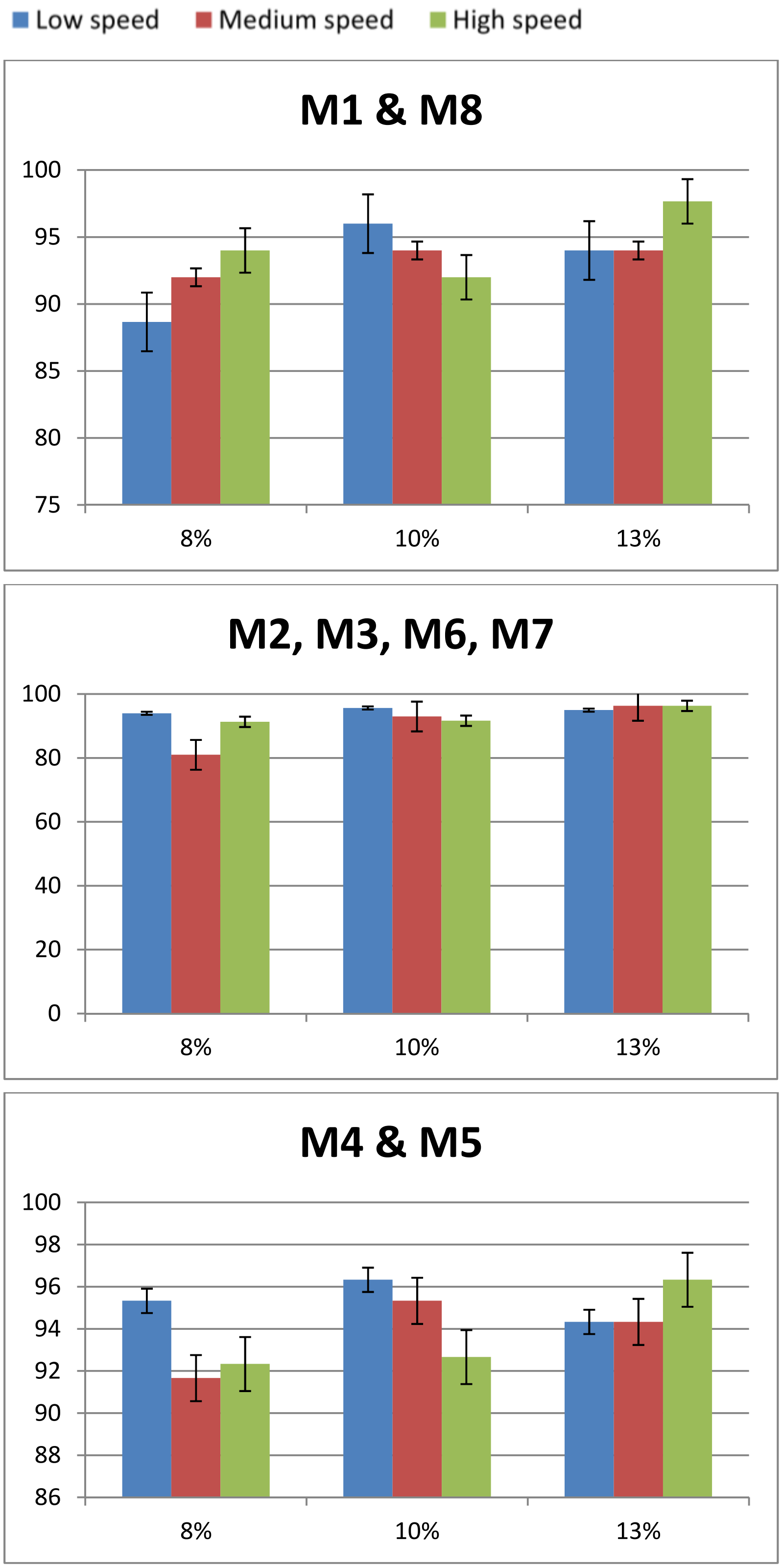


Soybean Germination Reports – John Deere

By Fan Speed



By Manifold Position



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