ADF Project Progress Report Format

1. **Project title, ADF file number and reporting period.**

   Improved Integrated Disease Management for Oats (*Avena sativa* L.) in Saskatchewan
   20170205
   December 5, 2017 to June 30, 2019

2. **Name of the Principal Investigator and contact information.**

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4. **Abstract (Not more than 250 words).** *Describe in lay language the progress towards the project objectives over the last reporting period. Include any key findings and any interim conclusions. Include any deviations from the original methodology.*

After our first year of study, we have made progress towards our objectives. To achieve our objectives, four study locations in Saskatchewan's main oat growing regions were selected. A split-plot design with four replicates was established at each location. The main plots were fungicide timing: untreated, flag leaf, and heading. The sub-plots were a combination of variety and seeding rate. The two varieties selected, CS Camden and Summit, differed in their genetic levels for yield, lodging, and disease resistance. The two seeding rates were 1x (300 seeds/m^2) and 1.5x (450 seeds/m^2). Our first objective was to understand the interaction between varietal resistance and fungicide application. Results indicate that the effectiveness of fungicide application does not significantly differ between the two varieties selected. Therefore, any treatment benefits were attributed solely to differences in genetic resistance and the location. The second objective was to determine the impact seed rate and plant populations have on optimal application timing. Results indicate that seeding rate did not significantly influence tillering, as expected at all sites. This unexpected effect is likely due to the dry conditions at many of the sites. Therefore for the first reporting period, there were no significant interactions between seeding rate and optimal application timing. The third objective was to determine integrated disease management strategies for oats. After 1 year of study, there were no discernable treatment effects identified. We hope that in further years of study, discernable integrated disease management strategies can be identified and made applicable for all of Eastern Saskatchewan's oat growing regions.

5. **Introduction:** *Brief project background and rationale.*

The Canadian Prairie provinces produce most of North America's oat destined for human consumption. In Saskatchewan, milling oat production is largely concentrated within crop districts 5, 6, 8, and 9. These districts are typically the wettest areas in the province, and where the risk of foliar diseases is greatest. Historically, rust species have been the most devastating fungal disease in oats. Crown rust (*Puccinia coronata* f.sp. *avenae*) has been known to cause 10 to 40% yield losses annually (Fetch et al., 2011). This can result in losses of up to $16 million, making it an economically significant yield and quality limiting factor (McCalumm et al. 2007). As well, Stem rust (*Puccinia graminis* f.sp. *avenae*) has resulted in epidemics during 1935, 1977, and 2003 causing serious yield and quality losses of up to $3 million annually (Fetch et al. 2011; McCalumm et al. 2007). The current method of controlling these fungal diseases include growing resistance cultivars, seeding early, and fungicide applications (McCallum et al. 2007).

Southern portions of the province are more prone to infection by rust species because the pathogen overwinters in the United States and moves northward with air currents. Rust spores usually reach significant levels in June on the Canadian Prairies (McCallum et al. 2007). This allows considerable time for disease progression to intensify before maturity and harvesting. After infecting southern portions of the province, the pathogen gradually moves northward as the growing season progresses. Therefore, northern growing areas are less prone to severe infections. Furthermore, when rust develops earlier in the spring, the risk of losses increases and so too does the need for additional control measures.

The wet and humid growing conditions in the dominant oat growing are also highly conducive to the development of head and other leaf diseases. Pyrenophora leaf blotch, Stagonospora leaf blotch, and Septoria leaf blotch complex are other foliar diseases of concern (May et al. 2014). Although these diseases are more prominent in more northern oat growing regions. However, little is known about the impact these leaf diseases have on yield, quality, and the economics of oat production throughout the region.

Tilt (propiconazole) and Folicur (tebuconazole) are effective fungicides for controlling rust diseases, as well as Fusarium Head Blight (McCallum et al. 2007; Picinini and Fernandes 1994). The optimal timing for control of both rust and blotch complexes is at flag leaf stage (Zadoks 39) (Bowen et al. 2016). This differs from optimal application timing for the management of head diseases, which is typically after head emergence. This makes disease management decisions difficult, especially when reports of effective fungicide application for these diseases in oats being anecdotal. In addition, it is suggested that due to the late onset of Crown rust in northern growing areas, optimal fungicide application in these growing areas may be later than traditionally recommended.

Increasing the efficacy of fungicide application in any crop, including oats, is contingent on correct disease identification, fungicide production selection, and application timing (Soovali and Koppel 2011). Studies documenting yield and/or quality improvements from fungicidal control of leaf blotch complexes are limited as well. While Fusarium Head Blight (FHB) does not significantly reduce yield and quality in oats currently, it does in wheat grown throughout the same regions. Although symptoms of FHB are not frequently noted on oat, growers question the implication the disease might have. Therefore, this study will also allow us to be potentially proactive in managing FHB in oat. Furthermore, due to the low price of oats, fungicide efficacy needs to be noticeable in order to improve the economics of fungicide application. This will also help to ensure that these diseases are being adequately controlled, while not overusing fungicides. This task requires an enhanced understanding of how agronomic practices can be used together to develop an integrated disease management system for oats.

Currently, genetic resistance to Crown rust is the primary control method in Canada. Unfortunately, genetic resistance to Stem rust is limited, making Integrated Disease Management more important. Although resistant cultivars are highly effective in reducing yield loss, Crown rust is constantly evolving resulting in reduced efficacy of resistant genes overtime. Also, little is known regarding the varietal differences in genetic resistance to Septoria leaf blotch complex and Fusarium Head Blight. Although genetic resistance is a highly beneficial trait, selection of other traits like lodging resistance and test weight, maybe of higher priority to growers. Consequently, this results in an increased reliance on fungicide application for disease control, under these circumstances.

Previous studies suggest that increased seeding rate is also effective in reducing tillering in cereals. With reduced tillering, the crop develops approximately at the same rate. This effectively should allow growers to improve application timing and in turn improve fungicide efficacy. Unfortunately, there are no studies combining seeding rate, fungicide use, and genetic resistance for oat disease management.

This project will build on the first piece of scientific literature combining fungicide and variety selection for yield and quality improvements for oats in the Northern Great Plains of North America. This research by May et al. (2014) found varieties which were rated to susceptible to Oat Crown Rust (ie. AC Morgan) consistently responded to fungicide application with a 17 to 27% yield increase when disease pressure was high and increased test weight. However, the authors note that beta-glucan levels were more affected by seeding date and cultivar selection than fungicide application. As well, those cultivars with genetic resistance for Crown Rust (ie. Leggett) did not benefit from fungicide application.

This project will also build on an Estonian study by Soovali and Koppel (2011), focusing on the identification of optimal fungicide application timing to control leaf and head diseases in oats. In this study, fungicides were applied at either flag leaf or head, to four cultivars varying in genetic resistance levels. The authors found that under low leaf spot disease pressure, early fungicide application provided better disease control overall, except when disease pressure was high in certain varieties, when late application was significantly better.

Overall, Oat growers across the province have identified that further information regarding Integrated Disease Management is crucial for high yielding and quality oats to be continuously produced in the province. Therefore, this project is intended to build on the research of others and develop the information necessary to fill in known information gaps in oat agronomy across Saskatchewan.

6. Objectives and the *progress towards meeting each objective*

Objectives (*Please list the original objectives and/or revised objectives if Ministry-approved revisions have been made to original objective. A justification is needed for any deviation from original objectives)*	**Progress (e.g. completed/in progress)**
a) Understand the interaction of varietal resistance and fungicide application	In progress
b) Determine the impact plant populations have on optimal fungicide application	In progress
c) Determine integrated disease management strategies in Oats (*Avena sativa* L.)	In progress

Please add additional lines as required.

7. Methodology: *Specify project activities undertaken during this reporting period. Include approaches, experimental design, tests, materials, sites, etc. Please note that any significant changes from the original work plan will require written approval from the Ministry.*

This small plot research project was conducted in 2018 at four Saskatchewan locations: Indian Head, Melfort, Redvers, and Yorkton. Each of these four locations are Agri-ARM sites representing the different climatic conditions within the Black soil zone. The project was setup in a split block design with four replicates. The main plot consisted of fungicide timing with applications at either flag leaf (Zadoks 39), Heading (Zadoks 59), or neither (control). The sub-plots consisted of a combination of two varieties and two seeding rates. The two varieties differed in their yield potential, lodging resistance, and disease resistance. CS Camden is higher yielding, has very good lodging resistance, is susceptible to Stem Rust and marginally susceptible to Crown Rust. Summit is lower yielding, has good lodging resistance, and has intermediate resistance to Stem Rust and Crown Rust. The 300 seeds m^{-2} seeding rate, is the recommended seeding rate; while 450 seeds m^{-2} is 1.5x the recommended rate. Together, the three fungicide application timings and four variety X seeding rate treatments combine to make 12 treatments (Table 1).

Table 1: Fungicide application timing and variety X seeding rate treatment summary for Integrated Disease Management in Oats at four locations in 2018.

Treatment #	Fungicide Application Timing (Main Plot)	Variety X Seeding Rate (Sub-plot)
1	Untreated	CS Camden at 300 seeds m^{-2}

2		CS Camden at 450 seeds m^{-2}
3		Summit at 300 seeds m^{-2}
4		Summit at 450 seeds m^{-2}
5	Zadoks 39 (Flag Leaf)	CS Camden at 300 seeds m^{-2}
6		CS Camden at 450 seeds m^{-2}
7		Summit at 300 seeds m^{-2}
8		Summit at 450 seeds m^{-2}
9	Zadoks 59 (Heading)	CS Camden at 300 seeds m^{-2}
10		CS Camden at 450 seeds m^{-2}
11		Summit at 300 seeds m^{-2}
12		Summit at 450 seeds m^{-2}

Plot sizes varied between locations, due to logistical requirements, with plots a minimum 2m by 6m. Row spacing varied between locations with Redvers on 10-inch row spacing, while the other three sites were on 12-inch row spacing. All sites were seeded between May 7 and 15 2018, into pea or canola stubble, at 0.75 and 1.5 inches deep (Table A1). The two seeding rates were corrected based the seed lot's respective germination (%) and seed weight (g/1000 seeds). No seed treatments were applied. In most cases, seeding and fertilization were completed in the same operation. All fertilizer applications were made to target a 150 bu/ac oat crop (Table A2). At all sites, the total amount of nitrogen was balanced for nitrogen provided by other fertilizers.

General applications of herbicide, insecticide, and pre-harvested aid products were site dependent to ensure non-liming yield conditions (Table A2). For both fungicide application timings, Caramba was the product used and applied at label rates. At flag leaf, Caramba was applied at 280 mL/ac in 40 L/ac of water. At heading, Caramba was applied at 400 mL/ac, in 40 L/ac of water as well. Application dates are summarized in Table A1. Furthermore, all foliar applications were made using the spray equipment available at each site. After physiological maturity, plots were harvested using a plot combine between August 10 and September 28 (Table A1).

Data collection included plant density, tiller density, rust and leaf spot ratings, FHB infection ratings, lodging, maturity, yield, seed quality, and milling quality. Plant density was calculated based on the number of oat seedlings along two 1 meter crop rows 4 weeks after planting. Tiller density was determined by destructively sampling two 0.5 m rows per plot. Prior to fungicide application, and at the milk stage, 10 flag and penultimate leaves from each plot were assessed for Crown and Stem rust as well as leaf spot diseases, using the Cobb and Horsfall-Barratt scales. Prior to maturity, the % of plot affected by Fusarium Head Blight (FHB) was assessed. As well, each plot was rated using the Belgian Lodging Scale (area [1-9] * Intensity [1-5] * 0.2). At the first detection of plant dry down, each plot was rated for maturity in relation to each other with 1 being more advance, 2 being the mean, and 3 being behind. After combining, samples were cleaned, weighed, and corrected for 13.5% moisture. Thousand kernel weight was assessed by counting and weighing 1000 seeds. From the cleaned grain sample, 500g was sub-divided and sent to General Mills for milling analysis (protein, plump, thins, unhulled, groats, beta-glucan, and fat). An additional 300g sample was sent to Seed Solution Seed Labs for analysis of all pathogens found on the seeds.

For statistical analysis, each site-year (location) was analyzed separately, as it was the first year of the study. A comprehensive, multi-location analysis is planned for years 2 and 3 of this project. Fungicide timing and variety X seeding rate were fixed effects, while replicate was a random effect. All means were separated using LSD at $p<0.05$.

8. **Results and discussion:** *Describe research accomplishments during the reporting period under relevant objectives listed under section 6. The results need to be accompanied with tables, graphs and/or other illustrations. Provide discussion necessary to the full understanding of the results. Where applicable, results should be discussed in the context of existing knowledge and relevant literature. Detail any major concerns or project setbacks.*

Growing Season Conditions

At all four locations, the average temperature during the 4-month growing season period was warmer than the long-term climate normal (Table 2). As well, all four locations received less precipitation than the long-term climate normal (Table 3). At all locations, May was 3 to 4°C warmer and had 4 (Melfort) to 51 mm (Yorkton) less precipitation. June was 2°C warmer at Redvers and Yorkton, and 1°C warmer in Indian Head and Melfort. Melfort was the only location to receive less precipitation in June than normal, while Yorkton and Redvers had 40 mm more. July and August were within 1°C of the long-term climate normal at all four sites, while all sites had 7.2 (Melfort) to 47 mm (Indian Head) less rain than normal. Overall, the dry and warm conditions in Melfort could have had a potential effect on seedling emergence. The warm and wet conditions at Redvers and Yorkton could also provide the potential for increased leaf spot diseases. Lastly, the warm and dry conditions in July and August could limit the amount of Fusarium Head Blight development and hasten maturity for earlier maturity.

Table 2: Mean temperature (°C) values at the four study locations in 2018 compared to the long-term climate normal. All data was obtained from the nearest Environment and Climate Change Canada location.

Location	Period	May	June	July	August	Average
Indian Head	2018	13.9	16.5	17.5	17.6	16.4
	Long-Term	10.8	15.8	18.2	17.4	15.6
Melfort	2018	13.9	16.8	17.5	15.9	16.0
	Long-Term	10.7	15.9	17.5	16.8	15.2
Redvers	2018	15.2	18.3	18.7	17.8	17.5
	Long-Term	11.1	16.2	18.7	18.0	16.0
Yorkton	2018	14.0	17.7	18.3	18.1	17.0
	Long-Term	10.4	15.5	17.9	17.1	15.2

Table 3: Total precipitation (mm) values at the four study locations in 2018 compared to the long-term climate normal. All data was obtained from the nearest Environment and Climate Change Canada location.

Location	Period	May	June	July	August	Average
Indian Head	2018	23.7	90.0	30.4	3.9	148.0
	Long-Term	51.7	77.4	63.8	51.2	244.1
Melfort	2018	38.5	46.6	69.5	43.2	197.8
	Long-Term	42.9	54.3	76.7	52.4	226.3
Redvers	2018	21.1	137.2	48.3	9.9	216.5
	Long-Term	60.0	95.2	65.5	46.6	267.3
Yorkton	2018	0.8	120.1	53.8	21.1	195.8
	Long-Term	51.3	80.1	78.2	62.2	271.8

Plant Density

As expected, the variety by seeding rate factor had a significant effect on plant populations at all four locations (Table 4). Further to expectations, there were no significant effects by fungicide timing or the two-way interaction, as the fungicide applications had not yet taken place. Overall, Indian Head had the highest plant density, while Redvers had the lowest (Table B1).

Table 4: Statistical summary of treatment effects on plant density (plants/m^2) for the Integrated Disease Management in Oats study at four locations in 2018.

Source	Indian Head (IH)	Melfort (ME)	Redvers (RD)	Yorkton (YK)
Fungicide Timing (FT)	0.4848	0.9090	0.3006	0.6064
Variety X Seeding Rate (VSR)	<0.0001***	0.0041**	<0.0001***	<0.0001***

FT * VSR	0.2178	0.7978	0.3205	0.1505
Grand Mean	367.5	354.8	295.8	303.5
CV (REP * FT)	6.4	10.4	11.7	9.5
CV (REP * FT * VSR)	6.5	16.7	12.8	10.8

*** p<0.001; ** p<0.05 to 0.01; *p<0.05

At Indian Head, Redvers, and Yorkton, the plant density in the 300 seeds/m^2 treatments were significantly lower than their respective 450 seeds/m^2 counterparts, as expected (Figure 1). At Indian Head and Redvers, there were no significant differences between the plant density of the two varieties seeded at 300 seeds/m^2; while CS Camden had slightly more plants/m^2 than Summit in Yorkton. At Melfort, there were no significant differences between the two varieties at 300 seeds/m^2; however, they were also not significantly different from CS Camden at 450 seeds/m^2. At Melfort and Redvers, Summit seeded at 450 seeds/m^2 had the greatest plant density, while at Indian Head and Yorkton, CS Camden at 450 seeds/m^2 were the greatest. Overall, plant density within the individual treatments, were largely as expected. The 450 seeds/m^2 treatments had greater plant density than the 300 seeds/m^2. When seeded at 300 seeds/m^2, there was similar establishment between the two varieties. While at higher seeding rates, there were significant differences between the density of the two varieties, depending on the location.

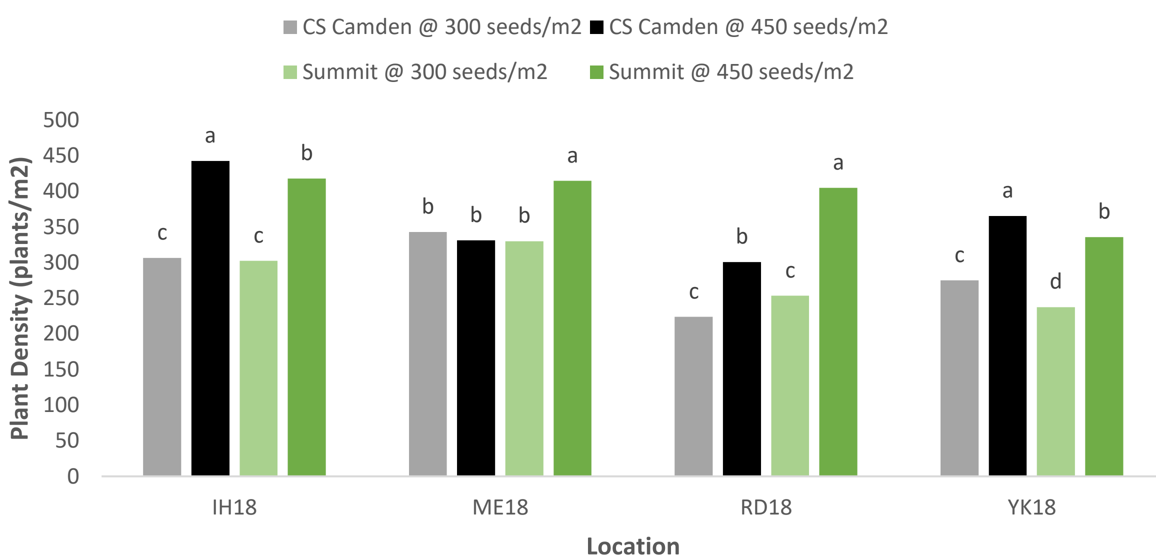

Figure 1: Variety X Seeding Rate effect on plant density (plants/m^2) at four Eastern Saskatchewan locations in 2018.

Tiller Density

As expected, the variety by seeding rate factor had a significant effect on tiller density in 3 of 4 locations (Table 5). The significant effect of fungicide timing on tiller density at Yorkton, and Melfort at p<0.1 are false positives (Type I error), as fungicide had not yet been applied to the plots. Overall, Indian Head had a greater number of tillers than the other three locations; while Melfort and Yorkton had the least (Table B2). This effect at Indian Head is likely due to the counting of panicles/m^2 to account for the number of tillers, rather than the number of actual tillers from destructive sampling. Sampling methods for this variable will be improved upon for later reporting periods.

Table 5: Statistical summary of treatment effects on tiller density (tillers/m^2) for the Integrated Disease Management in Oats study at four locations in 2018.

Source	Indian Head (IH)	Melfort (ME)	Redvers (RD)	Yorkton (YK)
Fungicide Timing (FT)	0.5804	0.0819	0.6074	0.0312*
Variety X Seeding Rate (VSR)	<0.0001***	0.1285	0.0008**	0.0332*
FT * VSR	0.4397	0.2474	0.2764	0.9494
Grand Mean	412.1	259.9	280.9	260.6
CV (REP * FT)	7.8	23.4	17.7	7.7
CV (REP * FT * VSR)	7.6	15.1	17.6	15.7

*** p<0.001; ** p<0.05 to 0.01; *p<0.05

At Indian Head, tiller density was significantly affected by seeding rate, while the two varieties had a similar number of tillers within either seeding rate treatment (Figure 2). A similar trend occurred in Yorkton, although not statistically so. In Yorkton, there was only a significant difference in the number of tillers between CS Camden at 300 seeds/m^2 and Summit at 450 seeds/m^2. At RD18, seeding rate had the opposite effect on tiller density compared to Indian Head. Meanwhile, at Melfort, the only significant difference in the number of tillers was between the two seeding rates of CS Camden. Overall, Redvers was the only location where the expected effect of seeding rate on tillering occurred. Previous research has found that when seeding rate is increased, the number of tillers produced becomes fewer. This suggests that the environmental conditions at Redvers during the earlier parts of the growing season did not restrict growth. Whereas in Indian Head, Melfort, and Yorkton, conditions did not limit the number of tiller development and thus the number of tillers did not decrease proportionally to the change in seeding rate.

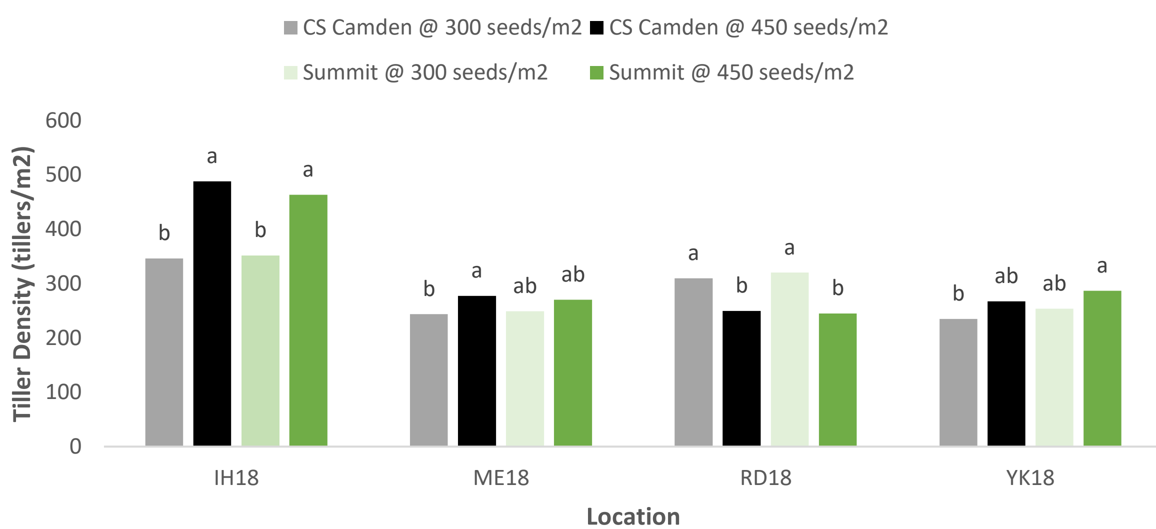

Figure 2: Variety X Seeding Rate effect on tiller density (tillers/m^2) at four Eastern Saskatchewan locations in 2018.

Disease Ratings

Rust and Leaf Spot

Prior to fungicide application at the flag leaf stage, there was very little disease present at all three locations. At Indian Head and Melfort there was only a trace of leaf spot diseases found; while in Redvers and Yorkton up to 3% leaf spot diseases were found. At Yorkton, there was a slight tendency for CS Camden to have greater leaf spot symptoms than Summit on average (3% vs. 1%, respectfully).

Prior to fungicide application at heading, average disease severity increased from traces to <3% at Indian Head and Yorkton (Table B3). While, average disease severity was similar at Redvers between the two application timings. Unfortunately, the disease ratings at this timing, in Melfort, were missed and thus are not included in this section of analysis. At Indian Head and Yorkton, there were significant differences in the amount of leaf spot symptoms due to fungicide timing (Table 6). At these two locations, plus Redvers, the variety by seeding rate factor also had a significant effect on disease symptoms. At all three locations, the two-way interaction did not have a significant effect.

Table 6: Statistical summary of treatment effects on average disease severity (%) prior to fungicide application at heading for the Integrated Disease Management in Oats study at three locations in 2018.

Source	Indian Head (IH)	Redvers (RD)	Yorkton (YK)
Fungicide Timing (FT)	0.0068**	0.1112	0.0002**
Variety X Seeding Rate (VSR)	0.0010**	0.0031**	0.0397*
FT * VSR	0.9591	0.7055	0.0628
Grand Mean	1.7	1.2	2.1
CV (REP * FT)	8.4	17.4	34.9
CV (REP * FT * VSR)	11.5	18.7	47.7

*** p<0.001; ** p<0.05 to 0.01; *p<0.05

In Indian Head, fungicide application at the flag leaf stage significantly reduced average disease severity in comparison to the untreated control. At this location, the average disease rating was reduced from 1.7 in the untreated control to 1.6 based on the Horsfall-Barret scale. However, this does indicate that there was still less than 3% disease overall in both treatments. In Yorkton, the untreated control had 6 to 12% disease symptoms, while disease symptoms in the plots treated with fungicide at flag leaf had 1 to 3%. Therefore, fungicide application at the flag leaf stage, significantly reduced disease severity in Yorkton 2018.

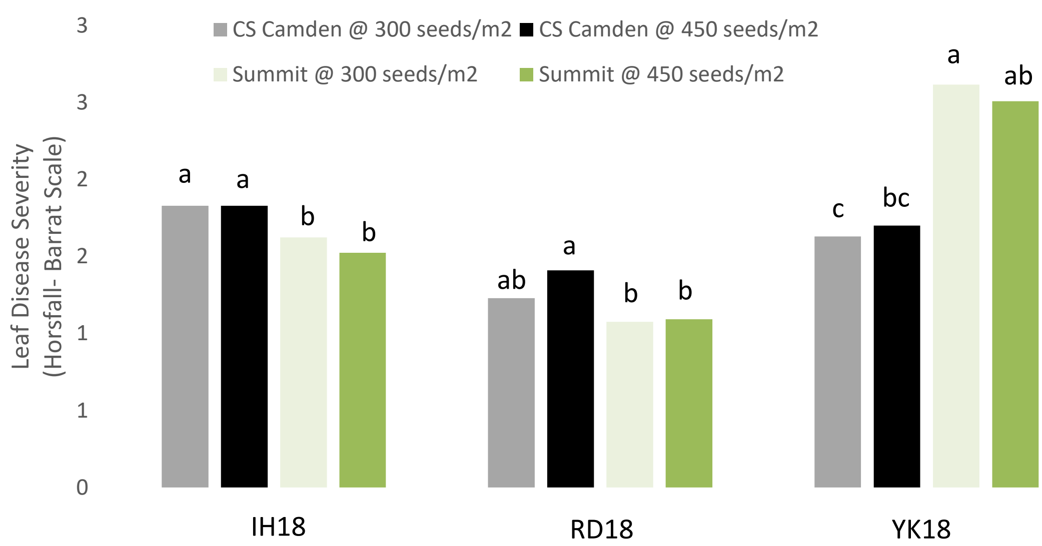

Figure 3: Variety X Seeding Rate effect on leaf disease severity (Horsfall-Barrat Scale) at three Eastern Saskatchewan locations in 2018.

At the milk stage, after all fungicide treatments had been applied and prior to senescence, disease severity was higher in Indian Head than Melfort (Table B4). At this time, disease severity at Redvers and Yorkton was not recorded. At Indian Head, disease severity increased to between 12 and 25% on average from the <3% prior. It was noted that the increase in disease severity was likely confounded with early senescence, brought on by drought. However, the variety by seeding rate factor did have a significant effect on disease severity at this time in Indian Head, yet not in Melfort (Table 7). Furthermore, fungicide timing and the two-way interaction did not have a significant effect on disease severity prior to senescence.

Table 7: Statistical summary of treatment effects on average disease severity (%) at the milk stage (prior to senescence) for the Integrated Disease Management in Oats study at two locations in 2018.

Source	Indian Head (IH)	Melfort (ME)
Fungicide Timing (FT)	0.6244	0.4219
Variety X Seeding Rate (VSR)	<0.0001***	0.1798
FT * VSR	0.4777	0.2793
Grand Mean	5.3	1.1
CV (REP * FT)	16.5	12.0
CV (REP * FT * VSR)	8.1	9.2

*** p<0.001; ** p<0.05 to 0.01; *p<0.05

At Indian Head, CS Camden at 450 seeds/m^2 had 25 to 50% disease severity, which was significantly greater than the other three treatments (Table 7). Both CS Camden at 300 seeds/m^2 and Summit at 450 seeds/m^2 had similar disease levels with 12 to 25% disease severity on average. Summit at 300 seeds/m^2 had the lowest disease severity of the four treatments at 6 to 12% severity. Overall, fungicidal control of leaf spot diseases in oats gave mixed results and no discernible trends emerged after one year of study.

Table 7: Variety X seeding rate treatment effects on average disease severity (%) at the milk stage (prior to senescence) for the Integrated Disease Management in Oats study at two locations in 2018.

Variety X Seeding Rate	Horsfall-Barratt Scale[z]	% Disease Severity
CS Camden @ 300 seeds/m^2	5.2 b	12 – 25
CS Camden @ 450 seeds/m^2	6.0 a	25 – 50
Summit @ 300 seeds/m^2	4.6 c	6 – 12
Summit @ 450 seeds/m^2	5.3 b	12 – 25

[z] Values with the same letters are statistically similar

Crown Rust, Stem Rust, and Fusarium Head Blight

At each of the four locations, there were no visual symptoms of Crown Rust, Stem Rust, or Fusarium Head Blight found. This result is not unexpected as both Crown and Stem Rust infections are dependent on northern winds from the United States. Thus, infection is dependent on favourable weather conditions and the presence of rust varies from year to year. Furthermore, it was expected there would be little to no Fusarium Head Blight as the disease is relatively uncommon in oats across Saskatchewan. However, it is becoming an increasing concern.

<u>Lodging</u>

The variety by seeding rate factor had a significant effect on lodging at the all three locations, where lodging occurred (Table 8). Fungicide timing nor the two-way interaction did not have a significant effect on lodging at all three locations. However, fungicide timing did have an effect in Yorkton 2018 at the p<0.1 level. This suggests that there was a slight influence of fungicide timing on the rate of lodging that occurred in Yorkton. Overall, Yorkton had approximately 25% lodging across all treatments and had the highest rates of the four locations (Table B5). At Indian Head and Redvers there was less than 10% lodging across treatments, with large variability between the rate of lodging within the individual plots. Lodging did not occur at Melfort 2018.

Table 8: Statistical summary of treatment effects on lodging (Belgian scale) for the Integrated Disease Management in Oats study at three locations in 2018. Lodging did not occur in Melfort 2018.

Source	Indian Head (IH)	Redvers (RD)	Yorkton (YK)
Fungicide Timing (FT)	0.8297	0.6576	0.0723
Variety X Seeding Rate (VSR)	<0.0001***	0.0010**	0.0003**
FT * VSR	0.5027	0.6405	0.9091
Grand Mean	0.3	0.6	2.5
CV (REP * FT)	26.9	101.0	11.5
CV (REP * FT * VSR)	27.2	115.6	28.3

*** p<0.001; ** p<0.05 to 0.01; *p<0.05

At all three locations were lodging occurred, Summit tended to have more lodging than CS Camden (Figure 4). This reflects the lodging rating found in the Saskatchewan Seed Variety Guide, where CS Camden has a very good lodging rating, while Summit is rated as good. In Indian Head, CS Camden at 300 seeds/m^2 had significantly less lodging that the other three treatments, while the rate of lodging in the two Summit treatments were similar. In Redvers, Summit at 450 seeds/m^2 had significantly higher lodging than the other three treatments which were similar. At Yorkton, there were similar rates of lodging between the two seeding rate treatments of each variety. These results suggest that increasing the seeding rate to 450 seeds/m^2 does not significantly increase the rate of lodging, under the low lodging conditions experienced in 2018. Therefore, when the risk of lodging is low, lodging severity is primarily impacted by the variety selected.

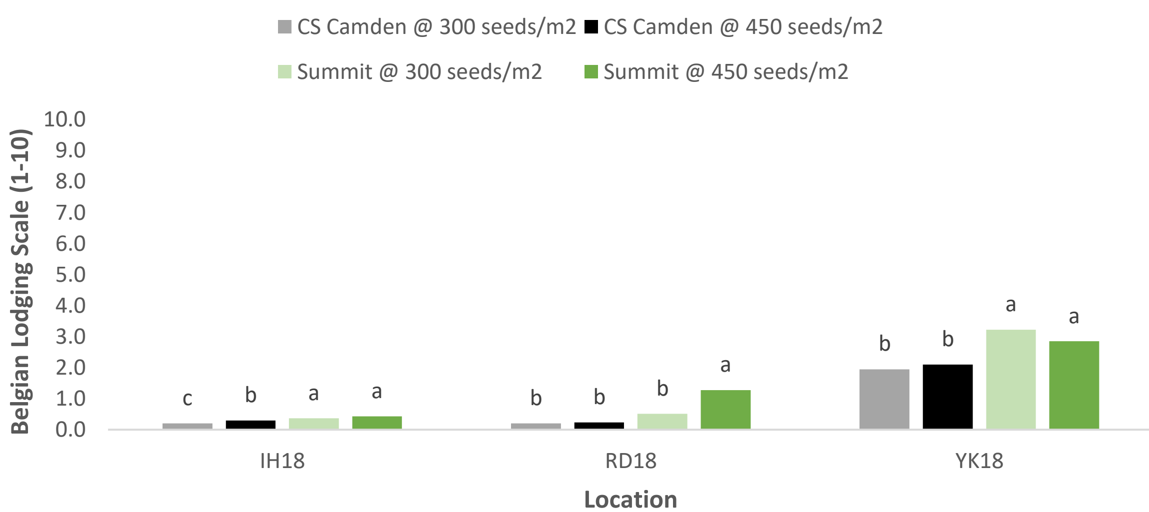

Figure 4: Variety X Seeding Rate effect on lodging (Belgian Scale [1-10]) at three Eastern Saskatchewan locations in 2018. No lodging occurred in Melfort 2018.

Maturity

The variety X seeding rate factor also had a significant effect on maturity (Table 9). As with lodging, the two-way interaction did not have a significant effect on maturity; while fungicide timing only had a significant effect in Yorkton at the p<0.1 level. Across all four locations, there was average maturity (rating of 2) between the treatments (Table B6). Indian Head was the only site not to experience considerable variability between the maturity of each plot of the individual treatments (CV <15%).

Table 9: Statistical summary of treatment effects on maturity for the Integrated Disease Management in Oats study at four locations in 2018.

Source	Indian Head (IH)	Melfort (ME)	Redvers (RD)	Yorkton (YK)
Fungicide Timing (FT)	0.4219	0.3033	0.5060	0.0893
Variety X Seeding Rate (VSR)	<0.0001***	0.0042**	0.0227*	0.0007**
FT * VSR	0.6881	0.9425	0.6050	0.3964
Grand Mean	1.9	1.9	2.1	2.0
CV (REP * FT)	12.9	29.1	27.7	31.4
CV (REP * FT * VSR)	11.9	32.7	29.2	26.9

*** p<0.001; ** p<0.05 to 0.01; *p<0.05

The effect of variety and seeding rate on relative maturity resulted in mixed outcomes across locations. At Indian Head, increasing seeding rate to 450 seeds/m^2 resulted in delayed maturity compared to the lower seeding rate treatments (Figure 5). Higher seeding rates are often associated with advanced maturity. However, the higher seeding rate treatments at IH18 also resulted in increased tiller formation. Increased tillering can cause delays in maturity, due to variability in the growth stages of the tillers. Therefore, although it was anticipated that the increased seeding rates would result in advanced maturity, the delay in maturity due to increased tiller formation, is not an unexpected result. At Redvers, a similar trend occurred, with higher seeding rates resulting in delayed maturity. However, this was unexpected, as there was reduced tillering associated with the higher seeding rate treatments at this site. Why this result occurred in both varieties is unknown, although it was only statistically significant within the Summit treatments. At Melfort, the maturity of both CS Camden treatments was similar to each other and Summit at 450 seeds/m^2. This result is unexpected, as Summit at 300 seeds/m^2 had a similar plant and tiller density to the other three treatments. Therefore, this finding is likely of little agronomic significance. In Yorkton, increasing the seeding rate to 450 seeds/m^2 in CS Camden significantly advanced maturity, while maturity was similar between the two seeding rates of Summit. Overall, any significant differences in the relative maturity was location dependent and no discernable trends were identified.

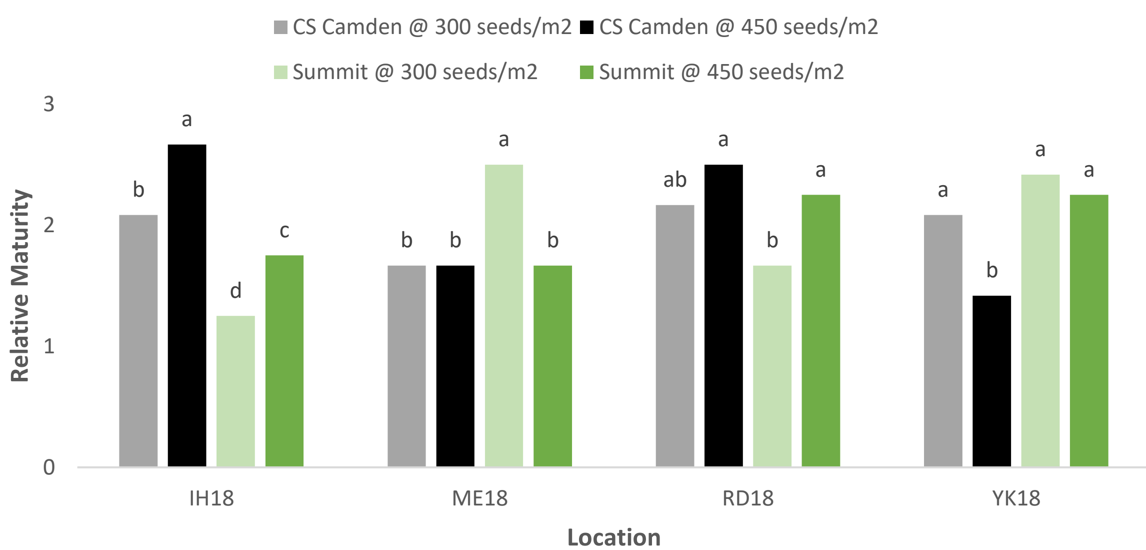

Figure 5: Variety X Seeding Rate effect on maturity (relative [1- advanced; 2-mean; 3-behind]) at four Eastern Saskatchewan locations in 2018.

Yield

Fungicide timing had a significant effect on yield at 2 of 4 locations, while the variety by seeding rate factor was significant at 3 of 4 locations (Table 10). The two-way interaction did not have a significant effect on yield at any of the four study locations. Overall, yields were highest at Melfort followed by Redvers, then Yorkton. This resulted in Indian Head having the lowest average yield of the study locations (Table B7).

Table 10: Statistical summary of treatment effects on yield (kg/ha) for the Integrated Disease Management in Oats study at four locations in 2018.

Source	Indian Head (IH)	Melfort (ME)	Redvers (RD)	Yorkton (YK)
Fungicide Timing (FT)	0.8081	0.0076**	0.4309	0.0080**
Variety X Seeding Rate (VSR)	0.0112*	0.0153*	0.0030**	0.1727
FT * VSR	0.9612	0.9999	0.2403	0.6360
Grand Mean	4437.9	6446.3	5961.2	5488.9
CV (REP * FT)	7.4	6.0	8.6	6.0
CV (REP * FT * VSR)	2.7	9.9	5.0	10.4

*** p<0.001; ** p<0.05 to 0.01; *p<0.05

In Melfort, yield was significantly increased by approximately 600 kg/ha with the application of fungicide at flag leaf (Figure 6). Furthermore, there was no benefit to applying fungicide at heading in comparison to the untreated control. This result is interesting in that there was no significant difference between the severity of leaf spot diseases at this location. With fungicide application at the flag leaf stage having a significant impact on yield, one would expect there to be significant effects of fungicide treatments on leaf spot diseases as well. In Yorkton, there were no significant difference in yield when fungicide was applied at flag leaf compared to the untreated control. However, fungicide application at heading resulted in an approximate 400 to 600 kg/ha decrease in yield compared to the two other treatments. This effect is unexpected, as fungicide application should protect or maintain yield. Had there been a significant delay in maturity at this location associated with fungicide application, this end result could have been expected. Although there was a statistically significant decrease in yield associated with fungicide application at heading, it is likely of little agronomic importance. The little agronomic importance is due to the result only being found at 1 of 4 study locations. Furthermore, with an average yield of 5489 kg/ha (82 bu/ac) at this location, the loss of 400 to 600 kg/ha (6 to 8 bu/ac) could potentially be an acceptable amount of loss for oat producers, when fungicide is applied under conditions conducive to the development of fusarium head blight. However, this trend should be monitored throughout the study period to determine if the effect carries on.

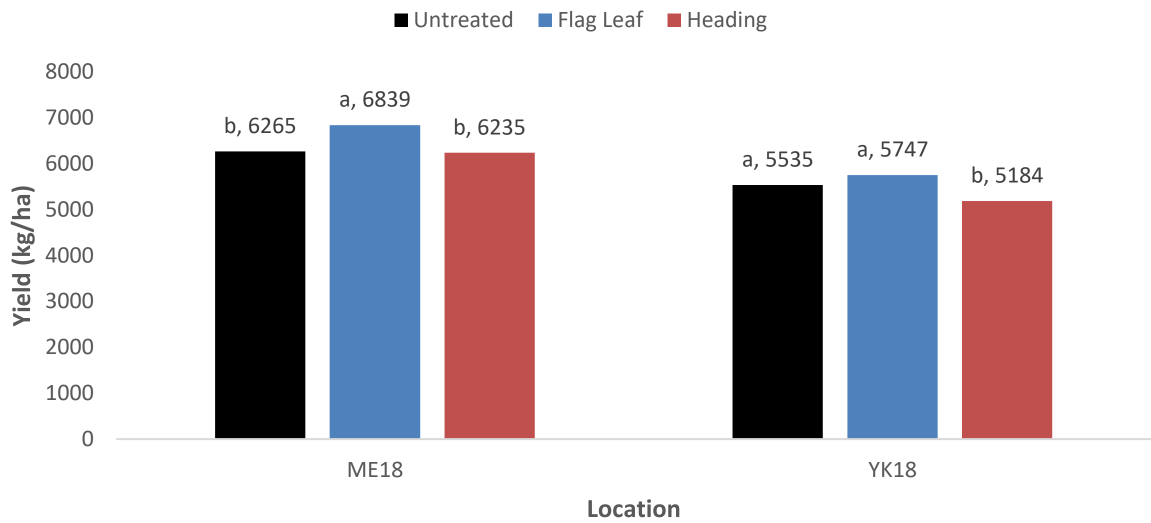

Figure 6: Fungicide timing effect on yield (kg/ha) at Melfort and Yorkton, SK in 2018.

At all three sites, each variety had similar yields whether seeded at 300 or 450 seeds/m^2 (Figure 7). At Melfort, CS Camden tended to yield more than Summit, while it was similar in Indian Head, and less than Summit in Redvers. At Indian Head and Redvers, Summit seeded at 400 seeds/m^2 yielded greater than CS Camden; while in Melfort CS Camden yielded greater than Summit at 400 seeds/m^2. Furthermore, Summit also yielded greater than CS Camden at Yorkton 2018 when seeded at 300 seeds/m^2. Overall, the anticipated trend of higher seeding rates resulting in greater yields did not occur. This is likely driven by differences in plant and tiller density, as well as maturity, between the different locations. The largest trend affecting yield in 2018 was innate yield differences between CS Camden and Summit.

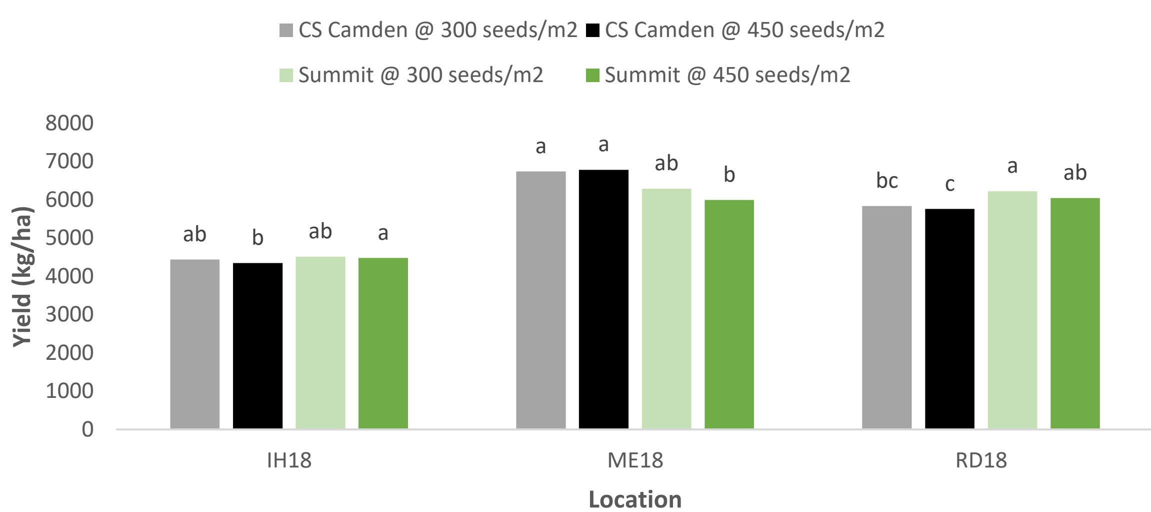

Figure 7: Variety and seeding rate effect on yield (kg/ha) at three Eastern Saskatchewan locations, in 2018.

Quality

Thousand Kernel Weight (TKW)

Fungicide timing had a significant effect on TKW at Redvers, while the variety by seeding rate factor had a significant effect on TKW at Indian Head, Melfort, and Redvers (Table 11). The two-way interaction did not insignificantly affected TKW at any location. Furthermore, there were no significant treatment effects on TKW in Yorkton. Overall, Melfort had a slightly higher TKW on average than Indian Head (Table B8).

Table 11: Statistical summary of treatment effects on thousand kernel weight (g/1000 seeds) for the Integrated Disease Management in Oats study at four locations in 2018.

Source	Indian Head (IH)	Melfort (ME)	Redvers (RD)	Yorkton (YK)
Fungicide Timing (FT)	0.7029	0.3721	0.0088**	0.4414
Variety X Seeding Rate (VSR)	<0.0001***	0.0012**	0.0025**	0.2457
FT * VSR	0.4557	0.3703	0.9125	0.9018
Grand Mean	30.9	36.1	38.6	37.1
CV (REP * FT)	3.4	2.4	4.4	7.4
CV (REP * FT * VSR)	2.5	3.1	3.5	8.4

*** p<0.001; ** p<0.05 to 0.01; *p<0.05

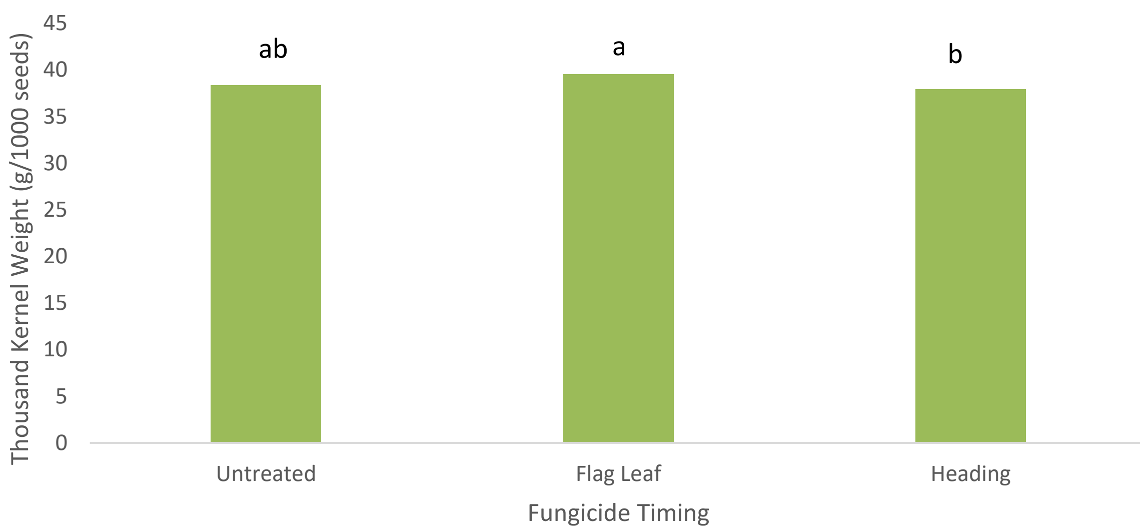

Figure 8: Fungicide timing effect on TKW (g/1000 seeds) at three Eastern Saskatchewan locations, in 2018.

At Redvers, application of fungicide at the flag leaf stage tended to increase TKW, while application at heading decreased TKW in comparison to the untreated control (Figure 8). However, only the difference in TKW between flag leaf and heading timing was significant. At Indian Head, the 450 seeds/m^2 seeding rate resulted in reduced TKW compared to 300 seeds/m^2 rates in both varieties (Figure 9). This resulted in the two varieties having similar TKWs in each seeding rate treatments. In Melfort and Redvers, CS Camden had a greater TKW than Summit. At these locations, seeding rate did not influence the TKW of each variety. Overall, any significant differences in TKW in this study were within 4 g/1000 seeds of each other. Therefore, any significant differences are likely of little agronomic importance.

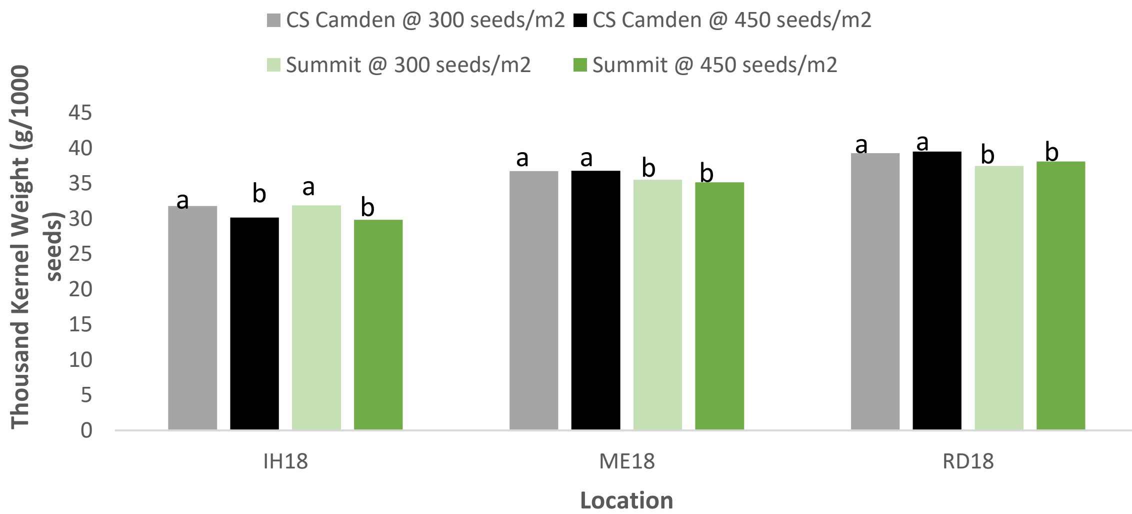

Figure 9: Variety and seeding rate effect on TKW (g/1000 seeds) at three Eastern Saskatchewan locations, in 2018.

Milling Quality

Milling quality analysis was not replicated within site-year, therefore, no statistical analysis was completed and only trends across sites are reported. Specific details on the milling quality of each treatments per site-year can be found in the appendices (Table B9). In the untreated control plots, CS Camden had greater protein, less plumps, more thins, more unhulled, less groats, similar beta-glucan and similar fat to Summit. When fungicide was applied at flag leaf and at heading, there was a tendency for % beta-glucan to increase over levels found in Summit, under the same set of fungicide treatments. Otherwise parameters were similar between CS Camden in the Untreated control and in comparison, to Summit. Results indicate that changes in seeding rates within and between varieties, did not modify milling quality greatly. As for application timing, the average % of plumps were increased by 1% when applied at heading over flag leaf timing and the untreated control, otherwise all milling quality parameters were similar. This effect is not surprising, as there was minimal disease found in the plots, therefore, its likely fungicide application would not have a substantial disease control and subsequently affect yield and quality in oats.

Table 12: Treatment effect on milling quality (protein, plump, thins, unhulled, groats, beta-glucan, fat) averaged across 4 Eastern Saskatchewan locations in 2018.

Treatment	Protein (%)	Plump (%)	Thins (%)	Unhulled (g)	Groats (%)	Beta-Glucan (%)	Fat (%)
Untrt – CS Camden @ 300 seeds/m^2	17.2	76.5	4.6	1.2	68.6	4.8	5.9
Untrt – CS Camden @ 450 seeds/m^2	17.1	74.6	5.6	1.2	68.7	5.0	5.8
Untrt – Summit @ 300 seeds/m^2	15.6	82.7	4.5	0.1	73.2	4.7	5.9
Untrt – Summit @ 450 seeds/m^2	16.2	81.8	4.4	0.1	74.0	4.6	5.7
Flag Leaf – CS Camden @ 300 seeds/m^2	17.1	74.9	5.0	1.2	68.8	5.0	6.0
Flag Leaf – CS Camden @ 450 seeds/m^2	17.0	75.0	5.7	1.0	69.5	5.0	5.8
Flag Leaf – Summit @ 300 seeds/m^2	15.0	83.2	4.3	0.4	73.2	4.5	5.9
Flag Leaf – Summit @ 450 seeds/m^2	15.6	82.8	3.8	0.1	73.9	4.6	5.8
Heading – CS Camden @ 300 seeds/m^2	17.1	76.3	4.6	0.8	69.6	5.0	5.6
Heading – CS Camden @ 450 seeds/m^2	17.4	74.6	5.1	0.9	69.2	5.0	5.8

Heading – Summit @ 300 seeds/m^2	15.6	84.4	4.2	0.1	74.0	4.1	5.8
Heading – Summit @ 450 seeds/m^2	15.7	83.6	4.7	0.1	74.5	4.5	5.7
Average	16.4	79.2	4.7	0.6	71.4	4.7	5.8

*** p<0.001; ** p<0.05 to 0.01; *p<0.05

Seed Disease Levels

On the seeds, there were six fungal diseases tested for: *Fusarium poae*, *Fusarium avenaceum, Fusarium graminearum, Fusarium sporotrichioides, Cochliobolus sativus,* and *Alternaria spp.* At all four locations, presence of *F.avenaceum*, *F. graminearum*, and *F. sporotrichioides* varied between and within locations. If present, levels of these three fusarium species, varied from 0 to 2%. Due to the low incidence and severity of these three species, data was not statistically analyzed. Conversely, due to the higher incidence of *F. poae*, *Alternaria spp*., and *C. sativus*, these species are the primary focus for this section of grain quality analysis and were statistically analyzed. However, there were no significant treatment effects on *C. sativus*, at any location, thus results are not reported. It is not suprising that *F. poae* and *Alternaria spp.* are the most common pathogens, as Grafenhan (2014) also reported that these two were the most commonly present fungal species in 2013 & 2014, in Saskatchewan.

At all four locations, fungicide timing, variety X seeding rate, and the two-way interaction did not have any significant treatment effects on the percent *F. poae* (Table 13). However, at p<0.1, the variety X seeding rate factor had a significant effect on *F. poae* at both Redvers and Yorkton. Overall, *F. poae* infection was relatively minor across all sites, averaging less than 12% (Table B10). Indian Head had the least amount of *F. poae*, followed by Redvers and Yorkton. This left Melfort to have the highest levels of this pathogen. Lastly, there was considerable variability between the amounts of *F. poae* within the individual plots at each location.

Table 13: Statistical summary of treatment effects on *Fusarium poae* (%) for the Integrated Disease Management in Oats study at four locations in 2018.

Source	Indian Head (IH)	Melfort (ME)	Redvers (RD)	Yorkton (YK)
Fungicide Timing (FT)	0.5502	0.1600	0.7066	0.1757
Variety X Seeding Rate (VSR)	0.4027	0.4364	0.0881	0.0935
FT * VSR	0.8621	0.8124	0.1411	0.7282
Grand Mean	0.4	11.9	4.5	8.1
CV (REP * FT)	153.6	25.26	52.7	62.2
CV (REP * FT * VSR)	148.8	23.74	44.2	42.1

*** p<0.001; ** p<0.05 to 0.01; *p<0.05

At Redvers, CS Camden at 450 seeds/m^2 had 2.1% greater disease than at the 300 seeds/m^2 rate (Data not shown; Table B10). At this location, Summit in both seeding rate treatments had similar levels of *F. poae* to each other, as well as both rates of CS Camden. Similar trends at Yorkton occurred, however, it was Summit at 450 seeds/m^2 that had 3.1% greater levels of *F. poae* than the 300 seeds/m^2 rate. Furthermore, CS Camden at 300 seeds/m^2 had 3.5% more disease than Summit at the same seeding rate. Overall, there were minimal differences between treatments and there was a low % of *F. poae*. Therefore, any significant treatment effects are likely of little agronomic significance. However, as *Fuasarium poae* can produce mycotoxins harmful to both humans and livestock, this pathogen needs to be continuously monitored for any significant treatment effects as this was the second most prevalent fusarium species in this study.

Fungicide timing had a significant effect on *Alternaria spp.* in Indian Head, and at Melfort at the p<0.1 level (Table 14). The variety X seeding rate effect had a significant effect in Indian Head as well. There was no significant effect caused by the two-way interaction at any of the four locations. The presence of *Alternaria spp.* was highest in Redvers (82%) and lowest in Indian Head (28%). Both Melfort and Redvers had similar levels of this pathogen averaging 51 to 55%.

Table 14: Statistical summary of treatment effects on *Alternaria spp.* (%) for the Integrated Disease Management in Oats study at four locations in 2018.

Source	Indian Head (IH)	Melfort (ME)	Redvers (RD)	Yorkton (YK)
Fungicide Timing (FT)	0.0461*	0.0614	0.3132	0.7343
Variety X Seeding Rate (VSR)	0.0006**	0.6727	0.4604	0.1806
FT * VSR	0.5224	0.7619	0.2909	0.9552
Grand Mean	28.2	55.3	82.2	51.0
CV (REP * FT)	10.3	8.5	3.7	13.7
CV (REP * FT * VSR)	12.6	8.8	5.0	12.5

*** p<0.001; ** p<0.05 to 0.01; *p<0.05

At Indian Head, there was a significant increase in % *Alternaria spp.* in both fungicide treatments compared to the untreated control (Table B11). This is unexpected, as fungicide application should reduce the incidence and severity of fungal diseases. Furthermore, as there were no significant difference in the maturity of the fungicide treatments, one cannot speculate that delays in maturity allowed for more time for infection to set in. In Melfort, where fungicide timing was significant at p<0.1, there was a tendency for fungicide application at the flag leaf stage to reduce *Alternaria spp.* in comparison to the untreated control and at application at heading. In Indian Head, each variety had similar levels of % *Alternaria spp.*; Thus, seeding rate did not have a significant effect on the pathogen within each variety. Furthermore, CS Camden had greater levels of *Alternaria* than Summit. As *Alternaria* causes leaf spot diseases, and oats are commonly planted from farm saved seed, this could be a great concern for replanting based on levels found in Redvers. As there were no significant treatment effects, and there was high incidence of this pathogen at this site, this pathogen should be continuously monitored as it could potentially cause great yield and quality losses in the future.

Table 15: Variety X seeding rate treatment effect on *Alternarian spp.* (%) severity for the Integrated Disease Management in Oats study in Indian Head, 2018.

Variety X Seeding Rate	*% Alternaria spp.*
CS Camden @ 300 seeds/m^2	31 a
CS Camden @ 450 seeds/m^2	31 a
Summit @ 300 seeds/m^2	26 b
Summit @ 450 seeds/m^2	26 b

[z] Values with the same letters are statistically similar

9. Interim conclusions (If any).

Overall, fungicide timing, variety X seeding rate, and the two-way interaction effects resulted in mixed outcomes across locations. Generally, treatment effects were site specific, minimal, and likely of little agronomic importance. Therefore, no discernible treatment trends were found. However, this is the first year of study and there is the potential for significant treatment effects to still be identified.

10. List any technology transfer activities undertaken in relation to this project: *Include conference presentations, talks, papers published etc.*

This trial was featured at the NE Branch SIA's annual AgUpdate presented on February 7th, 2019. It was also featured in the January issue of the SaskOat's Oat Scoop newsletter.

11. Identify any changes expected to industry contributions, in-kind support, collaborations or other resources.

There have been no expected changes to industry contributions, in-kind support, collaborators, and other resources.

12. **Appendices:** *Include any additional materials supporting the previous sections, e.g. detailed data tables, maps, graphs, specifications, literature cited, acknowledgments.*

References:

Bowen, K. Hagan, A., Pegues, M., and Jones, J. 2016. Yield losses due to Crown Oat Rust in Winter Oats in Alabama. *Plant Health Progress.* **17** (2): 95-100.

Fetch, T., McCallum, B., Menzies, J., Rashid, K., Tenuta, A. 2011. Rust diseases in Canada. *Prairie soils and Crop Journal. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.690.6329&rep=rep1&type=pdf*.

Grafenhan, T. 2014. Occurrence and fate of toxigenic fungi and associated mycotoxins in Oats. https://poga.ca/images/pdf/agm2014/Mycotoxin.pdf

May, W.E., Ames, N., Irvine, R.B., Kutcher, H. R. Lafond, G. P. and Shirtliffe, S. J. 2014. Are fungicide applications to control crown rust of oat beneficial? *Can. J. Plant Sci.* **94:** 911-922. Doi: 10.4141/CjPS2013-333.

McCallum, B.D., Fetch, T., and Chong, J. 2007. Cereal rust control in Canada. *Australian Journal of Agricultural Research*. **58:** 639 – 647. Doi: 10.1071/AR06145

Picinini, E.C. and Fernandes, J.M. 1994. Efficacy of fungicide for controlling crow rust of oats. *Fitopatologia Brasilerira.* **19** (1): 74-78.

Soovali, P. and Koppel, M. 2011. Timing of fungicide application for profitable disease management in oat (*Avena sativa* L.). *Agriculture.* **98** (2): 167-174.

Table A1: Seeding, foliar treatment application, and harvest dates at the four study locations in 2018.

Location	Seeded	Flag Fungicide	Heading Fungicide	Harvested
		2018		
Indian Head	May 11	June 25	July 3	August 10
Melfort	May 15	June 29	July 13	September 28
Redvers	May 7	June 25	July 5	August 21
Yorkton	May 11	June 21	July 15	August 30

Table A2: Fertilizer, herbicide, and pre-harvest aid applications at the four study locations in 2018.

Location	Fertilizer Application (kg N-P_2O_5-K_2S-S/ha)	Pre-seed Herbicide	In-crop Herbicide	Pre-harvested Aid
		2018		
Indian Head	100-25-13-13	0.67 L/ac Glyphosate 540 May 11	0.405 L/ac Buctril M June 6	Not Applied
Melfort	146-46-11-6	0.5 L/ac Glyphosate 540 May 11	0.17 L/ac A & 0.8 L/ac B Prestige XC June 14	Not Applied
Redvers	139-42-5-4	Not Applied	0.405 L/ac Buctril M June 9	Not Applied
Yorkton	158-66-0-0	Not Applied	Frontline 0.5 L/ac	Not Applied

Table B1: Influence of fungicide timing and variety X seeding rate level on plant density (plants/m^2) of oats, at 4 Saskatchewan locations in 2018.

Fungicide Timing	Variety X Seeding Rate	Indian Head	Melfort	Redvers	Yorkton
Untreated	All	373	352	288	299
Flag Leaf (Zadok 39)		362	357	292	302
Heading (Zadok 59)		367	356	308	309
All	Camden @ 300 seeds	307	343	224	275
	Camden @ 450 seeds	443	331	301	366
	Summit @ 300 seeds	302	330	253	238
	Summit @ 450 seeds	418	415	405	336
Untreated	Camden @ 300 seeds	298	346	234	265
	Camden @ 450 seeds	444	303	298	349
	Summit @ 300 seeds	304	350	253	236
	Summit @ 450 seeds	445	408	368	345
Flag Leaf	Camden @ 300 seeds	303	353	216	259
	Camden @ 450 seeds	436	329	290	384
	Summit @ 300 seeds	307	324	258	254
	Summit @ 450 seeds	402	422	402	312
Heading	Camden @ 300 seeds	319	331	222	301
	Camden @ 450 seeds	448	362	314	363
	Summit @ 300 seeds	296	317	250	223
	Summit @ 450 seeds	406	414	445	350
All	**All**	**367**	**355**	**296**	**303**

Table B2: Influence of fungicide timing and variety X seeding rate level on tiller density (tillers/m^2) of oats, at 4 Saskatchewan locations in 2018.

Fungicide Timing	Variety X Seeding Rate	Indian Head	Melfort	Redvers	Yorkton
Untreated	All	412	140	272	246
Flag Leaf (Zadok 39)		406	137	291	265
Heading (Zadok 59)		418	113	280	271
All	Camden @ 300 seeds	346	122	309	235
	Camden @ 450 seeds	488	139	250	267
	Summit @ 300 seeds	352	125	320	254
	Summit @ 450 seeds	463	135	245	286
Untreated	Camden @ 300 seeds	328	143	323	216
	Camden @ 450 seeds	486	156	259	251
	Summit @ 300 seeds	347	124	279	253
	Summit @ 450 seeds	487	137	229	264
Flag Leaf	Camden @ 300 seeds	349	114	286	235
	Camden @ 450 seeds	488	147	242	268
	Summit @ 300 seeds	343	143	364	257
	Summit @ 450 seeds	443	144	270	299
Heading	Camden @ 300 seeds	360	107	319	254
	Camden @ 450 seeds	490	113	248	282
	Summit @ 300 seeds	365	106	317	251
	Summit @ 450 seeds	459	124	235	296
All	**All**	**412**	**130**	**281**	**261**

Table B3: Influence of fungicide timing and variety X seeding rate level on average disease severity (%), prior to fungicide application at heading, at 4 Saskatchewan locations in 2018.

Fungicide Timing	Variety X Seeding Rate	Indian Head	Melfort	Redvers	Yorkton
Untreated	All	1.7		1.3	3.6
Flag Leaf (Zadok 39)		1.6		1.1	1.7
Heading (Zadok 59)		1.8		1.2	1.0
All	Camden @ 300 seeds	1.8		1.2	1.6
	Camden @ 450 seeds	1.8		1.4	1.7
	Summit @ 300 seeds	1.6		1.1	2.6
	Summit @ 450 seeds	1.5		1.1	2.5
Untreated	Camden @ 300 seeds	1.8		1.4	2.2
	Camden @ 450 seeds	1.9		1.6	2.6
	Summit @ 300 seeds	1.7		1.1	5.0
	Summit @ 450 seeds	1.6		1.2	4.5
Flag Leaf	Camden @ 300 seeds	1.8		1.2	1.8
	Camden @ 450 seeds	1.7		1.3	1.3
	Summit @ 300 seeds	1.5		1.1	2.1
	Summit @ 450 seeds	1.4		1.0	1.8
Heading	Camden @ 300 seeds	1.9		1.1	0.9
	Camden @ 450 seeds	2.0		1.4	1.2
	Summit @ 300 seeds	1.8		1.0	0.9
	Summit @ 450 seeds	1.7		1.1	1.2
All	**All**	**1.7**		**1.2**	**2.1**

Table B4: Influence of fungicide timing and variety X seeding rate level on average disease severity (%), prior to senescence, at 4 Saskatchewan locations in 2018.

Fungicide Timing	Variety X Seeding Rate	Indian Head	Melfort	Redvers	Yorkton
Untreated	All	5.4	1.1		
Flag Leaf (Zadok 39)		5.4	1.1		
Heading (Zadok 59)		5.0	1.1		
All	Camden @ 300 seeds	5.2	1.1		
	Camden @ 450 seeds	6.0	1.1		
	Summit @ 300 seeds	4.6	1.1		
	Summit @ 450 seeds	5.3	1.1		
Untreated	Camden @ 300 seeds	5.3	1.3		
	Camden @ 450 seeds	6.3	1.1		
	Summit @ 300 seeds	4.5	1.1		
	Summit @ 450 seeds	5.5	1.1		
Flag Leaf	Camden @ 300 seeds	5.2	1.1		
	Camden @ 450 seeds	5.8	1.1		
	Summit @ 300 seeds	5.0	1.1		
	Summit @ 450 seeds	5.5	1.1		
Heading	Camden @ 300 seeds	5.0	1.1		
	Camden @ 450 seeds	6.0	1.1		
	Summit @ 300 seeds	4.5	1.2		
	Summit @ 450 seeds	5.0	1.1		
All	**All**	**5.3**	**1.1**		

Table B5: Influence of fungicide timing and variety X seeding rate level on lodging (Belgian Scale) of oats, at 4 Saskatchewan locations in 2018.

Fungicide Timing	Variety X Seeding Rate	Indian Head	Melfort	Redvers	Yorkton
Untreated	All	0.3	0.2	0.5	2.4
Flag Leaf (Zadok 39)		0.3	0.2	0.7	2.5
Heading (Zadok 59)		0.3	0.2	0.6	2.7
All	Camden @ 300 seeds	0.2	0.2	0.2	2.0
	Camden @ 450 seeds	0.3	0.2	0.2	2.1
	Summit @ 300 seeds	0.4	0.2	0.5	3.2
	Summit @ 450 seeds	0.4	0.2	1.3	2.9
Untreated	Camden @ 300 seeds	0.2	0.2	0.2	1.8
	Camden @ 450 seeds	0.3	0.2	0.3	1.8
	Summit @ 300 seeds	0.4	0.2	0.4	3.4
	Summit @ 450 seeds	0.5	0.2	1.0	2.7
Flag Leaf	Camden @ 300 seeds	0.2	0.2	0.2	2.0
	Camden @ 450 seeds	0.4	0.2	0.2	2.3
	Summit @ 300 seeds	0.4	0.2	1.0	2.9
	Summit @ 450 seeds	0.4	0.2	1.3	2.7
Heading	Camden @ 300 seeds	0.2	0.2	0.2	2.0
	Camden @ 450 seeds	0.3	0.2	0.2	2.3
	Summit @ 300 seeds	0.4	0.2	0.2	3.4
	Summit @ 450 seeds	0.5	0.2	1.6	3.2
All	**All**	**0.3**	**0.2**	**0.6**	**2.5**

Table B6: Influence of fungicide timing and variety X seeding rate level on maturity of oats, at 4 Saskatchewan locations in 2018.

Fungicide Timing	Variety X Seeding Rate	Indian Head	Melfort	Redvers	Yorkton
Untreated	All	2	2	2	2
Flag Leaf (Zadok 39)		2	2	2	2
Heading (Zadok 59)		2	2	2	2
All	Camden @ 300 seeds	2	2	2	2
	Camden @ 450 seeds	3	2	3	1
	Summit @ 300 seeds	1	3	2	2
	Summit @ 450 seeds	2	2	2	2
Untreated	Camden @ 300 seeds	2	2	2	2
	Camden @ 450 seeds	3	2	3	2
	Summit @ 300 seeds	1	2	2	2
	Summit @ 450 seeds	2	2	2	3
Flag Leaf	Camden @ 300 seeds	2	2	2	3
	Camden @ 450 seeds	3	2	2	2
	Summit @ 300 seeds	1	3	2	3
	Summit @ 450 seeds	2	2	3	2
Heading	Camden @ 300 seeds	2	2	2	2
	Camden @ 450 seeds	3	2	3	1
	Summit @ 300 seeds	1	3	1	2
	Summit @ 450 seeds	2	2	2	2
All	**All**	**2**	**2**	**2**	**2**

Table B7: Influence of fungicide timing and variety X seeding rate level on yield (kg/ha) of oats, at 4 Saskatchewan locations in 2018.

Fungicide Timing	Variety X Seeding Rate	Indian Head	Melfort	Redvers	Yorkton
Untreated	All	4464	6265	5824	5535
Flag Leaf (Zadok 39)		4394	6839	6074	5747
Heading (Zadok 59)		4456	6235	5985	5184
All	Camden @ 300 seeds	4431	6732	5834	5749
	Camden @ 450 seeds	4341	6779	5754	5338
	Summit @ 300 seeds	4506	6282	6214	5590
	Summit @ 450 seeds	4474	5993	6041	5278
Untreated	Camden @ 300 seeds	4458	6586	5658	6160
	Camden @ 450 seeds	4378	6628	5758	5273
	Summit @ 300 seeds	4549	6118	5895	5436
	Summit @ 450 seeds	4472	5727	5986	5272
Flag Leaf	Camden @ 300 seeds	4409	7114	5922	5814
	Camden @ 450 seeds	4298	7185	5980	5733
	Summit @ 300 seeds	4455	6665	6314	6024
	Summit @ 450 seeds	4412	6392	6081	5418
Heading	Camden @ 300 seeds	4427	6495	5923	5272
	Camden @ 450 seeds	4346	6523	5526	5009
	Summit @ 300 seeds	4514	6063	6435	5310
	Summit @ 450 seeds	4537	5860	6057	5145
All	**All**	**4438**	**6446**	**5961**	**5489**

Table B8: Influence of fungicide timing and variety X seeding rate level on TKW (g/1000 seeds) of oats, at 4 Saskatchewan locations in 2018.

Fungicide Timing	Variety X Seeding Rate	Indian Head	Melfort	Redvers	Yorkton
Untreated	All	31	36	38	38
Flag Leaf (Zadok 39)		31	36	40	37
Heading (Zadok 59)		31	36	38	37
All	Camden @ 300 seeds	32	37	39	38
	Camden @ 450 seeds	30	37	40	38
	Summit @ 300 seeds	32	36	37	37
	Summit @ 450 seeds	30	35	38	36
Untreated	Camden @ 300 seeds	32	37	39	40
	Camden @ 450 seeds	30	37	39	38
	Summit @ 300 seeds	32	35	38	37
	Summit @ 450 seeds	30	35	38	37
Flag Leaf	Camden @ 300 seeds	32	37	40	38
	Camden @ 450 seeds	30	36	40	37
	Summit @ 300 seeds	32	36	38	38
	Summit @ 450 seeds	29	36	39	34
Heading	Camden @ 300 seeds	32	37	39	37
	Camden @ 450 seeds	31	38	39	38
	Summit @ 300 seeds	32	35	36	36
	Summit @ 450 seeds	30	36	37	36
All	**All**	**31**	**36**	**39**	**37**

Table B9: Influence of fungicide timing and variety X seeding rate level on milling quality (protein, plump, thins, unhulled, groats, beta-glucan, and fat) of oats, at 4 Saskatchewan locations in 2018.

Location	Treatment	Protein (%)	Plump (%)	Thins (%)	Unhulled (g)	Groats (%)	Beta-Glucan (%)	Fat (%)
Indian Head	Untreated – CS Camden @ 300 seeds/m^2	19.6	40.0	10.2	1.4	66.6	4.7	5.8
	Untreated – CS Camden @ 450 seeds/m^2	19.3	31.0	15.3	1.4	66.0	4.9	6.0
	Untreated – Summit @ 300 seeds/m^2	18.0	72.9	6.2	0.2	72.0	4.7	5.8
	Untreated – Summit @ 450 seeds/m^2	18.2	65.6	7.7	0.2	71.3	4.8	5.8
	Flag Leaf – CS Camden @ 300 seeds/m^2	19.9	36.6	12.7	1.3	66.8	4.9	5.9
	Flag Leaf – CS Camden @ 450 seeds/m^2	19.5	28.5	17.0	1.0	66.6	4.9	5.8
	Flag Leaf – Summit @ 300 seeds/m^2	17.8	70.9	6.5	1.0	71.9	4.7	5.9
	Flag Leaf – Summit @ 450 seeds/m^2	18.1	63.7	7.3	0.2	71.7	4.8	5.7
	Heading – CS Camden @ 300 seeds/m^2	19.8	36.9	10.6	1.2	67.5	5.1	4.7
	Heading – CS Camden @ 450 seeds/m^2	19.4	30.1	13.5	1.6	66.5	4.9	6.0
	Heading – Summit @ 300 seeds/m^2	18.0	73.9	6.0	0.1	71.8	3.7	5.9
	Heading – Summit @ 450 seeds/m^2	17.8	68.0	8.4	0.2	71.9	4.8	5.8
	Indian Head Average	***18.8***	***51.5***	***10.1***	***0.8***	***69.2***	***4.7***	***5.8***
Melfort	Untreated – CS Camden @ 300 seeds/m^2	19.7	91.0	2.0	0.1	70.9	4.9	6.1
	Untreated – CS Camden @ 450 seeds/m^2	18.6	91.1	2.8	0.6	72.2	5.2	6.1
	Untreated – Summit @ 300 seeds/m^2	17.9	89.6	2.8	0.0	76.1	4.6	6.0
	Untreated – Summit @ 450 seeds/m^2	18.5	88.5	2.6	0.0	77.9	4.6	6.1
	Flag Leaf – CS Camden @ 300 seeds/m^2	18.7	89.3	2.3	0.4	71.2	5.0	6.6
	Flag Leaf – CS Camden @ 450 seeds/m^2	18.9	90.6	1.7	0.5	71.8	4.9	6.4
	Flag Leaf – Summit @ 300 seeds/m^2	16.4	88.5	2.7	0.0	76.1	4.3	5.9
	Flag Leaf – Summit @ 450 seeds/m^2	17.3	90.6	1.9	0.0	76.6	4.1	6.1
	Heading – CS Camden @ 300 seeds/m^2	19.4	92.6	2.0	0.1	71.1	5.0	5.9
	Heading – CS Camden @ 450 seeds/m^2	20.3	91.6	2.0	0.4	72.2	5.3	6.0
	Heading – Summit @ 300 seeds/m^2	17.4	89.1	3.1	0.0	76.2	4.3	6.1
	Heading – Summit @ 450 seeds/m^2	17.3	91.8	2.0	0.0	77.1	4.3	5.9
	Melfort Average	18.4	90.4	2.3	0.2	74.1	4.7	6.1
Redvers	Untreated – CS Camden @ 300 seeds/m^2	15.0	88.7	2.4	2.0	66.3	4.8	5.9
	Untreated – CS Camden @ 450 seeds/m^2	15.5	88.1	1.9	1.4	65.6	5.1	5.8
	Untreated – Summit @ 300 seeds/m^2	13.7	85.6	4.5	0.1	69.5	4.8	6.0
	Untreated – Summit @ 450 seeds/m^2	14.2	86.6	3.2	0.1	70.6	4.6	5.7
	Flag Leaf – CS Camden @ 300 seeds/m^2	15.1	87.4	2.2	1.8	67.4	4.9	6.0
	Flag Leaf – CS Camden @ 450 seeds/m^2	15.0	90.1	1.8	1.3	67.5	5.1	5.7
	Flag Leaf – Summit @ 300 seeds/m^2	13.2	89.3	2.9	0.2	70.5	4.5	5.9

Location	Treatment	Protein (%)	Plump (%)	Thins (%)	Unhulled (g)	Groats (%)	Beta-Glucan (%)	Fat (%)
	Flag Leaf – Summit @ 450 seeds/m^2	13.5	89.7	2.8	0.1	72.0	4.7	5.9
	Heading – CS Camden @ 300 seeds/m^2	14.1	88.6	2.1	1.2	68.8	4.8	6.1
	Heading – CS Camden @ 450 seeds/m^2	14.8	88.9	2.1	0.4	67.3	4.8	5.8
	Heading – Summit @ 300 seeds/m^2	12.4	89.2	3.0	0.1	72.0	4.1	5.9
	Heading – Summit @ 450 seeds/m^2	12.4	87.8	4.1	0.1	72.6	4.2	5.8
	Redvers Average	***14.1***	***88.3***	***2.8***	***0.7***	***69.2***	***4.7***	***5.9***
Yorkton	Untreated – CS Camden @ 300 seeds/m^2	14.5	86.3	3.6	1.3	70.5	4.7	5.6
	Untreated – CS Camden @ 450 seeds/m^2	15.0	88.1	2.4	1.2	70.9	4.6	5.4
	Untreated – Summit @ 300 seeds/m^2	12.8	82.8	4.4	0.1	75.0	4.8	5.6
	Untreated – Summit @ 450 seeds/m^2	13.8	26.3	4.1	0.2	76.0	4.4	5.3
	Flag Leaf – CS Camden @ 300 seeds/m^2	14.8	26.2	2.7	1.3	69.6	5.2	5.5
	Flag Leaf – CS Camden @ 450 seeds/m^2	14.7	90.8	2.1	1.0	72.2	5.0	5.2
	Flag Leaf – Summit @ 300 seeds/m^2	12.7	83.9	5.0	0.3	74.1	4.4	5.7
	Flag Leaf – Summit @ 450 seeds/m^2	13.6	87.0	3.1	0.0	75.2	4.6	5.5
	Heading – CS Camden @ 300 seeds/m^2	14.9	86.9	3.6	0.7	71.0	4.9	5.6
	Heading – CS Camden @ 450 seeds/m^2	15.1	87.9	2.6	1.0	70.8	4.8	5.4
	Heading – Summit @ 300 seeds/m^2	14.4	85.2	4.8	0.1	76.0	4.3	5.3
	Heading – Summit @ 450 seeds/m^2	15.3	86.7	4.3	0.0	76.5	4.6	5.3
	Yorkton Average	***14.3***	***86.5***	***3.6***	***0.6***	***73.2***	***4.7***	***5.5***
All	**All**	**16.4**	**79.2**	**4.7**	**0.6**	**71.4**	**4.7**	**5.8**

Table B10: Influence of fungicide timing and variety X seeding rate level on *Fusarium poae.* (%) of oats, at 4 Saskatchewan locations in 2018.

Fungicide Timing	Variety X Seeding Rate	Indian Head	Melfort	Redvers	Yorkton
Untreated	All	0.6	11.8	4.3	8.4
Flag Leaf (Zadok 39)		0.4	13.2	4.9	9.8
Heading (Zadok 59)		0.3	10.8	4.4	6.0
All	Camden @ 300 seeds	0.4	11.8	3.5	9.0
	Camden @ 450 seeds	0.3	11.0	5.6	8.6
	Summit @ 300 seeds	0.3	12.0	4.8	5.8
	Summit @ 450 seeds	0.7	12.9	4.1	8.9
Untreated	Camden @ 300 seeds	0.5	10.3	2.8	8.5
	Camden @ 450 seeds	0.3	11.0	5.6	9.8
	Summit @ 300 seeds	0.5	12.3	4.1	6.0
	Summit @ 450 seeds	1.0	13.5	4.5	9.5
Flag Leaf	Camden @ 300 seeds	0.3	14.3	3.6	10.8
	Camden @ 450 seeds	0.5	12.3	5.5	9.5
	Summit @ 300 seeds	0.3	12.3	7.3	6.8
	Summit @ 450 seeds	0.5	14.0	3.4	12.3
Heading	Camden @ 300 seeds	0.5	10.8	4.3	7.8
	Camden @ 450 seeds	0.3	9.8	5.8	6.5
	Summit @ 300 seeds	0.0	11.5	3.0	4.8
	Summit @ 450 seeds	0.5	11.3	4.5	5.0
All	**All**	**0.4**	**11.9**	**4.5**	**8.1**

Table B11: Influence of fungicide timing and variety X seeding rate level on *Alternaria spp.* (%) of oats, at 4 Saskatchewan locations in 2018.

Fungicide Timing	Variety X Seeding Rate	Indian Head	Melfort	Redvers	Yorkton
Untreated	All	26	55	81	52
Flag Leaf (Zadok 39)		29	53	82	51
Heading (Zadok 59)		29	58	53	50
All	Camden @ 300 seeds	31	54	82	53
	Camden @ 450 seeds	31	53	83	54
	Summit @ 300 seeds	26	56	83	49
	Summit @ 450 seeds	26	56	81	49
Untreated	Camden @ 300 seeds	29	54	81	53
	Camden @ 450 seeds	28	56	84	56
	Summit @ 300 seeds	24	56	81	49
	Summit @ 450 seeds	25	54	81	49
Flag Leaf	Camden @ 300 seeds	33	54	82	55
	Camden @ 450 seeds	30	52	85	52
	Summit @ 300 seeds	28	53	84	49
	Summit @ 450 seeds	26	54	78	50
Heading	Camden @ 300 seeds	30	54	84	50
	Camden @ 450 seeds	34	60	81	53
	Summit @ 300 seeds	26	60	84	49
	Summit @ 450 seeds	27	58	84	48
All	**All**	**28**	**55**	**82**	**51**