2017 Annual Report
for the

Agricultural Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Seeding Rate Response of Modern Fall Rye Varieties

(Project #20160341)

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Project Identification

1. **Project Title:** Seeding Rate Response of Modern Fall Rye Varieties
2. **Project Number:** 20160341
3. **Producer Group Sponsoring the Project:** Indian Head Agricultural Research Foundation
4. **Project Location(s):** Indian Head, Saskatchewan, R.M. #156
5. **Project start and end dates (month & year):** Sep-2016 to Dec-2017
6. **Project contact person & contact details:**

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Objectives and Rationale

7. **Project objectives:**

The objective of this project was to demonstrate the optimum fall rye seeding rates for high yielding hybrids versus conventional open pollinated varieties.

8. **Project Rationale:**

While fall rye acres have dramatically declined since peaking in the 1980s (due to herbicides, other profitable crop options, and marketing challenges), the introduction of new hybrid varieties has led to renewed interest in this crop. Averaged across the major provincial zones, the five currently available hybrids yield 111-127% (119% on average) of the current check (and highest yielding open pollinated variety) Hazlet (Saskatchewan Seed Growers Association 2018 Guide). Traditionally, fall rye has been grown as a low-input crop, likely because it has relatively high nitrogen (N) use efficiency compared to winter wheat and tends to be grown on poorer land. A separate project (ADOPT #20160339) is evaluating hybrid versus open-pollinated (OP) fall rye response to N fertilizer applications; however, when transitioning to hybrids, seed costs for this crop will increase considerably. This increase is due to the combination of higher initial costs and the requirement to purchase new seed annually. Farmers will benefit from third party validation of optimal seeding rates in order to help them make informed decisions and the necessary investments with confidence. The objective of this project was to demonstrate both the overall yield potential and relative responses to varying seeding rates for OP versus hybrid fall rye. The project was also conducted in 2015-16; therefore, this report will summarize the results from both years.

Methodology and Results

9. **Methodology:**

Field trials near Indian Head were established in the fall of 2015 (50.556 N, 103.603 W) and continued in 2016 (50.554 N, 103.572 W). Indian Head is located in the thin-Black soil zone of southeast Saskatchewan and the soil is classified as an Indian Head clay with typical organic matter concentrations of 4.5-5.5%. The treatments were a factorial combination of two varieties and six seeding rates. The variety was either Hazlet (OP) or Brasetto (hybrid) and the seeding rates were 50, 110, 170, 230, 290 or 350 viable seeds m^{-2}. The twelve treatments were arranged in a four replicate Randomized Complete Block Design (RBCD).

Selected agronomic information is provided in Table 1. Fall rye seed treated with Cruiser Maxx® Vibrance® was direct seeded into canola stubble on September 20 and September 27 in 2015 and 2016, respectively. Seed rates varied as per protocol and the fertilizer sources were urea (side-banded), monoammonium phosphate (side-banded), and potassium sulphate (seed-placed) at Indian Head. Fertilizer rates were held constant across treatments to supply 115-30-47-16 kg $N-P_2O_5-K_2O-S$/ha. Weeds were controlled using registered pre-emergent and in-crop herbicide applications. Foliar fungicide was applied at early heading (prior to anthesis) to protect against late occurring leaf disease and, potentially, fusarium head blight. Pre-harvest glyphosate was applied after all plots had reached physiological maturity and the centre five rows of each plot were straight-combined on August 12-13 (2016) and August 24 (2017).

Table 1. Agronomic information for the ADOPT Fall Rye Seeding Rate Response Demonstration at Indian Head during the 2016 and 2017 growing seasons.

Factor / Field Operation	2015-16	2016-17
Previous Crop	Canola (LL)	Canola (LL)
Pre-emergent herbicide	880 g glyphosate ha^{-1} + 729 g 2,4-D ha^{-1} (Sep-24-2015)	880 g glyphosate ha^{-1} + 729 g 2,4-D ha^{-1} (Sep-30-2016)
Seed Treatment	Cruiser Vibrance Quattro	Cruiser Vibrance Quattro
Seeding Date	Sep-20-2015	Sep-27-2016
Row spacing	30 cm	30 cm
kg $N-P_2O_5-K_2O-S$ ha^{-1}	115-30-47-16	115-30-47-16
Fall Plant Density	Oct-15-2015	Nov-1-2016
Spring Plant Density	Apr-28-2016	May 4-2017
In-crop herbicide	280 g bromoxynil ha^{-1} + 280 g MCPA ester ha^{-1} + 198 g tralkoxydim ha^{-1} (May-17-2015)	280 g bromoxynil ha^{-1} + 280 g MCPA ester ha^{-1} + 198 g tralkoxydim ha^{-1} (May-30-2017)
Foliar fungicide	89 g metconazole ha^{-1} (June 5)	89 g metconazole ha^{-1} (June 10)
Head Density	Jun-15-2016	Jul-14-2017
Pre-harvest herbicide	880 g glyphosate ha^{-1} (Jul-28-2016)	880 g glyphosate ha^{-1} (Aug-11-2017)
Harvest date	Aug-12-2016	Aug-24-2017

n/a – information not available

Various data were collected during the growing season and from the harvested grain samples. Emergence was determined both in the fall and again in the spring by counting the number of plants in two marked 1 m sections of crop row and calculating plants m^{-2}. Head density was determined by counting the number of heads in the marked sections of crop row and calculating heads m^{-2}. The average number of heads per plant was estimated by dividing the observed heads m^{-2} by the corresponding plants m^{-2} measured in the spring. Lodging was assessed at maturity using the Belgian lodging scale where both the area of the plot affected (A=1-9) and the intensity of lodging in affected areas (I=1-5) are rated. The lodging index (LI) is calculated using the formula $LI = A \times I \times 0.2$. Yields were determined from the harvested grain samples and are expressed as kg ha^{-1} clean seed (corrected to 14% seed moisture content). Dockage was determined from a 1000 g sub-sample using CGC methodology and grain moisture was determined from a Labtronics Model 919 moisture meter for the purpose of correcting grain yields. All ergot bodies were handpicked from a 500 g clean subsample and subsequently weighed to determine percent ergot. For composites in 2016 and each plot in 2017, falling number analyses were completed in-kind by AAFC Lethbridge (Jamie Larsen). Daily temperature and precipitation data were estimated using online data from the Environment Canada weather station located approximately 3-5 km of the field sites.

Response data were analysed using the Mixed procedure of SAS with the effects of year (Y), variety (VAR), seeding rate (SR) and their interaction (VAR × SR, Y × VAR, Y × SR, and Y × VAR × SR) considered fixed. Replicate effects were treated as random. Treatment means were separated using Fisher's protected LSD test with orthogonal contrasts used to determine whether the observed N responses were linear or quadratic (curvilinear). All treatment effects and differences between means were considered significant at $P \leq 0.05$.

10. Results:

Growing season weather

Weather data for the 2016 and 2017 growing seasons at Indian Head are presented in Table 2. In 2015-16, fall moisture was adequate while the winter was milder than normal with very little snow cover or extreme temperatures throughout the entire winter. For the 2016-17 fall/winter, October was cold and wet but November was warmer than normal. Temperatures and snow cover from December through March were approximately normal but conditions were warm and dry through April and into the spring. While there was good initial moisture both springs, the 2016 season was much wetter overall (112% of long-term average growing season precipitation) with far greater yield potential for the crop but also more potential for disease and lodging. The 2017 spring season was dry (52% of long-term average growing season precipitation) which, combined with a hard frost (low of approximately -6º C) on May 18 substantially reduced the overall yield potential of crop. Despite the poor conditions, the plots were uniform and the observed responses for both years were considered reliable and representative for the environmental conditions encountered. The contrasting growing season conditions provide a robust evaluation of fall rye responses to varying seeding rates.

Table 2. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 15-2016 and 2016-17 growing season at Indian Head, SK.

Year	April	May	June	July	August	Avg. / Total
	------ Mean Temperature (°C) ------					
IH-2016	3.8	13.9	17.5	18.5	17.1	14.2
IH-2017	4.2	11.6	15.5	18.4	16.7	13.3
IH-LT	4.2	10.8	15.8	18.2	17.4	13.3
	------ Precipitation (mm) ------					
IH-2016	13.9	72.6	63.0	112.8	29.8	292
IH-2017	18.5	10.4	65.6	15.4	25.2	135
IH-LT	17.1	51.8	77.4	63.8	51.2	261

Detailed Field Trial Results

The overall tests of fixed effects are presented for all response variables in Table 3. In this test, p-values less than or equal to 0.05 signify at least 95% confidence that observed variation is due to treatment effects as opposed to naturally occurring and random variability. The effects of year were significant for all variables except tillers/plant and both variety and seeding rate effects were significant for all variables. Variety interactions with seeding rate (VAR × SR) were significant for fall plant density, tillers/plant, lodging, grain yield and ergot. Two way interactions with year (i.e. Y × VAR and Y × SR) were significant in numerous cases which will be discussed in greater detail where appropriate. The three-way interaction (Y × VAR × NR) was not significant for any variables.

Table 3. Test of fixed effects year (Y), variety (VAR) and seeding rate (SR) for selected fall rye response variables at Indian Head over a two-year period.

Effect	**Fall Plant Density**	**Spring Plant Density**	**Head Density**	**Tillers / Plant**	**Lodging Rating**	**Grain Yield**	**Percent Ergot**
	------ p-values ------						
Year (Y)	< 0.001	< 0.001	0.002	0.300	< 0.001	< 0.001	< 0.001
Variety (VAR)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Seed Rate (SR)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
VAR × SR	0.006	0.297	0.763	< 0.001	0.006	0.010	0.003
Y × VAR	0.811	0.017	0.016	0.928	< 0.001	< 0.001	0.013
Y × SR	0.459	< 0.001	0.649	0.008	0.001	0.871	< 0.001
Y × VAR × SR	0.071	0.306	0.797	0.914	0.436	0.465	0.256

Treatment means for the two varieties (averaged across seeding rates) are presented for individual growing seasons and averaged across the two years in Table 4.

With the exception of the spring measurements in 2017 where there was no difference, estimated plant populations were always higher for the conventional variety (Hazlet) than for the hybrid (Brasetto). Averaged over the two-year period, the observed differences were 32 plants/m^2 (24%) in the fall and 19 plants/m^2 (14%) in the spring. Final overall plant populations were higher in 2016 than 2017 and there appeared to be more winterkill in the second year of the study – possibly due to the relatively late seeding and cold fall resulting in smaller, weaker plants going in the winter.

Overall head density was higher for the hybrid rye both years individually and by 58 heads/m^2 (13%) when averaged across years. While significant in both cases, the magnitude of the difference in head density between varieties was much higher under the harsher conditions in 2016-17 than the previous year where conditions were more favourable (22% versus 6%). Head density is an important yield component and a function of both the number of plants established and the tillering ability of individual plants.

The average number of tillers per plant was relatively consistent over the two year period but higher, on average, for the hybrid rye than the OP variety. Across seeding rates and years, 3.4 heads per plant were measured for the conventional variety compared to 4.6 for the hybrid.

Lodging was a much greater concern in 2016 than in 2017 but was significantly worse for the OP variety in both years. In 2016-17 the mean lodging rating was 1.7 versus 0.4 for the OP and hybrid varieties, respectively while in 2017-18 the values were 0.5 and 0.2. The possible range of values with this rating scale is 0-9; therefore, with the exception of a few treatments in 2016, lodging was never considered to be a major agronomic concern.

Grain yields were nearly twice as high overall in 2016 (6014 kg/ha) than in 2017 (3133 kg/ha); however, the relative performance of the two varieties was reasonably consistent. The average yield advantage to the hybrid rye over the OP variety was 1363 kg/ha or 26% in 2016 compared to 492 kg/ha (17%) under the lower yielding conditions in 2017. This suggests that, while advantages to the hybrid can be expected under a wide range of environmental conditions, greatest benefits may be realized under more favourable growing conditions where the overall yield potential is higher.

Ergot is one of the most common and important factors leading to grade reduction in fall rye. Overall percent ergot was somewhat higher in 2016 versus 2017 and was also consistently higher for the hybrid variety. In 2016, 0.33% and 0.65% percent ergot were observed for the hybrid and OP varieties while in 2017 the observed concentrations were 0.25% and 0.35%. The maximum allowable ergot concentrations are 0.05% for No. 1, 0. 20% for No. 2, and 0.33% for No. 3 Canada Western Rye.

Table 4. Treatment means for variety (by year) effects on selected fall rye response variables at Indian Head over a two-year period. For each variable, means within a group followed by the same letter do not significantly differ (Fisher's protected LSD test, $P \leq 0.05$).

Year	**Fall Plant Density** (plants/m^2)	**Spring Plant Density** (plants/m^2)	**Head Density** (heads/m^2)	**Tiller Frequency** (heads/plant)	**Severity of Lodging** (0-10)	**Grain Yield** (kg/ha)	**Ergot Concentration** (%)
OP-16	178.0 a	175.0 a	471.1 b	3.3 b	1.66 a	5332 b	0.33 b
HYB-16	144.7 b	143.7 b	497.3 a	4.5 a	0.43 b	6695 a	0.65 a
S.E.M.	3.25	3.62	8.98	0.14	0.075	56.9	0.047
OP-17	161.9 a	127.2 a	397.5 b	3.5 b	0.52 a	2887 b	0.25 b
HYB-17	130.4 b	120.0 a	486.5 a	4.7 a	0.20 b	3379 a	0.35 a
S.E.M.	4.30	6.00	17.77	0.26	0.023	85.6	0.056
OP-avg	169.9 a	151.1 a	434.3 b	3.4 b	1.09 a	4109 b	0.29 b
HYB-avg	137.5 b	131.8 b	491.9 a	4.6 a	0.31 b	5037 a	0.50 a
S.E.M.	2.78	3.55	10.80	0.15	0.039	62.0	0.042

Complete results for seeding rate effects on the response variables measured along with those for associated interactions are presented in Tables 5-12 in the Appendices while the VAR × SR interactions are also presented graphically in Figures 1-7 in main body of the report.

For the fall plant densities, there was a significant VAR × SR interaction whereby the relationship was linear for the OP variety (i.e. plant populations kept increasing through all seeding rates) but quadratic for the hybrid (i.e. plant populations started levelling off at high seeding rates) (Fig. 1, Table 5). This was reasonably consistent both years of the demonstration but more prominent in 2017 where overall plant populations were lower. Similar to seeding rate trials for other crops, mortality increased with seeding rate for both varieties and in both years. This is due to heightened competition amongst plants within the rows at the higher seeding rates. Across years, fall plant populations ranged from 58-275 plants/m^2 for the OP variety and from 34-217 plants/m^2 for the hybrid.

When measured in the spring, overall plant densities were lower than they were in the fall and the responses for both varieties were quadratic (Fig. 2, Table 6). The difference between fall and spring populations was much higher in 2016-17 than the previous season and was also much more evident at the higher seeding rates. The difference between the two years was attributed to later seeding and poorer conditions for establishment in 2016-17. The difference across seeding rates was likely a result of smaller, weaker plants at denser populations. It is also probable that measurement error was higher in the spring as winter cereals can be difficult to accurately distinguish plants from tillers in a non-destructive manner at this time. When averaged across years, the spring plant populations ranged from 61-214 plants/m^2 for the OP variety and from 41-197 plants/m^2 for the hybrid. The fact that spring populations at the lower seeding rates were higher than those in the fall while the opposite occurred at high seeding rates is, at least partly, attributed to measurement error. Current industry seeding rate recommendations for fall rye are to target 180-200 plants/m^2 for optimum yield and quality.

Head densities were measured at the same locations as plant densities and are presented in Fig. 3 and Table 7 of the Appendices. Despite the overall higher head densities of the hybrid, there was no significant VAR × SR interaction (Table 3); however, the results of the orthogonal contrasts differed between varieties when averaged across years. For the OP variety the response was found to be linear while for the hybrid it was quadratic, levelling off at the highest seeding rates. Despite this difference, the relative rankings in the means separations were similar for both varieties with no significant differences in head density for seeding rates from 230-350 seeds/m^2 according to the multiple comparisons test. The overall head densities and responses to seeding rate were consistent from year-to-year. These results demonstrate an overall greater capacity to produce higher head densities with the hybrid and, particularly when considered in conjunction with the lower plant populations, improved ability to compensate for reduced populations through tillering.

The numbers of heads per plant (i.e. tillering) was affected by seeding rate and, according to the interactions (Table 3), the seeding rate response differed between varieties (Fig. 4, Table 8). As expected, the number of tillers was higher at lower seeding rates with an observed range from 7.6 heads/plant at 50 seeds/m^2 to 2.8 heads/plant at 350 seeds/m^2 when averaged across years and varieties. The significant VAR × SR interaction was due to a similar number of heads/plant between the hybrid and OP varieties at seeding rates from 170-350 seeds/m^2 but significantly more tillers for the hybrid at seeding rates of 50-110 seeds/m^2. Averaged across years, the values ranged from 2.4-5.8 heads/plant for OP rye and from

3.0-9.3 for the hybrid. For both varieties the responses were quadratic with values falling sharply as seeding rate increased from 50-170 seeds/m^2 then levelling off as the rates were increased further.

Lodging (rated at maturity) was also affected by seeding rate with a significant VAR × SR interaction. Lodging and the overall response to seeding rate also varied from year-to-year but there was no Y × VAR × SR interaction so the trends were otherwise similar. The overall seeding rate response was quadratic for both varieties with more lodging at both the lowest and highest seeding rates but, as previously indicated, was less severe for the hybrid with much less variation across seeding rates. Based on the two response curves, lodging was minimized at seeding rates of 170-230 seeds/m^2 for both varieties but, with the hybrid, the values did not significantly differ regardless of seeding rate when averaged across years.

Seeding rate effects on grain yield along with any associated interactions are presented in Fig. 6 and Table 10 of the Appendices. For yield, there was a VAR × SR interaction but neither the Y × SR nor Y × VAR × SR interactions were significant (Table 3), thereby indicating the responses were consistent both years. For the OP variety, neither the linear nor quadratic responses were significant when averaged across years (Table 10); however, rye yield at the 50 seeds/m^2 seeding rate was 8% lower than that of the highest yielding treatment (110 seeds/m^2). For the hybrid, maximum yield was achieved at 170-230 seeds/m^2 where yields were 18% greater than at the lowest seeding rate, on average. Hybrid rye yields declined slightly as the seeding rates were increased beyond 230 seeds/m^2. For individual years, the yield spreads amongst seeding rates for the hybrid were 883 kg/ha (15%) in 2016 and 822 kg/ha (29%) in 2017 with maximum yields were observed at 170 and 230 seeds/m^2, respectively. This suggests that hybrid rye has a greater ability to compensate at lower plant densities under wetter conditions than when drought is a major yield limiting factor, as was the case in 2017.

Percent ergot was affected by seeding rate with significant VAR × SR and Y × SR interactions but no Y × VAR × SR interaction (Table 3). Despite the Y × SR interaction, overall trends were similar between the two years; however, ergot levels were higher in 2016 and there was larger spread and more treatment separation across seeding rates than there was in 2017 (Table 11). Focussing on the VAR × SR interaction, the overall seeding rate response was similar for both varieties but percent ergot was substantially and significantly higher for the hybrid than the OP variety , at suboptimal seeding rates (< 170 seeds/m^2) (Fig. 7, Table 11). While the hybrid did tend to have more ergot than the OP variety at the higher seeding rates when averaged across years, the differences were much smaller and never statistically significant. These results demonstrate that using adequate seeding rates and other measures to ensure sufficient and uniform plant populations are important for minimizing ergot issues and subsequent grade reductions with fall rye. Even with optimal seeding rates, additional cleaning may be required to achieve top grades depending on environmental conditions.

While these measurements were not statistically analyzed, falling numbers for each treatment in 2016 are provided in Table 12. Falling number is a measure of bread making quality with higher numbers being desirable when targeting milling markets. Falling numbers were much higher overall with the hybrid (305 sec) than the OP variety (240 sec) when averaged across years; however, no clear or consistent effects of seeding rate were noted.

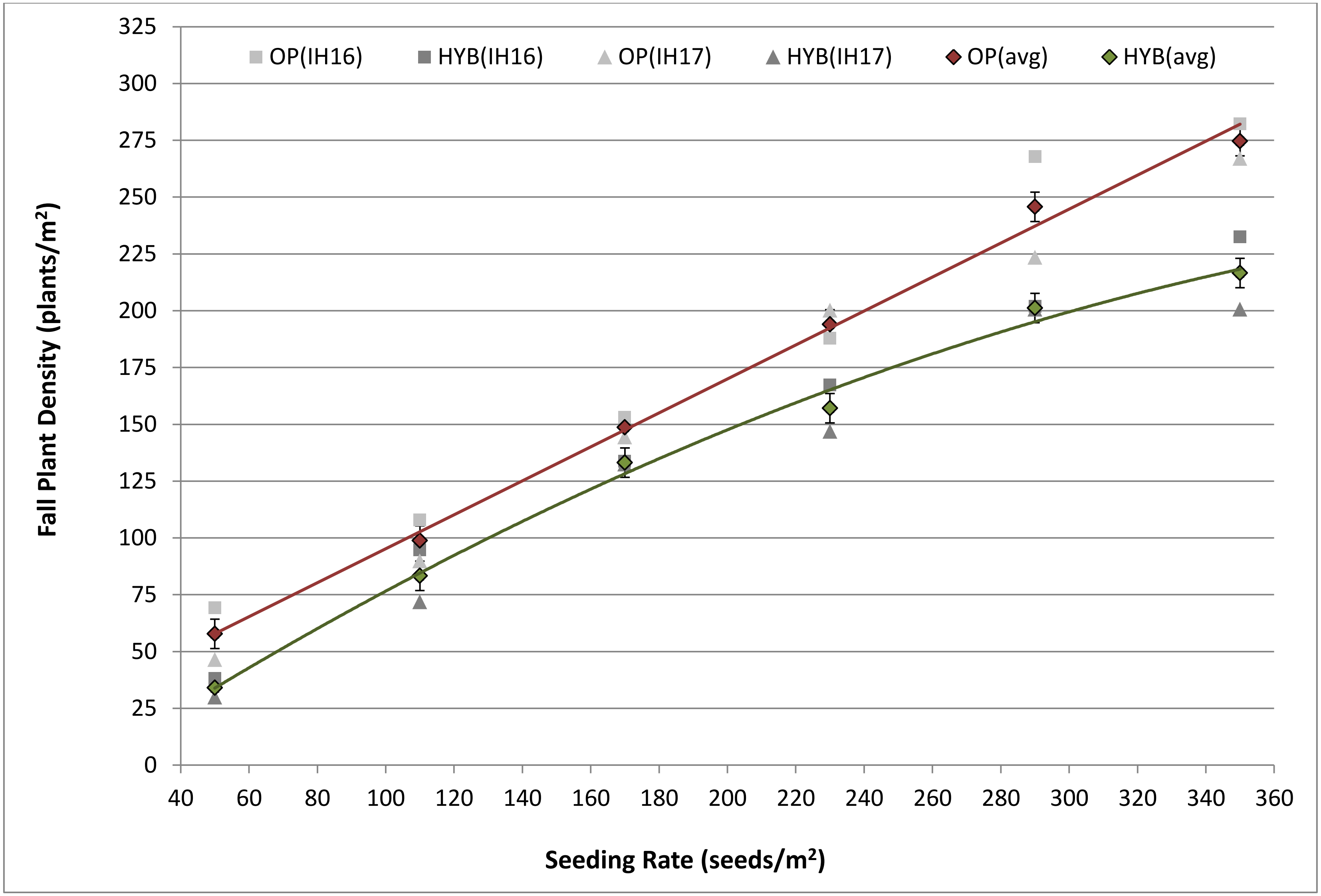

Figure 1. Seeding rate effects on fall rye (hybrid vs open pollinated) plant densities (measured in fall) over a two-year period at Indian Head (2016-17).

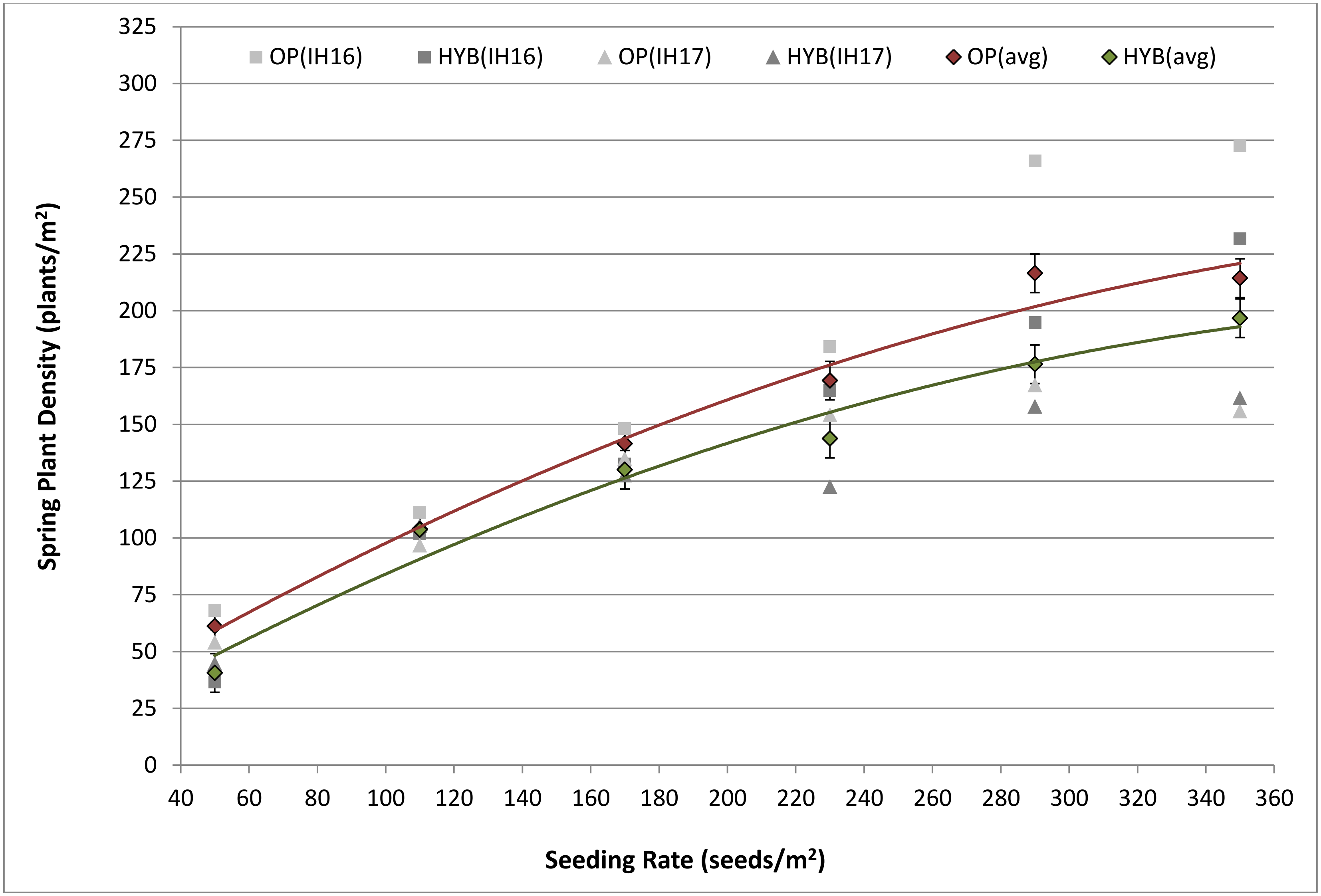

Figure 2. Seeding rate effects on fall rye (hybrid vs open pollinated) plant densities (measured in spring) over a two-year period at Indian Head (2016-17).

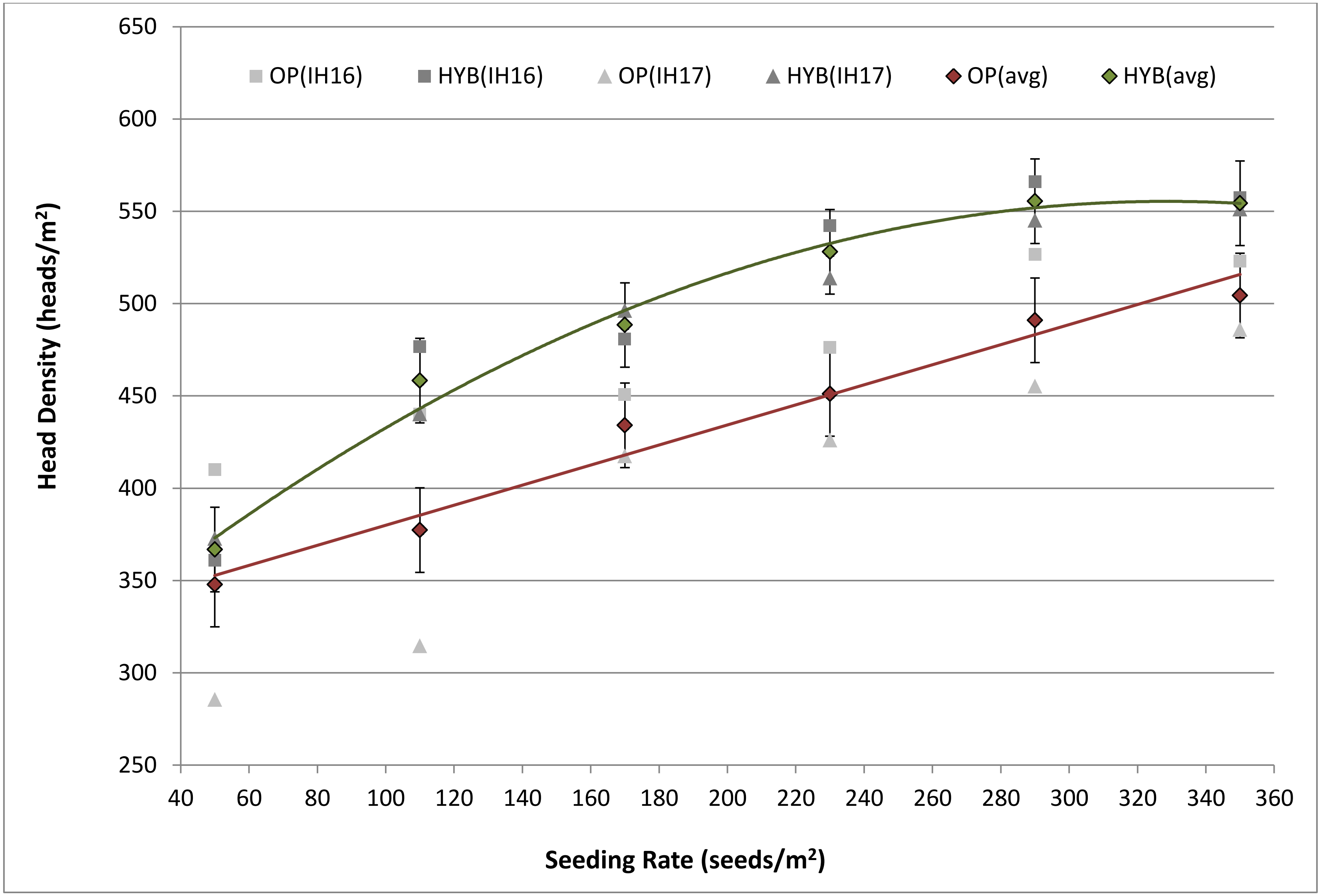

Figure 3. Seeding rate effects on fall rye (hybrid versus open pollinated) head densities over a two-year period at Indian Head (2016-17).

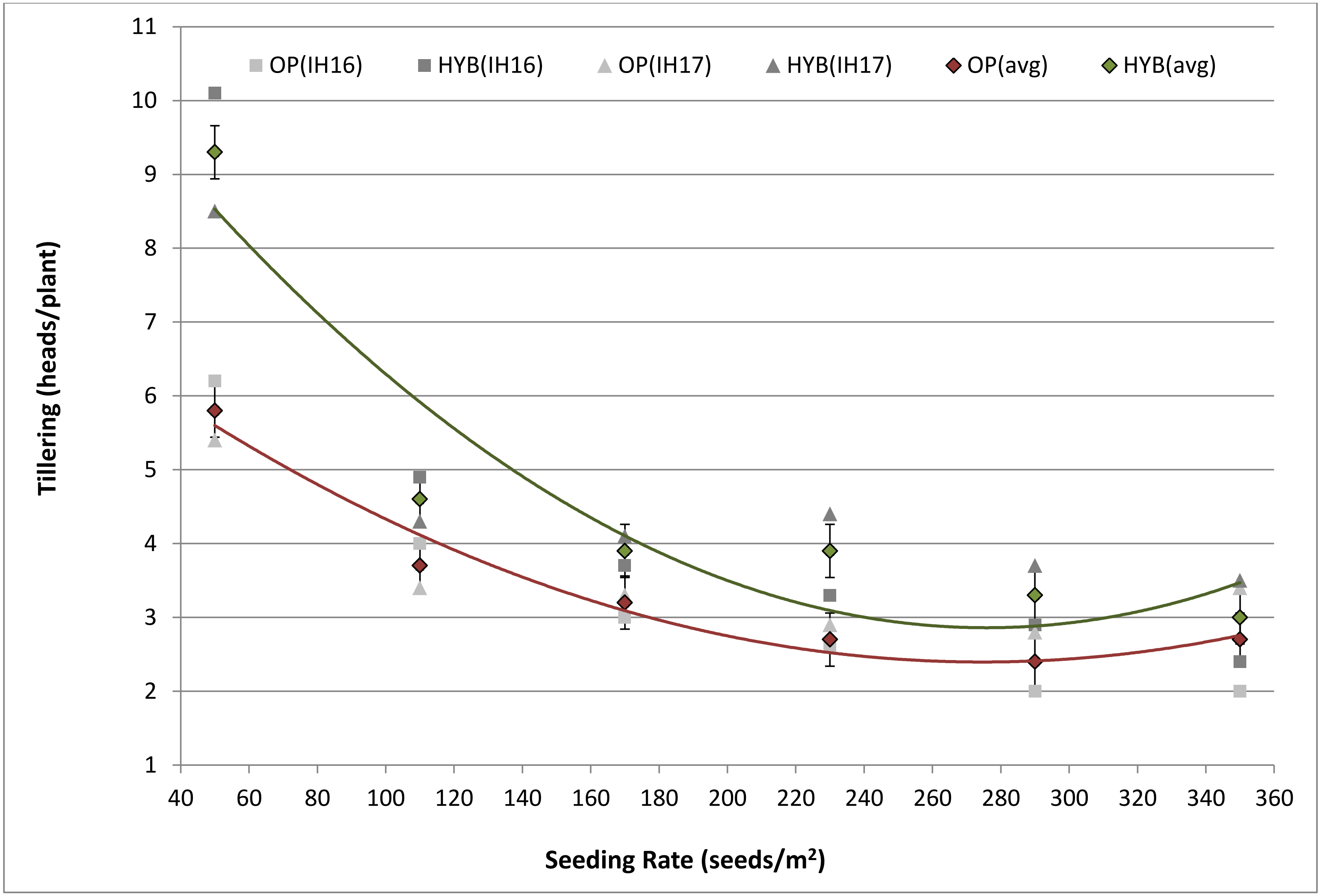

Figure 4. Seeding rate effects on fall rye (hybrid versus open pollinated) tillering over a two-year period at Indian Head (2016-17).

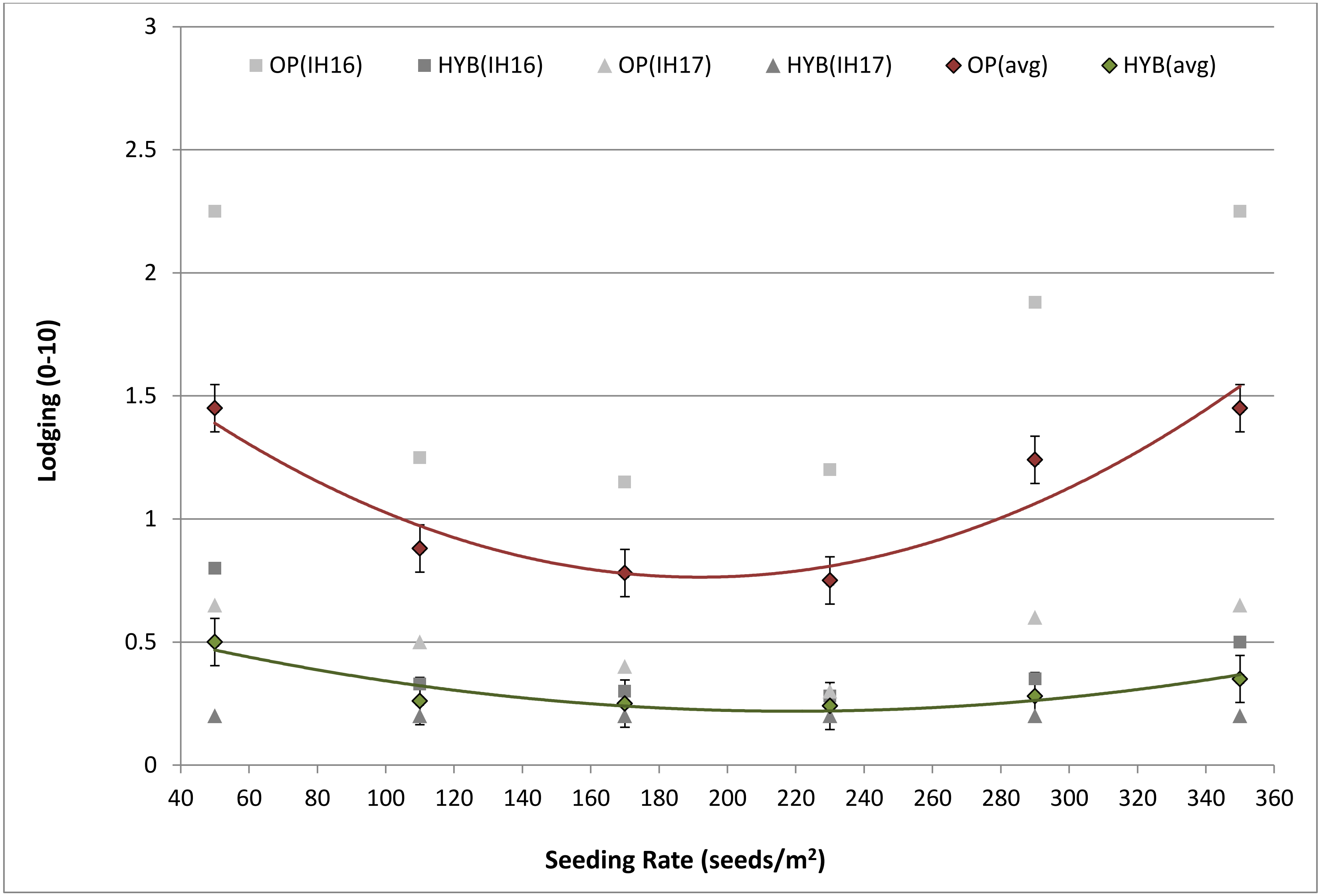

Figure 5. Seeding rate effects on fall rye (hybrid versus open pollinated) lodging over a two-year period at Indian Head (2016-17). Lodging was rated using the Belgian lodging scale which takes into account both area affected and lodging severity – higher values are indicative of more lodging.

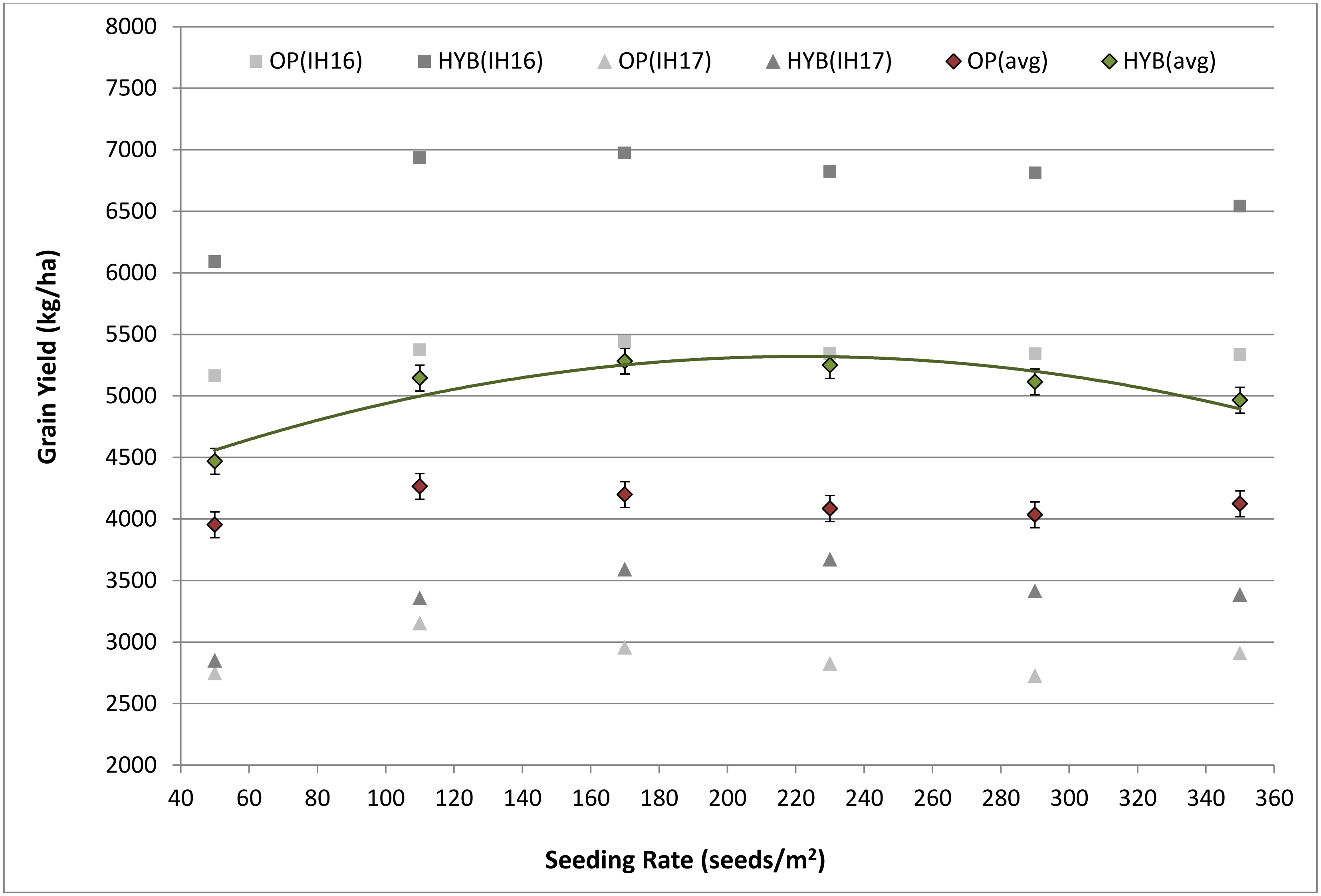

Figure 6. Seeding rate effects on fall rye (hybrid versus open pollinated) grain yield over a two-year period at Indian Head (2016-17).

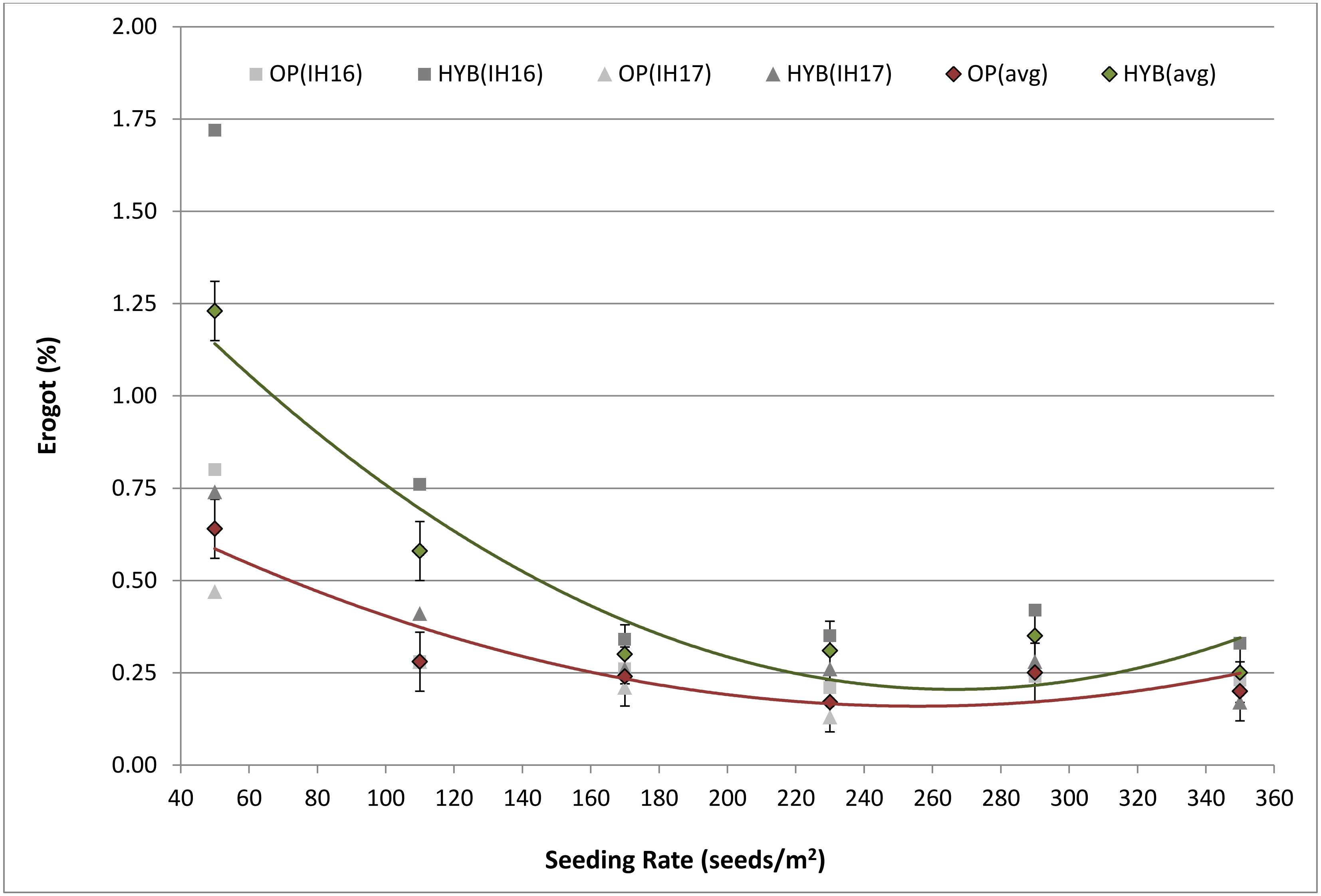

Figure 7. Seeding rate effects on percent ergot in fall rye (hybrid versus open pollinated) over a two-year period at Indian Head (2016-17).

Extension Activities and Dissemination of Results

In 2016, this demonstration was highlighted during the IHARF Crop Management Field Day (July 19, 219 registered guests) where Chris Holzapfel (IHARF) and Dr. Brian Beres (AAFC-Lethbridge) led a discussion on winter cereal agronomy and opportunities. The trial was also shown and discussed by Chris Holzapfel on a tour co-hosted with Arysta Lifesciences (July 26, 45 guests). In addition to these more formal tours, the site was visited by numerous growers, agronomists and researchers over the season. In 2017, the demonstration was again shown and discussed by Chris Holzapfel at the IHARF Crop Management Field Day (July 18, approximately 200 guests) with a focus on results from the previous season and the overall differences in winter cereal performance between the two years.

In addition to the field tours, results from the first year of this demonstration were presented by Chris Holzapfel at the Agri-ARM Research Update on January 12, 2017 as part of Crop Production Week, at the IHARF Winter Seminar and AGM in Weyburn, SK (February 1, 2017) and at a Crop Command Agronomy Meeting in South on March 16, 2017. Dr. Jamie Larsen presented the highlights of the first year results at the Saskatchewan Winter Cereals Development Commission AGM on January 9, 2017 and numerous other producer meetings. In addition, multiple industry representatives (i.e. FP Genetics and KWS) have utilized the preliminary results in their own extension and training activities throughout western Canada. The 2016 full report has been widely distributed as a download through the IHARF website and personal correspondence upon request. Updated, combined results from the project will be made available online (www.iharf.ca) in the winter of 2017-18 and through a variety of other media (i.e. oral presentations, popular agriculture press, fact sheets, etc.) as opportunities arise.

11. Conclusions and Recommendations

This project has demonstrated the relative yield potential and seeding rate response of modern open-pollinated (Hazlet) versus hybrid (Brasetto) fall rye varieties over two contrasting growing seasons at Indian Head, Saskatchewan. With good fall moisture conditions and a mild winter/spring, overall establishment was excellent in 2016 but somewhat more challenging in 2017 with later seeding and unusually cool conditions through the month that followed. For April through August, moisture was abundant in 2016 but much scarcer the following season and, when combined with spring frost, the overall rye yield potential was much lower. While fall plant densities were similar between the two years, there appeared to more thinning over the winter months under the less favourable conditions encountered in 2017, particularly at the highest seeding rates. Both varieties compensated well for lower plant populations through increased tillering but the hybrid consistently produced more heads plant^{-1} at lower seeding rates and also when averaged across seeding rates. This was evident in the measurements of head density where heads m^{-2} increased linearly with seeding rate for the OP rye and quadratically with the hybrid where head densities plateaued at 230-270 seeds/m^2. Minor lodging and significant treatment effects were detected whereby lodging was worse overall with the OP variety and most severe at the lowest and highest seeding rates. There was very little lodging in 2016-17 under the drier than normal conditions, regardless of the treatment. Even under wetter conditions, lodging was negligible at optimal seeding rates with the OP variety and regardless of seeding rate with the hybrid. The hybrid out-yielded the OP variety by 26% when averaged across seeding rates in 2015-16 and by 17% under the lower yielding conditions in 2016-17. The OP variety was relatively unresponsive to seeding rate but yields did tend to be lowest at the lowest seeding rate. The hybrid variety was more responsive with maximum yields achieved at 170-230 seeds/m^2 and slight declines as seeding rate was further increased to 350 seeds/m^2. The optimum seeding rate and overall range in yields across seeding rates was greater under the dry conditions of 2016-17 when compared to the much wetter previous season. From an economic perspective, grain yield is important but quality is also a major factor to consider when making management decisions. One of the greatest causes of down-grading in fall rye is ergot, which was consistently and significantly affected by seeding rate. Ergot was higher overall in the hybrid but, for both varieties, was greater at sub-optimal (< 170 seeds/m^2) seeding rates; however the seeding rate effect was much stronger with the hybrid. The hybrid still tended to have more ergot than the OP variety at higher seeding rates but the differences were not generally statistically significant. Overall, it appears that target seeding rates of approximately 170-230 seeds m^{-2} are sufficient to optimize both yield and quality across a wide range of environmental conditions with the higher end of the range being recommended if conditions are considered poor for establishment or dry weather is likely to be a yield limiting factor.

Supporting Information

12. Acknowledgements:

This project was supported by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement. The hybrid rye seed was provided in-kind by FP genetics and certain crop protection products were provided in-kind by Bayer CropScience and BASF. Throughout the project, Jamie Larsen (AAFC – Lethbridge) has assisted with the interpretation and dissemination of results and also completed the falling number analyses as an in-kind contribution to the project. The many contributions of past and present IHARF staff Danny Petty, Christiane Catellier, Dan Walker, Karter Kattler, Carly Miller, Shaelyn Stadnyk and Andrea De Roo are greatly appreciated.

13. Appendices

Table 5. Treatment means for seeding rate (by year and variety) effects on fall rye plant density (measured in the fall) at Indian Head over a two-year period. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

	2015-16			2016-17			Average		
Seeding Rate	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**
	---------- Fall Plant Density (plants/m^2) ----------								
50 seeds/m^2	69.3 e	38.1 f	53.7 f	46.4 e	29.9 d	38.1 f	57.8 f	34.0 e	45.9 f
110 seeds/m^2	107.9 d	94.7 e	101.3 e	89.8 d	71.8 c	80.8 e	98.8 e	83.3 d	91.0 e
170 seeds/m^2	153.0 c	133.7 d	143.3 d	144.4 c	132.5 b	138.4 d	148.7 d	133.1 c	140.9 d
230 seeds/m^2	187.9 b	167.3 c	177.6 c	200.2 b	146.9 b	173.5 c	194.0 c	157.1 b	175.5 c
290 seeds/m^2	267.8 a	201.8 b	234.8 b	223.5 b	200.6 a	212.0 b	245.7 b	201.2 a	223.4 b
350 seeds/m^2	282.2 a	232.6 a	257.4 a	267.0 a	200.6 a	233.8 a	274.6 a	216.6 a	245.6 a
S.E.M	7.65		5.45	10.32		7.33	6.46		4.62
Orthogonal Contrasts	---------- Pr > *F* ----------								
SR – lin	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
SR – quad	0.794	0.043	0.194	0.188	0.015	0.008	0.367	0.002	0.004

Table 6. Treatment means for seeding rate (by year and variety) effects on fall rye plant density (measured in the spring) at Indian Head over a two-year period. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, $P \leq 0.05$).

	2015-16			**2016-17**			**Average**		
Seeding Rate	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**
	---------- Spring Plant Density (plants/m^2) ----------								
50 seeds/m^2	68.1 e	36.5 f	52.3 f	54.1 c	44.7 c	49.4 d	61.1 e	40.6 d	50.9 e
110 seeds/m^2	111.1 d	101.7 e	106.4 e	96.8 b	105.4 b	101.1 c	103.9 d	103.6 c	103.8 d
170 seeds/m^2	148.1 c	132.5 d	140.3 d	134.9 ab	127.6 ab	131.2 b	141.5 c	130.0 b	135.8 c
230 seeds/m^2	184.2 b	164.9 c	174.5 c	154.2 a	122.6 ab	138.4 ab	169.2 b	143.7 b	156.5 b
290 seeds/m^2	265.8 a	194.8 b	230.3 b	167.3 a	157.9 a	162.6 a	216.5 a	176.4 a	196.4 a
350 seeds/m^2	272.7 a	231.7 a	252.2 a	155.9 a	161.6 a	158.7 ab	214.3 a	196.7 a	205.5 a
S.E.M	8.70		6.18	14.61		10.34	8.52		6.05
Orthogonal Contrasts	---------- Pr > F ----------								
SR – lin	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
SR – quad	0.982	0.073	0.196	0.005	0.067	0.002	0.019	0.018	0.001

Table 7. Treatment means for seeding rate (by year and variety) effects on fall rye head density at Indian Head over a two-year period. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

	2015-16			**2016-17**			**Average**		
Seeding Rate	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**
	Head Density (heads/m^2)								
50 seeds/m^2	410.1 d	360.9 c	385.5 d	285.5 c	372.8 b	329.1 c	347.8 d	366.8 d	357.3 d
110 seeds/m^2	440.1 cd	476.5 b	458.3 c	314.6 bc	440.1 ab	377.3 bc	377.3 cd	458.3 c	417.8 c
170 seeds/m^2	450.7 cd	480.7 b	465.7 c	417.5 ab	496.2 a	456.9 ab	434.1 bc	488.4 bc	461.3 bc
230 seeds/m^2	476.1 bc	542.2 a	509.2 b	426.1 ab	513.8 a	467.0 a	451.1 ab	528.0 ab	489.6 ab
290 seeds/m^2	526.6 a	566.0 a	546.3 a	455.2 a	545.1 a	500.1 a	490.9 a	555.5 a	523.2 a
350 seeds/m^2	522.9 a	557.4 a	540.1 ab	486.0 a	551.2 a	518.6 a	504.4 a	554.3 a	529.4 a
S.E.M	17.56		13.10	41.46		29.62	22.90		16.72
Orthogonal Contrasts	Pr > *F*								
SR – lin	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
SR – quad	0.955	0.001	0.012	0.403	0.240	0.197	0.468	0.022	0.034

Table 8. Treatment means for seeding rate (by year and variety) effects on fall rye tillering (calculated from spring plant population and head density measurements) at Indian Head over a two-year period. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

	2015-16			**2016-17**			**Average**		
Seeding Rate	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**
	------ Tillers (heads/plant) ------								
50 seeds/m^2	6.2 a	10.1 a	8.2 a	5.4 a	8.5 a	7.0 a	5.8 a	9.3 a	7.6 a
110 seeds/m^2	4.0 b	4.9 b	4.5 b	3.4 b	4.3 b	3.9 b	3.7 b	4.6 b	4.2 b
170 seeds/m^2	3.0 c	3.7 c	3.3 c	3.3 b	4.1 b	3.7 b	3.2 bc	3.9 bc	3.5 bc
230 seeds/m^2	2.6 cd	3.3 cd	3.0 cd	2.9 b	4.4 b	3.6 b	2.7 bc	3.9 bc	3.3 c
290 seeds/m^2	2.0 d	2.9 cd	2.4 de	2.8 b	3.7 b	3.2 b	2.4 c	3.3 c	2.8 c
350 seeds/m^2	2.0 d	2.4 d	2.2 e	3.4 b	3.5 b	3.5 b	2.7 c	3.0 c	2.8 c
S.E.M	0.34		0.24	0.63		0.44	0.36		0.25
Orthogonal Contrasts	------ Pr > *F* ------								
SR – lin	< 0.001	< 0.001	< 0.001	0.013	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
SR – quad	< 0.001	< 0.001	< 0.001	0.012	0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table 9. Treatment means for seeding rate (by year and variety) effects on lodging in fall rye at Indian Head over a two-year period. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

	2015-16			**2016-17**			**Average**		
Seeding Rate	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**
	---------- Lodging (0-10) ----------								
50 seeds/m^2	2.25 a	0.80 a	1.53 a	0.65 a	0.20 a	0.43 a	1.45 a	0.50 a	0.98 a
110 seeds/m^2	1.25 b	0.33 ab	0.79 cd	0.50 ab	0.20 a	0.35 abc	0.88 b	0.26 a	0.57 cd
170 seeds/m^2	1.15 b	0.30 ab	0.73 d	0.40 bc	0.20 a	0.30 bc	0.78 b	0.25 a	0.51 d
230 seeds/m^2	1.20 b	0.28 b	0.74 d	0.30 c	0.20 a	0.25 c	0.75 b	0.24 a	0.49 d
290 seeds/m^2	1.88 a	0.35 ab	1.11 bc	0.60 a	0.20 a	0.40 ab	1.24 a	0.28 a	0.76 bc
350 seeds/m^2	2.25 a	0.50 ab	1.38 ab	0.65 a	0.20 a	0.43 a	1.45 a	0.35 a	0.90 ab
S.E.M	0.183		0.129	0.057		0.040	0.096		0.068
Orthogonal Contrasts	---------- Pr > *F* ----------								
SR – lin	0.182	0.311	0.827	0.675	1.000	0.766	0.189	0.368	0.767
SR – quad	< 0.001	0.029	< 0.001	< 0.001	1.000	< 0.001	< 0.001	0.048	< 0.001

Table 10. Treatment means for seeding rate (by year and variety) effects on fall rye grain yield at Indian Head over a two-year period. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, $P \leq 0.05$).

	2015-16			**2016-17**			**Average**		
Seeding Rate	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**
	Grain Yield (kg/ha)								
50 seeds/m^2	5161 b	6089 c	5625 c	2748 a	2850 b	2799 b	3954 b	4469 c	4212 c
110 seeds/m^2	5374 a	6933 a	6153 a	3154 a	3357 a	3255 a	4264 a	5145 ab	4704 ab
170 seeds/m^2	5438 a	6972 a	6205 a	2957 a	3592 a	3275 a	4198 ab	5282 a	4740 a
230 seeds/m^2	5345 ab	6824 a	6085 a	2825 a	3672 a	3249 a	4085 ab	5248 a	4667 ab
290 seeds/m^2	5340 ab	6812 a	6076 ab	2727 a	3416 a	3072 ab	4034 ab	5114 ab	4574 ab
350 seeds/m^2	5334 ab	6542 b	5938 b	2911 a	3387 a	3149 a	4123 ab	4964 b	4544 b
S.E.M	86.1		70.1	178.6		131.0	105.0		82.0
Orthogonal Contrasts	Pr > *F*								
SR – lin	0.261	0.030	0.005	0.668	0.039	0.252	0.960	0.004	0.033
SR – quad	0.041	0.064	< 0.001	0.636	0.004	0.019	0.225	< 0.001	< 0.001

Table 11. Treatment means for seeding rate (by year and variety) effects on ergot in fall rye at Indian Head over a two-year period. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, $P \leq 0.05$).

	2015-16			**2016-17**			**Average**		
Seeding Rate	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**	**OP** (Hazlet)	**HYB** (Brasetto)	**Average**
	Ergot (%)								
50 seeds/m^2	0.80 a	1.72 a	1.26 a	0.47 a	0.74 a	0.61 a	0.64 a	1.23 a	0.93 a
110 seeds/m^2	0.28 b	0.76 b	0.52 b	0.28 ab	0.41 b	0.34 b	0.28 b	0.58 b	0.43 b
170 seeds/m^2	0.26 b	0.34 c	0.30 c	0.21 ab	0.26 b	0.24 b	0.24 b	0.30 c	0.27 c
230 seeds/m^2	0.21 b	0.35 c	0.28 c	0.13 b	0.26 b	0.19 b	0.17 b	0.31 c	0.24 c
290 seeds/m^2	0.24 b	0.42 c	0.33 c	0.26 ab	0.28 b	0.27 b	0.25 b	0.35 c	0.30 bc
350 seeds/m^2	0.23 b	0.33 c	0.28 c	0.17 ab	0.17 b	0.17 b	0.20 b	0.25 c	0.23 c
S.E.M	0.096		0.071	0.121		0.088	0.080		0.060
Orthogonal Contrasts	Pr > *F*								
SR – lin	< 0.001	< 0.001	< 0.001	0.102	0.003	0.001	< 0.001	< 0.001	< 0.001
SR – quad	0.002	< 0.001	< 0.001	0.224	0.107	0.043	0.004	< 0.001	< 0.001

Table 12. Treatment means for seeding rate (by year and variety) effects on falling number in fall rye at Indian Head over a three-year period. This test was completed on composite samples (as opposite to individual plot samples); therefore, statistical analyses were not completed.

	2015-16			2016-17			Average (Y)		
Seeding Rate	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)
	---------- Falling Number (seconds) ----------								
50 seeds/m^2	169.5	332.0	250.8	254.0	266.0	260.0	211.8	299.0	255.4
110 seeds/m^2	245.5	314.5	280.0	243.3	267.5	255.4	244.4	291.0	267.7
170 seeds/m^2	221.0	335.0	278.0	236.8	310.0	273.4	228.9	322.5	275.7
230 seeds/m^2	249.0	332.0	290.5	234.5	286.8	260.7	241.8	309.4	275.6
290 seeds/m^2	271.6	326.5	299.1	261.3	286.8	274.1	266.5	306.7	286.6
350 seeds/m^2	239.5	329.0	284.3	253.5	271.0	262.3	246.5	300.0	273.3

Figure A-1. Hazlet (OP) fall rye seeded at 50 seeds m^{-2} at Indian Head (July 29, 2016).

Figure A-2. Brasetto (HYB) fall rye seeded at 50 seeds m^{-2} at Indian Head (July 29, 2016).

Figure A-3. Hazlet (OP) fall rye seeded at 350 seeds m^{-2} at Indian Head (July 29, 2016).

Figure A-4. Brasetto (HYB) fall rye seeded at 350 seeds m^{-2} at Indian Head (July 29, 2016).

Figure A-5. Hazlet (OP) fall rye seeded at 50 seeds m^{-2} at Indian Head (August 1, 2017).

Figure A-6. Brasetto (HYB) fall rye seeded at 50 seeds m^{-2} at Indian Head (August 1, 2017).

Figure A-7. Hazlet (OP) fall rye seeded at 350 seeds m^{-2} at Indian Head (August 1, 2017).

Figure A-8. Brasetto (HYB) fall rye seeded at 350 seeds m^{-2} at Indian Head (August 1, 2017).

Abstract

14. Abstract/Summary:

Field trials with fall rye were completed over a two-year period near Indian Head, Saskatchewan to demonstrate yield potential and seeding rate response of open-pollinated versus hybrid fall rye. Overall, the open-pollinated variety (Hazlet) was more susceptible to lodging and produced fewer tillers and heads m^{-2} than the hybrid (Brasetto). Lodging was reduced by utilizing optimal seeding rates (170-230 seeds m^{-2}) but was negligible in the hybrid regardless of seeding rate. Across seeding rates, head density was higher with the hybrid. Head density increased linearly with seeding rate with the OP rye and quadratically with the hybrid. Especially at low seeding rates, the hybrid produced significantly more tillers per plant. The hybrid rye variety yielded 17-26% higher than the OP variety with the stronger advantage observed under more optimal growing conditions. The OP variety was relatively unresponsive to seeding rate but the hybrid was optimized at 170-230 seeds/m^2 with a stronger response and higher optimal seeding rate under dry conditions. Percent ergot was lower overall with the OP rye but seeding rates of at least 170 seeds/m^2 helped to minimize percent ergot for both varieties and the difference between varieties was negligible at higher seeding rates. While falling numbers were much higher for the hybrids, there were no clear and consistent trends observed for seeding rate effects on falling number.