2017 Annual Report
for the

Agricultural Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Nitrogen Response of Modern Fall Rye Varieties

(Project #20160339)

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Project Identification

1. **Project Title:** Nitrogen Response of Modern Fall Rye Varieties
2. **Project Number:** 20160339
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 nitrogen (N) fertilizer requirements of a high yielding fall rye hybrid 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 limited markets), the introduction of new hybrid varieties in western Canada 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. Seed costs for hybrid rye are understandably higher and a separate project (ADOPT #20160341) demonstrates hybrid versus open-pollinated (OP) fall rye response to varying seeding rates; however, when transitioning to hybrids, nutrient requirements for this crop may also increase. It is possible that farmers may require higher rates of N fertilizer to achieve the maximum yield potential of these modern fall rye varieties. The objective of this demonstration was to demonstrate the relative response of fall rye to N fertilization and overall yield potential of modern OP versus high yielding hybrids. Similar field trials were also conducted during the 2014-15 and 2015-16 growing seasons; therefore, this report will summarize the results from all three years.

Methodology and Results

9. **Methodology:**

A field trial was initiated in the fall of 2014 near Indian Head, Saskatchewan (50.556 N, 103.603 W) and repeated for each of the following two growing seasons. 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 N fertilizer rates. The variety was either Hazlet (OP) or Brasetto (hybrid) and the N rates were 6, 50, 100, 150, 200 or 250 kg N ha^{-1} (12 treatments in total). The treatments were arranged in a Randomized Complete Block Design (RBCD) with four replicates.

Selected agronomic information is provided in Table 1. Treated (Cruiser Maxx® Vibrance) fall rye seed was direct seeded into canola stubble on September 20-27 at a rate of 200 seeds m^{-2} and with all fertilizer applied during planting. The fertilizer sources were urea (46-0-0, side-banded as per protocol), monoammonium phosphate (side-banded), and potassium sulphate (seed-placed). With the exception of N, all fertilizer rates were balanced across treatments - thus 6 kg N ha^{-1} was supplied by the monoammonium phosphate in all treatments. Weeds were controlled using registered pre-emergent and in-crop herbicide applications. Fungicides were applied during early heading (prior to anthesis) to protect against late occurring leaf disease and, potentially, fusarium head blight. Pre-harvest glyphosate was applied at maturity and the centre five rows of each plot were straight-combined on August 13-24.

Table 1. Agronomic information for the ADOPT Fall Rye N Response Demonstration at Indian Head during the 2015, 2016 and 2017 growing seasons.

Factor / Field Operation	2014-15	2015-16	2016-17
Previous Crop	Canola (LL)	Canola (LL)	Canola (LL)
Pre-emergent herbicide	880 g glyphosate ha-1 + 729 g 2,4-D ha-1 (Sep-21-2014)	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)
Soil Nutrient Sampling	May-10-2015	Oct-23-2015	Oct-11-2016
Seed Treatment	Cruiser Vibrance Quattro	Cruiser Vibrance Quattro	Cruiser Vibrance Quattro
Seeding Date	Sep-23-2014	Sep-20-2015	Sep-27-2016
Row spacing	30 cm	30 cm	30 cm
kg P_2O_5-K_2O-S ha^{-1}	30-34-16	30-34-16	30-47-16
In-crop herbicide 1	280 g bromoxynil ha-1 + 280 g MCPA ester ha-1 + 198 g tralkoxydim ha-1 (May-25-2015)	280 g bromoxynil ha^{-1} + 280 g MCPA ester ha^{-1} + 198 g tralkoxydim ha^{-1} (May-17-2016)	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 12) 89 g metconazole ha-1 (June 17)^{Z}	89 g metconazole ha^{-1} (June 5)	89 g metconazole ha^{-1} (June 10)
Pre-harvest herbicide	880 g glyphosate ha^{-1} (Aug-14-2015)	880 g glyphosate ha^{-1} (Jul-28-2016)	880 g glyphosate ha^{-1} (Aug-11-2017)
Harvest date	Aug-21-2015	Aug-13/14-2016	Aug-24-2017

Composite soil samples were collected either in the fall or early spring and submitted to either ALS Laboratory Group Agricultural Services (2015 and 2016) or AgVise Laboratories (2017) for residual nutrient analyses. Overall plant height was determined by averaging the height of four plants per plot, measured after heading and stem elongation were completed. These measurements were intended to be independent of lodging (i.e. we attempted to stand the plants completely upright before measuring); however, this can be difficult and lodging tends to increase error in plant height measurements. 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 accounted for. 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 2015-16 and each plot in 2017, falling number analyses were completed in-kind by AAFC Lethbridge (Jamie Larsen). Daily temperatures and precipitation were recorded at the nearest 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), nitrogen fertilizer rate (NR) and their interaction (VAR × NR, Y × VAR, Y × NR, and Y × VAR × NR) considered fixed. Replicate effects were treated as random. Treatment means were separated using Fisher’s protected LSD test and orthogonal contrasts were 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 2015, 2016 and 2017 growing seasons at Indian Head are presented along with the long-term (1981-2010) averages in Table 2. The first year of the demonstration (2014-15), fall moisture conditions were optimal and there was adequate snow cover through the winter but by early April all snow had melted and the period that followed was dry with no significant precipitation events until mid-June. In 2015-16, fall moisture was adequate while the winter was milder than normal with very little snow cover or extreme temperatures. 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 initial moisture levels were good in all three springs, the 2016 season was much wetter overall (112% of long-term average growing season precipitation) with far greater yield potential for the rye but also more potential for disease and lodging. Unfortunately, damaging hail occurred in late July 2016 which reduced the yields that year but the damage was uniform across the trial and was not considered to have compromised the results. Both the 2015 and 2017 growing seasons were dry (83% and 52% of long-term average growing season precipitation, respectively). Spring frost also occurred in both 2015 and 2017 but was more severe in 2017 where temperatures fell to approximately -6º C on May 18 and caused substantial crop injury. Despite the poorer overall growing conditions in 2015 and especially 2017, the plots were uniform and the observed responses for all three 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 nitrogen rates.

Table 2. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2015, 2016 and 2017 growing seasons at Indian Head, SK.

Year	April	May	June	July	August	Avg. / Total
	------------------- Mean Temperature (°C) -------------------					
IH-2015	4.8	10.2	16.2	18.1	17.0	13.3
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-2015	9.5	15.6	38.3	94.6	58.8	217
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

Field Trial Results

Residual soil test nutrient levels are presented for each of the three years in Table 3. With 28-40 kg NO_3-N ha^{-1} available (0-60 cm), residual N levels were considered limiting and representative of typical fields in the Indian Head area. Residual phosphorus levels were low while potassium was sufficient and sulphur availability was considered marginal to adequate.

Table 3. Residual soil nutrient levels in fall rye nitrogen response demonstrations conducted over a three-year period at Indian Head, Saskatchewan (2014-15, 2015-16 and 2016-17).

Nutrient	IH-2015	IH-2016	IH-2017
	------------------- kg ha^{-1} -------------------		
NO_3-N (0-60 cm)	34	28	40
P (0-15 cm)	12	19	7
K (0-15 cm)	>605	> 605	729
SO_4-S (0-60 cm)	31	64	40

The overall tests of fixed effects are presented for all response variables in Table 4. 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 main effects of year, variety and N rate were significant for all response variables while the interaction between variety and N rate (VAR × NR) was significant for lodging, yield and protein but not plant height or ergot (Table 4). Two-way interactions with year (i.e. Y × VAR and Y × NR) were significant for all variables while the three-way interaction (Y × VAR × NR) was significant for lodging and protein but not plant height, yield or ergot.

Table 4. Test of fixed effects year (Y), variety (VAR) and nitrogen rate (NR) for selected fall rye response variables at Indian Head over a three-year period.

Effect	Plant Height	Lodging	Yield	Protein	Ergot
	---		p-values		---
Year (Y)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Variety (VAR)	< 0.001	< 0.001	< 0.001	< 0.001	0.011
Nitrogen Rate (NR)	0.002	< 0.001	< 0.001	< 0.001	< 0.001
VAR × NR	0.390	< 0.001	0.016	< 0.001	0.236
Y × VAR	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Y × NR	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Y × VAR × NR	0.527	< 0.001	0.182	0.017	0.098

Treatment means for the two varieties (averaged across N rates) are presented for individual growing seasons and averaged across the three years in Table 5.

While the overall plant height varied widely from year-to-year depending on the growing conditions, the OP variety was always taller than the hybrid by a range of 4-19 cm or 6-19% (Table 5). For both varieties, the plants were tallest under the wetter conditions of 2016, intermediate in 2015 and shortest in 2017, the driest of the three seasons. For the OP variety, the average (across N rates) height was 93, 106 and 67 cm in 2015, 2016 and 2017, respectively while, for the hybrid, the values were 78, 97, and 62 cm. Averaged across all three years, the OP variety was 89 cm tall and the hybrid was 79 cm. Shorter plants are desirable as they can be harvested more efficiently and are less prone lodging.

Lodging was very minor in both 2015 and 2017 (average ratings of 0.27-0.30) but more prominent in 2016 where the average rating was 1.17. Considering that maximum lodging rating values of 10.0 are mathematically possible, even in 2016 the lodging was considered very minor except for a few treatments. Despite the low severity, there was always less lodging with the hybrid compared to the OP variety when averaged across N rates. For example, in 2016 the average rating for the hybrid was only 0.3 versus 2.0 for the OP variety while the values averaged across years were 0.2 and 0.9, respectively.

Following the same pattern as plant height and lodging, grain yields were highest in 2016, substantially lower in 2015, and lowest in 2017. Across varieties and N rates the average yield for each of these years was 5598, 3553, and 2934 kg/ha, respectively. The hybrid yielded higher than the OP variety in each of the three years by a magnitude of 772 kg/ha (25%), 1320 kg/ha (27%), and 655 kg/ha (25%) in 2015, 2016 and 2017, respectively. Averaged across the three years the hybrid yielded 4479 kg/ha, 26% higher than OP variety at 3563 kg/ha.

Overall average grain protein was highest in 2015 (11.7%) followed by 2017 (10.5%) and then 2016 (10.2%). High protein is not particularly beneficial in rye since there are no premiums associated with it; however, it is a good indicator of N response and uptake. For individual years, grain protein was 0.8-1.1% higher in the OP variety than the hybrid and, averaged over the three-year period, grain protein concentrations were 11.3% and 10.4% for the OP and hybrid varieties, respectively.

Ergot is an important grading factor in rye was highest in 2015, followed by 2016 and then 2017 with overall averages of 0.71%, 0.42%, and 0.17%, respectively. In 2015, percent ergot was higher with the OP variety while there was more ergot with the hybrid in the two seasons that followed. Averaged across the three growing season, the observed ergot concentrations were 0.40 and 0.46 for the OP and hybrid varieties, respectively. For both varieties, further cleaning would have been required to achieve top milling grades as the maximum allowable ergot concentration before being down-graded to sample is only 0.33%.

Table 5. Treatment means for variety (by year) effects on selected fall rye response variables at Indian Head over a three-year period. For each variable, means within a group followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

Year	**Plant Height** (cm)	**Lodging** (0-10)	**Grain Yield** (kg/ha)	**Grain Protein** (%)	**Ergot** (%)
OP-15	93.2 a	0.392 a	3147 b	12.1 a	0.768 a
HYB-15	78.3 b	0.200 b	3919 a	11.3 b	0.635 b
S.E.M.	0.48	0.003	48.9	0.07	0.041
OP-16	106.0 a	2.025 a	4938 b	10.6 a	0.314 b
HYB-16	97.1 b	0.321 b	6258 a	9.7 b	0.528 c
S.E.M.	0.61	0.060	47.2	0.08	0.029
OP-17	66.5 a	0.333 a	2605 b	11.1 a	0.116 b
HYB-17	62.4 b	0.200 b	3260 a	10.0 b	0.229 a
S.E.M.	0.51	0.022	89.0	0.06	0.016
OP-avg	88.6 a	0.917 a	3563 b	11.3 a	0.399 b
HYB-avg	79.3 b	0.240 b	4479 a	10.4 b	0.464 a
S.E.M.	0.42	0.021	45.3	0.06	0.018

Complete results for N rate effects on the response variables measured along with those for associated interactions are presented in Tables 6-10 in the Appendices while the VAR × NR interactions are also presented graphically in Figures 1-5 in main body of the report.

For height, the overall N rate response was significant along with the Y × NR interaction; however, there was no interaction between variety and N rate detected (Table 4). This suggested that nitrogen effects on plant height differed from year-to-year but were consistent for both the OP and hybrid varieties. In 2015 and, to a lesser extent, 2017 there was slight decline in height as N rate was increased; however, this was likely due in part to minor lodging and subsequent measurement error as N fertilization will not typically reduce height and the trend was more prominent in the OP variety. In 2016, plants were shorter at the lowest N rate (7 kg N/ha) but statistically similar for rates ranging from

50-250 kg N/ha. When averaged across all three years, plant height for the OP variety peaked at 50 kg N/ha and declined as the N rate was increased to 250 kg N/ha (Fig. 1). While the trend was similar for the hybrid, there was less overall variation and no significant differences amongst the treatment means according to the multiple comparisons test.

All possible interactions were statistically significant for lodging (Table 4) but the overall trend was for lodging to increase with N fertilizer rate but only for the OP variety (Fig. 2, Table 7). Furthermore, there was very little variation in lodging ratings for the OP variety in either 2015 or 2017 while, in 2016, lodging increased as soon as N rate was increased past 50 kg N/ha and became more severe with each incremental increase in N. When averaged across years the lodging rates for the OP variety ranged from 0.35 at the lowest N rate to 1.73 at the highest. For the hybrid, the range was 0.20-0.27 with no significant differences amongst individual treatment means.

Nitrogen rate effects on grain yield are presented in Table 8 and Figure 3. Grain yield was affected by N rate with significant Y × NR and VAR × NR interactions detected (Table 4). The interaction between year and N rate was due to subtle differences in the responses in 2015 and 2017 versus that under the higher yielding conditions in 2016. While the overall response was quadratic all years, yields started to decline past rates of 150 kg N/ha in the drier years but kept on increasing, albeit at a diminishing rate, through rates right up to 250 kg N/ha in 2016. Despite the significant VAR × NR interaction, the responses were very similar for both the OP and hybrid rye. The hybrid yielded significantly higher than the OP variety at each individual N rate and yields did not differ amongst N rates ranging from 150-250 kg N/ha for either variety when averaged across the three-year period. While the economically optimal rate would be lower, according to the calculated response curves yields were maximized at approximately 190 kg N/ha for both the OP and hybrid varieties.

Nitrogen rate effects on grain protein concentrations are presented in Table 9 and Fig. 4 and showed significant VAR × NR, Y × NR, and Y × VAR × NR interactions (Table 4). The protein response to N rate was always significant and curvilinear (quadratic) regardless of the year or variety. There was subtle variation amongst individual years but on, on average, protein concentrations in the OP variety kept significantly climbing through the highest rate while they appeared to level off at approximately 200 kg N/ha with the hybrid. Similar patterns were observed in both 2015 and 2016 but not in 2017 where the responses were similar for the two varieties.

Nitrogen rate effects on ergot concentrations in the grain are presented in Table 10 and Fig. 5. Nitrogen rate affected ergot and the response varied across years but there were no VAR × NR or Y × VAR × NR interactions detected. For both varieties, percent ergot increased with N rate; however, there was more separation between treatments in 2015 and 2016 when overall ergot concentrations were higher. When averaged across years, there were subtle differences in the response between the two varieties with the relationship being shallow but linear for the OP variety and quadratic for the hybrid whereby the ergot rates appeared to be starting to increase more rapidly at the highest N rates. These results suggest that there are trade-offs between yield and quality when determining optimum N rates and, while the crop was quite responsive to high N rates for yield, rye quality can decline as N rates become excessive. Although falling number values were notably higher for the hybrid rye relative to the OP variety (288 versus 199 seconds) the N effects were somewhat inconsistent; however, falling number did usually tend to be lower at the highest N rates (not statistically analyzed).

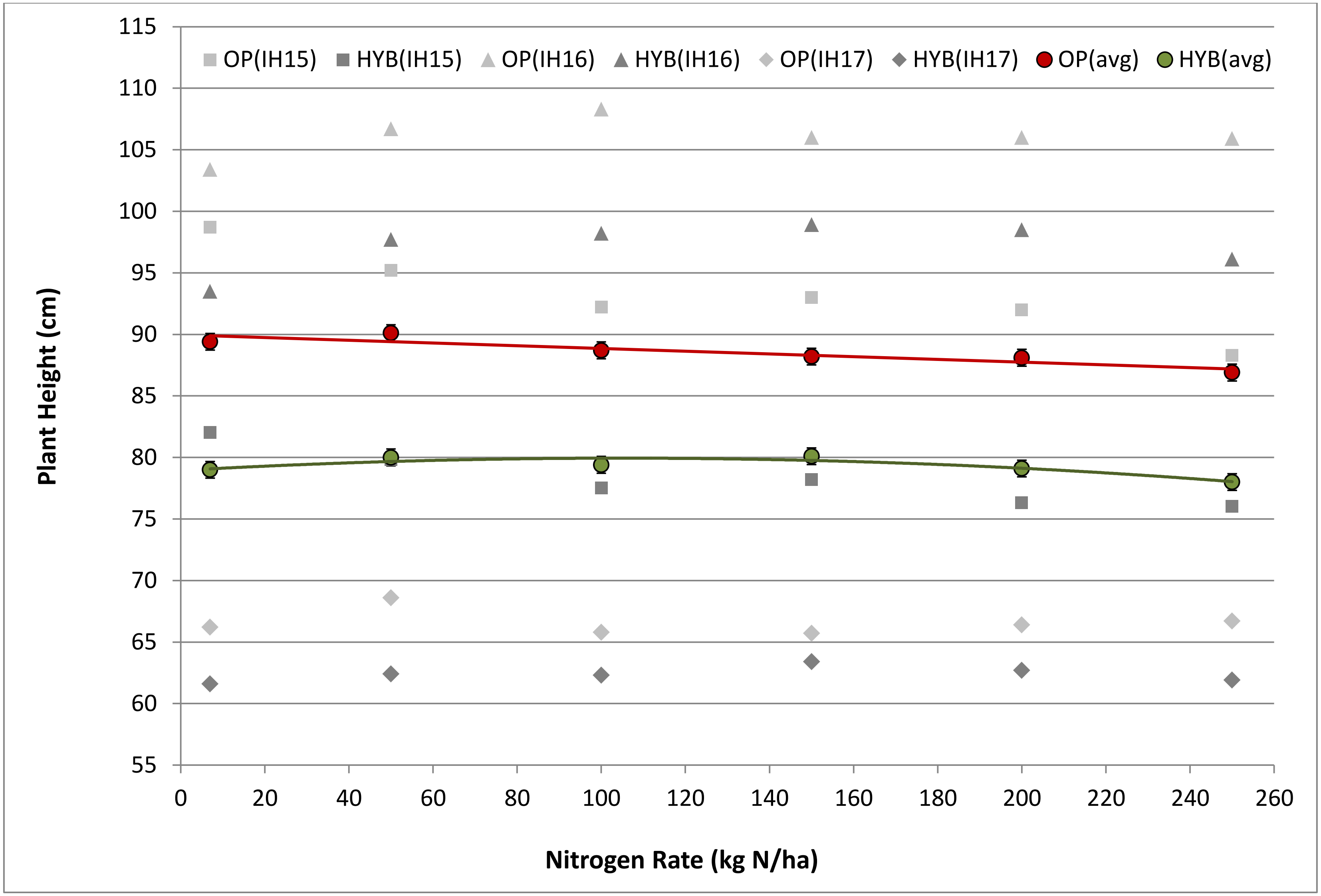

Figure 1. Nitrogen fertilizer rate effects on fall rye (hybrid versus open pollinated) plant height over a three-year period at Indian Head (2015-17).

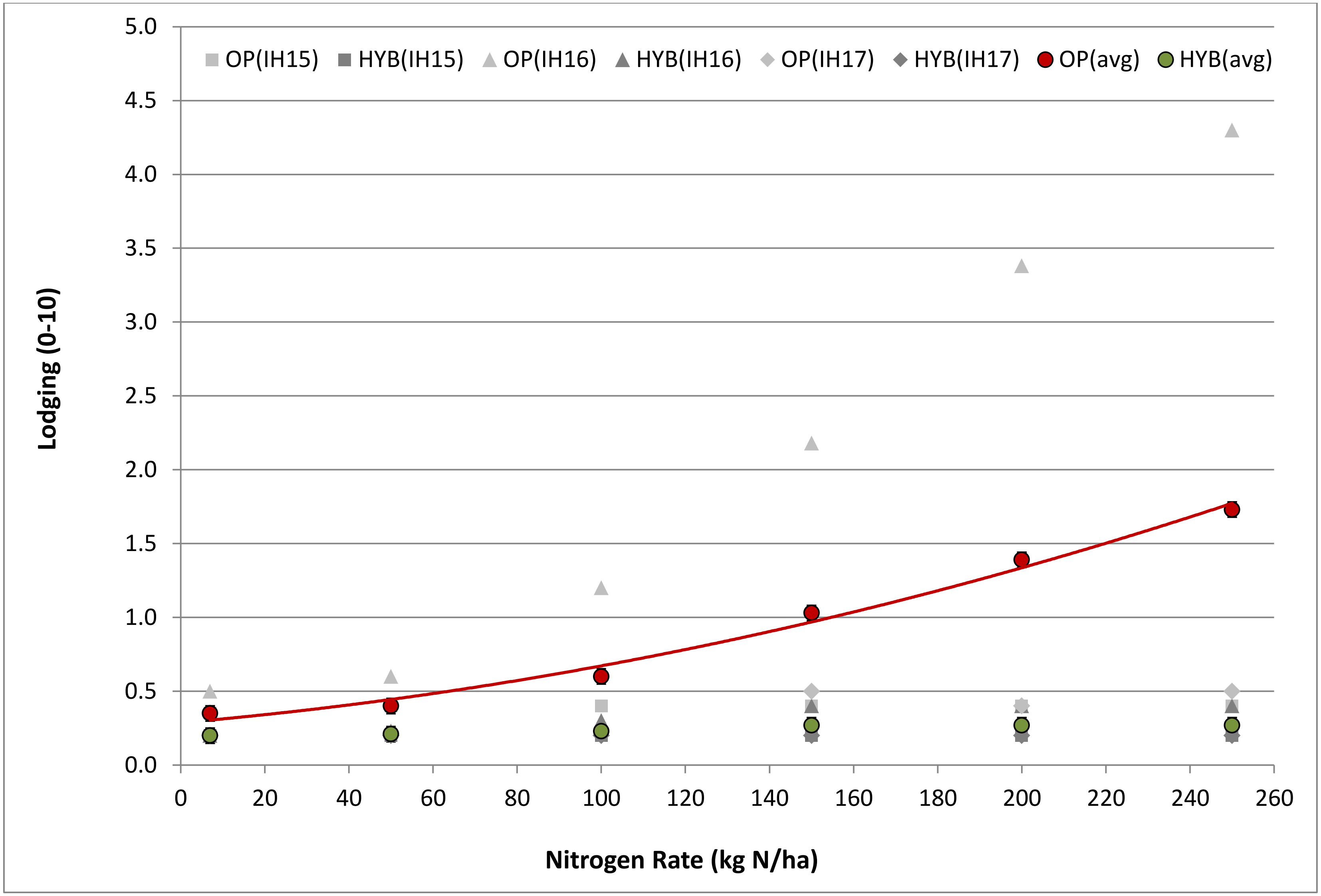

Figure 2. Nitrogen fertilizer rate effects on fall rye (hybrid versus open pollinated) lodging over a three-year period at Indian Head (2015-17). Lodging was rated using the Belgian lodging scale which takes into account both area affected and lodging severity – higher values are indicative of more lodging.

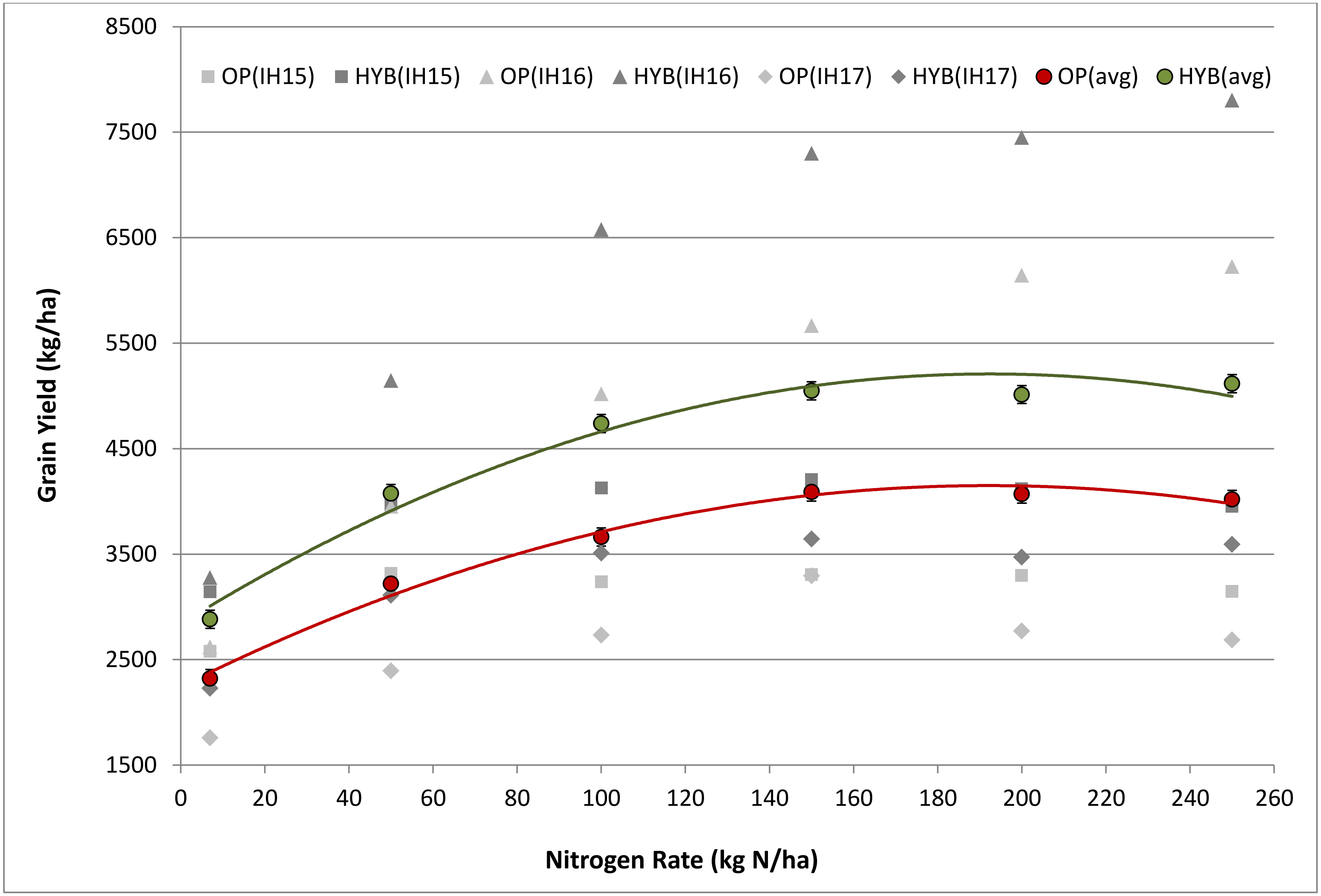

Figure 3. Nitrogen fertilizer rate effects on fall rye (hybrid versus open pollinated) grain yield over a three-year period at Indian Head (2015-17).

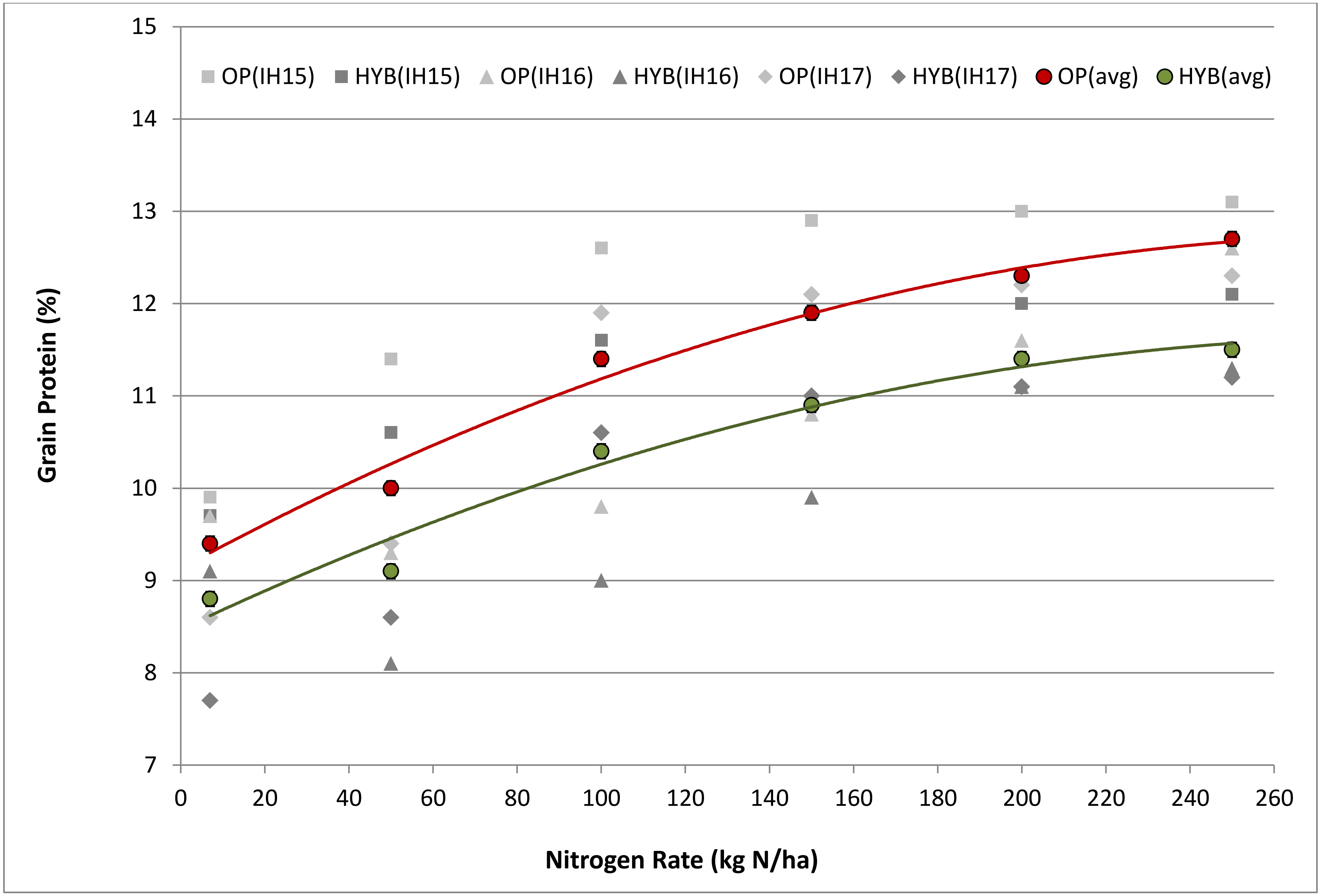

Figure 4. Nitrogen fertilizer rate effects on fall rye (hybrid versus open pollinated) grain protein over a three-year period at Indian Head (2015-17).

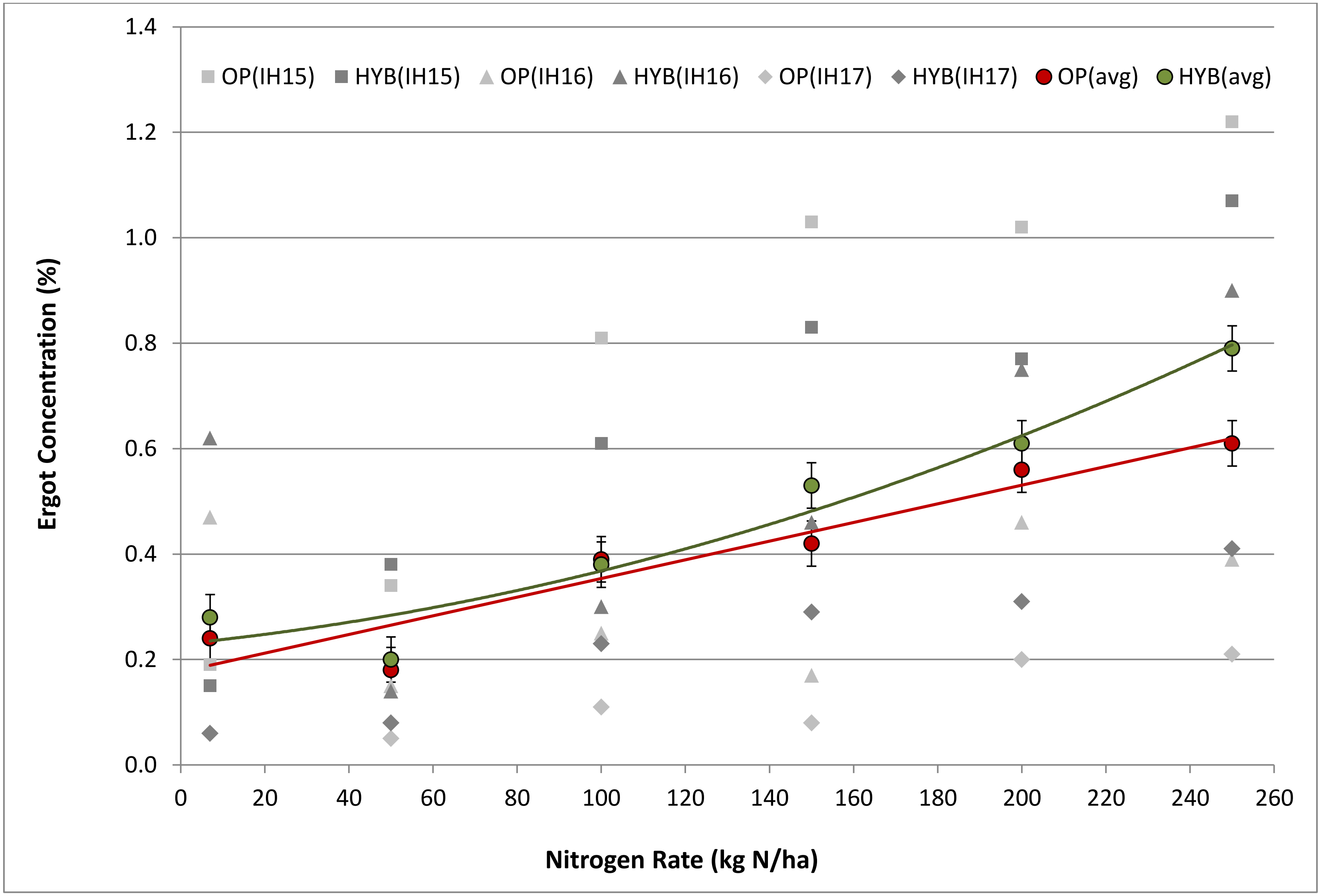

Figure 5. Nitrogen fertilizer rate effects on percent ergot in fall rye (hybrid versus open pollinated) over a three-year period at Indian Head (2015-17).

Extension Activities and Dissemination of Results

While this demonstration could not be shown at the 2015 Indian Head Crop Management Field Day for logistic reasons, the site was visited by numerous agronomists (i.e. Ducks Unlimited, Bayer CropScience), farmers and seed growers on several occasions throughout the growing season. In 2016, the demonstration was highlighted during the Indian Head 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 Indian Head 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 N fertilizer response of modern open-pollinated (Hazlet) versus hybrid (Brasetto) fall rye varieties over a three-year period (2015-17) at Indian Head, Saskatchewan. Overall, the OP rye was 12% taller than the hybrid and was also more susceptible to lodging at high N rates. Nitrogen effects on plant height were small and inconsistent but, specifically for the OP variety, lodging increased in a curvilinear manner with little impact at low N rates but increasing lodging as N rates were increased past 100 kg N/ha. For the hybrid, lodging was negligible regardless of N rate in all three years. Grain yields for the hybrid were 25-27% higher than the OP variety (across N rates); however, despite this yield difference, the N response curves were similar for the two varieties when averaged over the three-year period. Overall, the response to N fertilization was strong with maximum yields achieved at approximately 190 kg N/ha (based on the average response curves) and probable economic optimum rates between 100-150 kg N/ha depending on grain and fertilizer prices. The strongest N responses occurred in 2016 under the highest yielding conditions while the response was weakest in 2017, the driest of the three years. Protein concentrations were consistently higher for the OP variety (12.1% across years and N rates) than for the hybrid (11.3%) which was not necessarily unexpected considering the yield differences. While there was subtle variation from year to year, the N effect on protein was similar for the two varieties with protein increasing quadratically with N fertilizer rate. As typically seen with other crops, protein continued to increase at N rates beyond the point where yields had levelled off. Averaged across years, protein in the OP variety was higher than the hybrid at all individual N rates. For individual varieties each increase in N rate led to significantly higher protein concentrations with the exception of going from 200-250 kg N/ha for the hybrid. It should be noted, however, that there are no protein premiums for fall rye so there is no economic incentive to apply rates beyond those required to optimize yield. Ergot is often the most important grading factor in fall rye and was affected by year, variety and N rate. The variety effects were inconsistent in that ergot concentrations were higher with the OP variety in 2015 but the opposite occurred in 2016 and 2017. Percent ergot also increased with increasing N rate, most prominently in 2016 when overall pressure was highest but to some extent in each of the three years. All factors considered and with the exception of lodging, OP and hybrid rye varieties appeared to respond similarly to varying N fertilizer rates from a practical perspective. Despite the higher overall potential with the hybrid, yields for the two varieties were optimized at similar N rates and quality loss (i.e. higher ergot) occurred with both varieties when excessive N rates were applied. While these results do not necessarily suggest that different N rates should be applied for hybrid versus OP rye, they show that rye responds well to higher N fertilizer rates than have often been traditionally applied but, at the same time, too much N can potentially lead to quality loss such as higher ergot.

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 6. Treatment means for nitrogen fertilizer rate (by year and variety) effects on fall rye plant height at Indian Head over a three-year period. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

	2014-15			**2015-16**			**2016-17**			**Average (Y)**		
Nitrogen Rate	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)
	------ Height (cm) ------											
7 kg N/ha	98.7 a	82.0 a	90.3 a	103.4 b	93.5 b	98.4 b	66.2 ab	61.6 a	63.9 a	89.4 ab	79.0 a	84.2 ab
50 kg N/ha	95.2 b	79.8 ab	87.5 b	106.7 ab	97.7 a	102.2 a	68.6 a	62.4 a	65.5 a	90.1 a	80.0 a	85.1 a
100 kg N/ha	92.2 c	77.5 bc	84.8 c	108.3 a	98.2 a	103.3 a	65.8 b	62.3 a	64.1 a	88.7 ab	79.4 a	84.1 ab
150 kg N/ha	93.0 bc	78.2 bc	85.6 c	106.0 ab	98.9 a	102.4 a	65.7 b	63.4 a	64.5 a	88.2 bc	80.1 a	84.2 ab
200 kg N/ha	92.0 c	76.3 c	84.1 c	106.0 ab	98.5 a	102.2 a	66.4 ab	62.7 a	64.6 a	88.1 bc	79.1 a	83.6 bc
250 kg N/ha	88.3 d	76.0 c	82.1 d	105.9 ab	96.1 ab	101.0 a	66.7 ab	61.9 a	64.3 a	86.9 c	78.0 a	82.5 c
S.E.M	0.89		0.67	1.30		0.95	0.99		0.74	0.68		0.54
<u>Orthogonal Contrasts</u>	------ Pr > *F* ------											
NR – lin	< 0.001	< 0.001	< 0.001	0.379	0.081	0.126	0.599	0.659	0.126	< 0.001	0.161	< 0.001
NR – quad	0.316	0.124	0.079	0.020	0.020	< 0.001	0.640	0.225	0.586	0.482	0.029	0.042

Table 7. Treatment means for nitrogen fertilizer rate (by year and variety) effects on fall rye lodging at Indian Head over a three-year period. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, $P \leq 0.05$).

	2014-15			**2015-16**			**2016-17**			**Average (Y)**		
Nitrogen Rate	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)
	---------- Lodging (0-10) ----------											
7 kg N/ha	0.35 b	0.20 a	0.28 b	0.50 e	0.20 a	0.35 e	0.20 b	0.20 a	0.20 b	0.35 e	0.20 a	0.28 e
50 kg N/ha	0.40 a	0.20 a	0.30 a	0.60 e	0.23 a	0.41 e	0.20 b	0.20 a	0.20 b	0.40 e	0.21 a	0.30 e
100 kg N/ha	0.40 a	0.20 a	0.30 a	1.20 d	0.30 a	0.75 d	0.20 b	0.20 a	0.20 b	0.60 d	0.23 a	0.42 d
150 kg N/ha	0.40 a	0.20 a	0.30 a	2.18 c	0.40 a	1.29 c	0.50 a	0.20 a	0.35 a	1.03 c	0.27 a	0.65 c
200 kg N/ha	0.40 a	0.20 a	0.30 a	3.38 b	0.40 a	1.89 b	0.40 a	0.20 a	0.30 ab	1.39 b	0.27 a	0.83 b
250 kg N/ha	0.40 a	0.20 a	0.30 a	4.30 a	0.40 a	2.35 a	0.50 a	0.20 a	0.35 a	1.73 a	0.27 a	1.00 a
S.E.M	0.008		0.006	0.148		0.105	0.053		0.037	0.052		0.037
<u>Orthogonal Contrasts</u>	---------- Pr > *F* ----------											
NR – lin	0.001	1.000	0.015	< 0.001	0.198	< 0.001	< 0.001	1.000	< 0.001	< 0.001	0.220	< 0.001
NR – quad	0.003	1.000	0.026	< 0.001	0.726	0.006	0.971	1.000	0.980	0.000	0.740	0.013

Table 8. Treatment means for nitrogen fertilizer rate (by year and variety) effects on fall rye grain yield at Indian Head over a three-year period. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

	2014-15			**2015-16**			**2016-17**			**Average (Y)**		
Nitrogen Rate	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)
	---------- Grain Yield (kg/ha) ----------											
7 kg N/ha	2579 b	3143 b	2861 c	2621 e	3278 e	2950 f	1758 c	2228 b	1993 c	2320 d	2883 d	2601 d
50 kg N/ha	3315 a	3971 a	3643 ab	3953 d	5144 d	4549 e	2393 b	3110 a	2751 b	3220 c	4075 c	3648 c
100 kg N/ha	3239 a	4124 a	3681 ab	5019 c	6577 c	5798 d	2732 ab	3510 a	3121 ab	3663 b	4737 b	4200 b
150 kg N/ha	3306 a	4205 a	3756 a	5667 b	7298 b	6482 c	3295 a	3644 a	3470 a	4089 a	5049 a	4569 a
200 kg N/ha	3296 a	4118 a	3707 ab	6144 a	7449 b	6797 b	2770 ab	3472 a	3121 ab	4070 a	5013 a	4542 a
250 kg N/ha	3146 a	3951 a	3548 b	6225 a	7803 a	7014 a	2685 b	3593 a	3139 ab	4018 a	5116 a	4567 a
S.E.M	97.0		72.1	92.0		68.7	206.5		147.7	85.9		64.7
<u>Orthogonal Contrasts</u>	---------- Pr > *F* ----------											
NR – lin	0.004	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
NR – quad	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

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

	2014-15			**2015-16**			**2016-17**			**Average (Y)**		
Nitrogen Rate	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)
	---------- Protein (%) ----------											
7 kg N/ha	9.9 e	9.7 d	9.8 e	9.7 d	9.1 d	9.4 f	8.6 e	7.7 e	8.2 e	9.4 f	8.8 e	9.1 f
50 kg N/ha	11.4 d	10.6 c	11.0 d	9.3 e	8.1 e	8.7 e	9.4 d	8.6 d	9.0 d	10.0 e	9.1 d	9.6 e
100 kg N/ha	12.6 c	11.6 b	12.1 c	9.8 d	9.0 c	9.4 d	11.9 c	10.6 c	11.2 c	11.4 d	10.4 c	10.9 d
150 kg N/ha	12.9 b	11.9 a	12.4 b	10.8 c	9.9 b	10.4 c	12.1 b	11.0 b	11.5 b	11.9 c	10.9 b	11.4 c
200 kg N/ha	13.0 ab	12.0 a	12.5 ab	11.6 b	11.1 a	11.3 b	12.2 ab	11.1 ab	11.7 a	12.3 b	11.4 a	11.8 b
250 kg N/ha	13.1 a	12.1 a	12.6 a	12.6 a	11.3 a	11.9 a	12.3 a	11.2 a	11.7 a	12.7 a	11.5 a	12.1 a
S.E.M	0.11		0.09	0.16		0.12	0.08		0.07	0.08		0.07
Orthogonal Contrasts	---------- Pr > *F* ----------											
NR – lin	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
NR – quad	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 10. Treatment means for nitrogen fertilizer rate (by year and variety) effects on percent ergot in fall rye at Indian Head over a three-year period. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

	2014-15			**2015-16**			**2016-17**			**Average (Y)**		
Nitrogen Rate	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)
	------ Ergot (%) ------											
7 kg N/ha	0.19 c	0.15 d	0.17 d	0.47 a	0.62 bc	0.54 a	0.06 b	0.06 c	0.06 d	0.24 c	0.28 cd	0.26 e
50 kg N/ha	0.34 c	0.38 cd	0.36 d	0.15 c	0.14 e	0.14 c	0.05 b	0.08 c	0.06 d	0.18 c	0.20 d	0.19 e
100 kg N/ha	0.81 b	0.61 bc	0.71 c	0.25 bc	0.30 de	0.27 bc	0.11 ab	0.23 b	0.17 c	0.39 b	0.38 c	0.38 d
150 kg N/ha	1.03 ab	0.83 ab	0.93 b	0.17 c	0.46 cd	0.31 b	0.08 b	0.29 b	0.18 bc	0.42 b	0.53 b	0.47 c
200 kg N/ha	1.02 ab	0.77 b	0.90 bc	0.46 a	0.75 ab	0.61 a	0.20 a	0.31 ab	0.26 ab	0.56 a	0.61 b	0.59 b
250 kg N/ha	1.22 a	1.07 a	1.15 a	0.39 ab	0.90 a	0.65 a	0.21 a	0.41 a	0.31 a	0.61 a	0.79 a	0.70 a
S.E.M	0.100		0.071	0.071		0.050	0.039		0.027	0.043		0.030
<u>Orthogonal Contrasts</u>	------ Pr > *F* ------											
NR – lin	< 0.001	< 0.001	< 0.001	0.410	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
NR – quad	0.055	0.362	0.042	0.005	< 0.001	< 0.001	0.391	0.583	0.825	0.711	0.041	0.088

Table 11. Treatment means for nitrogen fertilizer 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.

	2014-15			**2015-16**			**2016-17**			**Average (Y)**		
Nitrogen Rate	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)	**OP** Hazlet)	**HYB** (Brasetto)	**Avg** (VAR)
	------------------- Falling Number (seconds) -------------------											
7 kg N/ha	126.5	261.0	193.8	274.0	317.0	295.5	252.0	334.3	293.2	217.5	304.1	260.8
50 kg N/ha	110.5	254.0	182.3	251.5	320.5	286.0	267.8	322.8	295.3	209.9	299.1	254.5
100 kg N/ha	120.5	247.0	183.8	181.0	322.0	251.5	229.3	289.3	259.3	176.9	286.1	231.5
150 kg N/ha	113.0	248.5	180.8	267.0	330.5	298.8	228.0	300.0	264.0	202.7	293.0	247.9
200 kg N/ha	109.0	219.5	164.3	225.0	301.5	263.3	237.8	293.0	265.4	190.6	271.3	231.0
250 kg N/ha	128.0	244.5	186.3	217.0	282.5	249.8	231.8	297.8	264.8	192.3	274.9	233.6

Figure A-1. Hazlet (OP) fall rye fertilized with 7 kg N ha^{-1} at Indian Head 2015 (July 30).

Figure A-2. Brasetto (HYB) fall rye fertilized with 7 kg N ha^{-1} at Indian Head 2015 (July 30).

Figure A-3. Hazlet (OP) fall rye fertilized with 250 kg N ha^{-1} at Indian Head 2015 (July 30).

Figure A-4. Brasetto (HYB) fall rye fertilized with 250 kg N ha^{-1} at Indian Head 2015 (July 30).

Figure A-5. Hazlet (OP) fall rye fertilized with 7 kg N ha^{-1} at Indian Head 2016 (July 29).

Figure A-6. Brasetto (HYB) fall rye fertilized with 7 kg N ha^{-1} at Indian Head 2016 (July 29).

Figure A-7. Hazlet (OP) fall rye fertilized with 250 kg N ha^{-1} at Indian Head 2016 (July 29).

Figure A-8. Brasetto (HYB) fall rye fertilized with 250 kg N ha^{-1} at Indian Head 2016 (July 29).

Figure A-9. Hazlet (OP) fall rye fertilized with 7 kg N ha^{-1} at Indian Head 2017 (August 1).

Figure A-10. Brasetto (HYB) fall rye fertilized with 7 kg N ha^{-1} at Indian Head 2017 (August 1).

Figure A-11. Hazlet (OP) fall rye fertilized with 250 kg N ha^{-1} at Indian Head 2017 (August 1).

Figure A-12. Brasetto (HYB) fall rye fertilized with 250 kg N ha^{-1} at Indian Head 2017 (August 1).

Abstract

14. Abstract/Summary:

Field trials were conducted over a three-year period near Indian Head, Saskatchewan to demonstrate the yield potential and nitrogen response of open-pollinated versus hybrid fall rye. The open-pollinated variety (Hazlet) was 23% taller than the hybrid (Brasetto). Lodging became increasingly severe with the OP variety when N rates were increased past 100 kg N/ha but there was no lodging with the hybrid regardless of N rate. While the hybrid yielded 25-27% higher than Hazlet, the overall yield response to N was similar with both varieties reaching their maximum potential yields at approximately 190 kg N/ha. Nitrogen rate effects on protein were similar between the two varieties and related to the yield responses; however, protein always peaked at much higher rates than grain yield. While protein is not a grading factor for rye, ergot is important and concentrations generally increased with nitrogen, especially when rates were increased beyond the optimal rates for maximizing yield. Variety effects on ergot were significant but inconsistent with less ergot in the hybrid relative to the OP variety in 2015 but more in 2016 and 2017. Overall results to date suggest that N can be managed similarly for hybrid versus OP fall rye, despite the higher yield potential of the hybrids; however, rye in generally responded to higher N rates than are often traditionally applied for this crop.
