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for the

Agricultural Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Options for Improved Winter Wheat Establishment and Disease Management

(Project #20150324)

Principal Applicant: Chris Holzapfel, MSc, PAg

Indian Head Agricultural Research Foundation, Box 156, Indian Head, SK, S0G 2K0

Correspondence: cholzapfel@iharf.ca

Project Identification

1. **Project Title:** Options for improved winter wheat establishment and disease management
2. **Project Number:** 20150324
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-2014 to Nov-2016
6. **Project contact person & contact details:**

Chris Holzapfel, Research Manager

Indian Head Agricultural Research Foundation

P.O. Box 156, Indian Head, SK, S0G 2K0

Phone: 306-695-4200

Email: cholzapfel@iharf.ca

Objectives and Rationale

7. **Project objectives:**

The objectives of this project were to demonstrate the use of seed treatments, higher seeding rates, and foliar fungicide applications to improve winter wheat establishment, yield, and quality.

8. **Project Rationale:**

One of the greatest challenges for winter wheat growers in Saskatchewan is successful establishment and overwintering of the crop. Common problems encountered include narrow windows for planting, dry or cool soils in the fall and winterkill, particularly when snow cover is limited. One obvious but effective method of improving winter wheat establishment is to use higher seeding rates; however the benefits to increasing seeding rates need to be weighed against higher seed costs and logistic implications (i.e. fewer acres per fill). Recent research in western Canada showed that seed treatments can also be effective for improving plant stands, winter survival and yield. This positive effect was mostly prominent at sub-optimal seeding rates (<300 seeds/m^2). Regarding disease, winter wheat is susceptible to both leaf spot diseases and fusarium head blight when conditions for disease are favourable and foliar fungicides are often economical under such circumstances. This project was conducted to demonstrate the relative contributions of these individual crop inputs to successful winter wheat establishment along with maintaining high yield potential and grain quality.

Methodology and Results

9. **Methodology:**

Field demonstrations were first established at Indian Head (Saskatchewan) in the fall of 2013 and continued for three growing seasons which will often be referred to simply as 2014, 2015 and 2016. The treatments were arranged in split plot design with foliar fungicide treatment as the main plot and seeding rates / seed treatments as the sub-plots. All treatments were replicated four times and included the following:

1. 200 seeds m^2 / Untreated Seed / No Fungicide
2. 300 seeds m^2 / Untreated Seed / No Fungicide
3. 400 seeds m^2 / Untreated Seed / No Fungicide
4. 200 seeds m^2 / Treated Seed / No Fungicide
5. 300 seeds m^2 / Treated Seed / No Fungicide

6. 400 seeds m^2 / Treated Seed / No Fungicide
7. 200 seeds m^2 / Untreated Seed / Fungicide Applied
8. 300 seeds m^2 / Untreated Seed / Fungicide Applied
9. 400 seeds m^2 / Untreated Seed / Fungicide Applied
10. 200 seeds m^2 / Treated Seed / Fungicide Applied
11. 300 seeds m^2 / Treated Seed / Fungicide Applied
12. 400 seeds m^2 / Treated Seed / Fungicide Applied

Pertinent agronomic information is provided in Table 1. Winter wheat in all years was direct-seeded into canola stubble in late September with all fertilizer either seed-placed or side-banded at planting. Weeds were controlled using registered herbicide applications and fungicides were applied as per protocol. Pre-harvest glyphosate was applied at physiological maturity and the plots were straight-combined as soon as it was fit to do so. Normalized difference vegetation index (NDVI) was measured using a handheld GreenSeeker during stem elongation (prior to flag leaf emergence). NDVI can be utilized as an indirect measure of crop vigour, canopy density and overall above-ground biomass. Yields were determined from the harvested grain samples which were corrected for dockage and to 14.5% seed moisture content. Dockage and test weights were determined using standardized CGC methodology and test weights are expressed as g 0.5 L^{-1}. Seed size was determined by mechanically counting and weighing a minimum of 500 seeds and calculating g 1000 $seeds^{-1}$ (TKW). Weather data were estimated from either Environment Canada or private weather stations which were always within 6 km from the trial sites.

Table 1. Selected agronomic information for winter wheat fungicide and seed treatment demonstrations over a three-year period at Indian Head.

Factor / Field Operation	Indian Head 2013-14	Indian Head 2014-15	Indian Head 2015-16
Previous Crop	Canola (LL)	Canola (LL)	Canola (LL)
Pre-emergent herbicide	890 g glyphosate/ha + 5 g florasolam/ha (28-Sep)	890 g glyphosate/ha + 5 g florasolam/ha (21-Sep)	890 g glyphosate/ha + 5 g florasolam/ha (24-Sep)
Cultivar	Moats	Moats	Moats
Seed Treatment [Z]	Raxil Pro	Raxil Pro-Shield	Raxil Pro
Seeding Date	23-Sep	22-Sep	21-Sep
Row spacing	30 cm	30 cm	30 cm
kg N-P_2O_5-K_2O-S/ha	115-35-48-16	115-30-48-16	115-30-0-15
In-crop herbicide 1	280 g bromoxynil/ha + 280 g MCPA ester/ha (8-Jun)	140 g fluroxypyr/ha + 99 g clopyralid/ha + 560 g MCPA ester/ha (25-May)	280 g bromoxynil/ha + 280 g MCPA ester/ha (22-Jun)
In-crop herbicide 2	15 g pyroxsulam/ha (8-Jun)	15 g pyroxsulam/ha (25-May)	15 g pyroxsulam/ha (22-May)
Flag-leaf fungicide	64 g pyraclostrobin + 49 g metconazole/ha (24-Jun)	64 g pyraclostrobin + 49 g metconazole/ha (10-Jun)	64 g pyraclostrobin + 49 g metconazole/ha (6-Jun)
Anthesis fungicide	100 g prothioconazole/ha + 100 g tebuconazole/ha (11-Jul)	100 g prothioconazole/ha + 100 g tebuconazole/ha (25-Jun)	100 g prothioconazole/ha + 100 g tebuconazole/ha (21-Jun)
Pre-harvest herbicide	890 g glyphosate/ha (20-Aug)	890 g glyphosate/ha (8-Aug)	890 g glyphosate/ha (29-Jul)
Harvest date	29-Aug	13-Aug	7-Aug

10. Results:

Growing season weather

Mean monthly temperatures and precipitation amounts (2014-16) along with the long-term averages for Indian Head are presented in Table 2. In 2013-14 at Indian Head, the winter wheat was well established in the fall and, while May and July were dry, June was much wetter than normal and moisture was not considered limiting at any point during the season. In 2014-15 at Indian Head, while moisture conditions were excellent in the fall and the winter wheat got off to a strong start, the spring was extremely dry with no significant precipitation until late June at which point the winter wheat was heading out and yields had already been limited. In 2015-16, the winter wheat was established well in the fall with essentially no mortality observed after a mild winter with very little snowfall. Early spring was drier than average but initial soil moisture was adequate and moisture was never limiting from late May onwards. Above average temperatures combined with high soil moisture and humidity resulted in relatively heavy disease pressure in 2015-16.

Table 2. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2014-15 growing seasons at Indian Head, SK.

Year	May	June	July	August	Avg. / Total
	---------- Mean Temperature (°C) ----------				
2016	14.0	17.5	18.5	17.2	16.8
2015	10.3	16.2	18.1	17.0	15.4
2014	10.2	14.4	17.3	17.4	14.8
Long-term	10.8	15.8	18.2	17.4	15.6
	---------- Precipitation (mm) ----------				
2016	72.6	63	112.8	29.8	278
2015	15.6	38.3	94.6	58.8	192
2014	36.0	199.2	7.8	142.2	385
Long-term	51.8	77.4	63.8	51.2	244

Effects on Crop Establishment

Overall tests of fixed effects for NDVI are presented in Table 3. These tests are used to determine whether a factor or interaction between factors affected specific response variable. Values ≤ 0.05 are considered significant and indicate 95% confidence that the treatment being tested had an effect on the corresponding response variable as opposed to any observed differences being due to random, naturally occurring variation.

Both higher seeding rates and seed treatment increased NDVI in 2014 and 2016; however, no treatments affected NDVI in 2015 (Tables 3 and 4). In 2014 at Indian Head, NDVI increased when the seeding rate was increased from 200 to 300 seeds m^{-2} but not from 300 to 400 seeds m^{-2}. NDVI in 2016 increased each time the seeding rate was increased; however, the greatest increase occurred when increasing the seeding rate from 200 to 300 seeds m^{-2}. The use of a seed treatment increased NDVI by 6 and 7% in 2014 and 2016, thereby suggesting that seed treatments had a positive impact on early-season vegetative growth in those years.

Table 3. Effects of fungicide, seed treatment, seeding rate and their interactions on winter wheat NDVI at Indian Head (2014-16). P-values of ≤ 0.05 indicate that an effect was significant and observed differences were not due to random or naturally occurring variability.

Variable	Fungicide (F)	Seed Trt (T)	Seeding Rate (R)	F x T	F x R	T x R	F x T x R
	---------- Pr. > *F* ----------						
IH-2014	0.842	**0.006**	**<0.001**	0.621	0.680	0.906	0.373
IH-2015	0.110	0.325	0.494	0.528	0.180	0.511	0.096
IH-2016	0.758	**0.003**	<**0.001**	0.325	0.947	0.805	0.989

Table 4. Main effect (seeding rate, seed treatment and fungicide) means for winter wheat NDVI. Data were analyzed separately for each year and main effect means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test; $P \leq 0.05$).

Main Effect	IH-2014	IH-2015	IH-2016
Fungicide			
1) Untreated	0.372 a	0.419 a	0.384 a
2) Treated	0.367 a	0.399 a	0.378 a
S.E.M.	0.020	0.007	0.012
Seed Treatment			
1) Untreated	0.358 b	0.411 a	0.368 b
2) Treated	0.380 a	0.406 a	0.394 a
S.E.M.	0.016	0.005	0.010
Seeding Rate			
1) 200 seeds m^{-2}	0.328 b	0.405 a	0.320 c
2) 300 seeds m^{-2}	0.392 a	0.413 a	0.394 b
3) 400 seeds m^{-2}	0.388 a	0.405 a	0.429 a
S.E.M.	0.017	0.006	0.010

Effects on Grain Yield

Tests of seeding rate, seed treatment and fungicide effects on winter wheat yield along with the main effects means are presented in Tables 5 and 6. Yields were affected by both fungicide (P < 0.001-0.014) and seeding rate (P = <.0001-0.017) in all three years and seed treatment in 2014 and 2015 only (P = 0.044-0.038) but not 2016 (P = 0.135). There were, however, significant interactions between fungicide and seed treatment detected in 2016 (P = 0.045) and between all three main effects in 2015 (P = 0.020).

Table 5. Effects of fungicide, seed treatment, seeding rate and their interactions on winter wheat grain yield at Indian Head (2014-16). P-values of ≤ 0.05 indicate that an effect was significant and observed differences were not due to random or naturally occurring variability.

Variable	Fungicide (F)	Seed Trt. (T)	Seeding Rate (R)	F x T	F x R	T x R	F x T x R
	------------------------	------------	------------	Pr. > *F*	------------	------------	------------------------
IH-2014	**0.014**	**0.044**	**0.017**	0.968	0.951	0.815	0.282
IH-2015	**0.001**	**0.038**	**0.009**	0.775	0.998	0.221	**0.020**
IH-2016	**0.001**	0.135	**<.0001**	**0.045**	0.490	0.930	0.151

Foliar fungicides increased winter wheat yield in each of the three years; however, the extent of the increases ranged from only 5% in 2015 to as high as 16% in 2016 (Table 6). Seed treatments resulted in higher winter wheat yield in 2014 and 2015 but not (when averaged across seeding rates and fungicide treatments) in 2016. The magnitude of the observed yield gains with seed treatments was generally small ranging from 2-3%. Doubling the seeding rate from 200 to 400 seeds m^{-2} increased yields by 2-

4% in 2014 and 2016; however, in 2015, yields at 200 seeds m^{-2} were 5% higher than those at the higher rates under the unusual environmental conditions that year. While early 2015 was dry, moisture conditions dramatically improved from late June onwards and, in general, later seeded or maturing crops had an advantage at this site. Winter wheat seeded at the 200 seeds m^{-2} rate always matured noticeably later than at the heavier rates; however, it was difficult to visibly distinguish between the 300-400 seeds m^{-2} rates. In 2015, the 3-way (F × T × R) was due to inconsistencies in the seed treatment response amongst some of the individual fungicide / seeding rate combinations (Table A-2). Focussing on the F × T interaction in 2016, seed treatments improved winter yield by 3% in the absence of foliar fungicide but did not affect yield when fungicides were applied (Table 7).

Table 6. Main effect (seeding rate, seed treatment and fungicide) means for winter wheat grain yield. Data were analyzed separately for each site and main effect means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test; $P \leq 0.05$).

Main Effect	IH-2014	IH-2015	IH-2016
Fungicide			
1) Untreated	4654 b	3336 b	4846 b
2) Treated	5346 a	3507 a	5793 a
S.E.M.	142.9	54.4	79.3
Seed Treatment			
1) Untreated	4947 b	3369 b	5293 a
2) Treated	5053 a	3473 a	5346 a
S.E.M.	104.1	54.4	75.3
Seeding Rate			
1) 200 seeds m^{-2}	4898 b	3530 a	5193 b
2) 300 seeds m^{-2}	5086 a	3390 b	5357 a
3) 400 seeds m^{-2}	5015 ab	3343 b	5409 a
S.E.M.	107.1	59.5	77.3

Table 7. Mean winter wheat grain yields for the observed fungicide × seed treatment (F × T) interaction at Indian Head in 2016. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test; $P \leq 0.05$).

Foliar Fungicide	Seed Treatment	Grain Yield
no	no	4784 c
no	yes	4909 b
yes	no	5804 a
yes	yes	5784 a
S.E.M.	S.E.M.	83.0

Effects on Test Weight & Seed Size

Tests of treatment effects and main effect means for test weight are presented in Tables 8 and 9 while those for TKW are in Tables 10 and 11. Winter wheat test weight was affected by foliar fungicide each year (P < 0.001-0.007), by seed treatment in 2015 (P < 0.001), and by seeding rate in 2015 and 2016 (P < 0.001-0.012). The effect of foliar fungicides on test weight was small but always positive with increases ranging from 0.8% in 2015 to 2.8% in 2016. In 2015 when test weights were significantly higher with seed treatments, the increase was 0.6%. Higher seeding rates had a positive effect on test weight in 2014 and 2016 (0.4-0.5%) and a slight negative effect (- 0.4%) in 2015. There were no interactions between factors detected for test weight in any years.

Table 8. Effects of fungicide, seed treatment, seeding rate and their interactions on winter wheat test weight. P-values of ≤ 0.05 indicate that an effect was significant and observed differences were not due to random or naturally occurring variability.

Variable	Fungicide (F)	Seed Trt (T)	Seeding Rate (R)	F x T	F x R	T x R	F x T x R
	---------- Pr. > *F* ----------						
IH-2014	**0.007**	0.674	0.053	0.836	0.137	0.758	0.817
IH-2015	**0.002**	**<0.001**	**<0.001**	0.920	0.796	0.260	0.207
IH-2016	**0.001**	0.236	**0.012**	0.386	0.388	0.967	0.802

Table 9. Main effect (seeding rate, seed treatment and fungicide) means for winter wheat test weight. Data were analyzed separately for each site and main effect means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test; *P* ≤ 0.05).

Main Effect	IH-2014	IH-2015	IH-2016
Fungicide			
1) Untreated	392.2 b	396.4 b	385.3 b
2) Treated	399.3 a	399.4 a	396.1 a
S.E.	1.21	0.22	0.81
Seed Treatment			
1) Untreated	395.6 a	396.8 b	390.4 a
2) Treated	395.9 a	399.1 a	391.0 a
S.E.	1.12	0.21	0.74
Seeding Rate			
1) 200 seeds m^{-2}	394.6 b	398.9 a	389.6 b
2) 300 seeds m^{-2}	396.2 a	397.4 b	391.2 a
3) 400 seeds m^{-2}	396.4 a	397.4 b	391.2 a
S.E.	1.16	2.43	0.78

Thousand kernel weights were affected by fungicide in all three years and seed treatment in one year (Table 10). Foliar fungicides consistently increased TKW with the change ranging from 2.2% in 2015 to

11.4% in 2016 and by 7.7% when averaged across all three years. The only year where seed treatments affected TKW was in 2015 where their use resulted in a 2.8% increase. Again, seeding rate did not significantly affect TKW in any year; however, an interaction between fungicide and seeding rate was detected in 2014 (*P* = 0.023). The interaction was due to a decline in TKW with increasing seeding rates in the absence of fungicides but not on the sprayed plots. This may have been due to higher disease with the denser crop canopies which was alleviated with foliar fungicide applications.

Table 10. Effects of fungicide, seed treatment, seeding rate and their interactions on winter wheat seed size (thousand kernel weight). P-values of ≤ 0.05 indicate that an effect was significant and observed differences were not due to random or naturally occurring variability.

Variable	Fungicide (F)	Seed Trt. (T)	Seeding Rate (R)	F x T	F x R	T x R	F x T x R
	---------- Pr. > *F* ----------						
IH-2014	**0.002**	0.644	0.708	0.741	**0.023**	0.783	0.100
IH-2015	**0.023**	**0.003**	0.769	0.384	0.791	0.408	0.517
IH-2016	**0.001**	0.777	0.493	0.192	0.440	0.348	0.537

Table 11. Main effect (seeding rate, seed treatment and fungicide) means for winter wheat seed size (thousand kernel weight). Data were analyzed separately for each site and main effect means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test; *P* ≤ 0.05).

Main Effect	IH-2014	IH-2015	IH-2016
Fungicide			
1) Untreated	31.2 b	31.4 b	29.5 b
2) Treated	34.5 a	32.1 a	33.3 a
S.E.	0.25	0.20	0.36
Seed Treatment			
1) Untreated	32.8 a	31.3 b	31.4 a
2) Treated	32.9 a	32.2 a	31.3 a
S.E.	0.23	0.20	0.30
Seeding Rate			
1) 200 seeds m^{-2}	33.0 a	31.9 a	31.6 a
2) 300 seeds m^{-2}	32.8 a	31.6 a	31.3 a
3) 400 seeds m^{-2}	32.8 a	31.9 a	31.2 a
S.E.	0.26	0.25	0.33

Table 12. Mean winter wheat thousand kernel weights for the observed fungicide × seeding rate (F × R) interaction at Indian Head in 2014. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test; $P \leq 0.05$).

Foliar Fungicide	Seeding Rate	g/1000 seeds
no	200 seeds/m^2	31.9 b
no	300 seeds/m^2	31.1 bc
no	400 seeds/m^2	30.8 c
yes	200 seeds/m^2	34.2 a
yes	300 seeds/m^2	34.6 a
yes	400 seeds/m^2	34.9 a
S.E.M.	S.E.M.	0.36

Extension and Acknowledgement

At Indian Head, this demonstration was a formal stop at the Crop Management Field Day on July 22, 2014. Agronomists from IHARF and Ducks Unlimited led a discussion of the opportunities and challenges associated with winter wheat production and discussed best management practices for this crop, particularly with regard to establishment and disease management. The tour was attended by over 200 registered guests and signs were in place to acknowledge the support of the Agricultural Demonstrations of Technologies and Practices (ADOPT) program. The field trials were not a formal stop at the Crop Management Field Day in 2015 but were visited by industry agronomists and producers on several occasions throughout the season. This demonstration was again part of the Crop Management Field Day in 2016 (July 19, 219 registered guests) where Chris Holzapfel (IHARF) and Dr. Brian Beres (AAFC-Lethbridge) led a discussion on winter wheat agronomy with a focus on N management, seed treatments, seeding rates and disease management. The trial was also shown and discussed by Chris Holzapfel on a tour co-hosted with Arysta Lifesciences (July 26, 2016, 45 guests). In addition to these more formal tours, the site was visited by numerous growers, agronomists and researchers over the season. In 2015, results to date were presented to approximately 200 registered guests at the IHARF Soil and Crop Management Seminar / AGM on February 4 at White City, SK and will also be presented at the Agri-ARM Research Update on January 12, 2017 as part of Crop Production Week. A summary of this work will be included in the 2016 IHARF Annual Report which, in addition to the full report, will be available online. Results will also be made available 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 demonstrated the merits of higher seeding rates and seed treatments for improving stand establishment and foliar fungicide applications for minimizing disease impacts on winter wheat yield and quality. Field trials were conducted near Indian Head, Saskatchewan for three consecutive growing seasons (2013-14, 2014-15, and 2015-16). While results were presented and discussed for individual years in the preceding text, the data were also combined across years and analyzed together in a single analyses (Tables 13 and 14).

Table 13. Effects of fungicide, seed treatment, seeding rate and their interactions on winter wheat NDVI, yield, test weight and thousand kernel weight (3 year average – site considered random). P-values of ≤ 0.05 indicate that an effect was significant and observed differences were not due to random or naturally occurring variability.

Variable	NDVI	Grain Yield	Test Weight	1000 Kernel Weight
	------------	------------ Pr. > *F*	------------	------------
Fungicide (F)	0.519	**<0.001**	**<0.001**	**<0. 001**
Seed Trt (T)	**0.001**	**0.004**	**<0.001**	0.061
Seed Rate (R)	**<0.001**	0.154	0.165	0.391
F × T	0.595	0.533	0.771	0.137
F × R	0.721	0.936	0.444	0.120
T × R	0.920	0.391	0.670	0.584
F × T × R	0.889	0.631	0.831	0.317

Focusing on establishment, increasing seeding rates is a reliable method of enhancing plant winter wheat stands; however, the additional seed costs must be weighed against the potential agronomic gains. Higher seeding rates increased early-season NDVI in 2/3 years and when averaged across years, suggesting earlier canopy closure which can be important for field uniformity and weed competition. In this demonstration, 200 seeds m^{-2} rates were not sufficient to optimize yield in 2/3 years; however, due to the unusual weather conditions in 2015, yields were significantly higher at 200 seeds m^{-2} than at the higher rates. Consequently, yields were similar for all seeding rates when averaged across site-years (Tables 13 and 14). While there were never any benefits to increasing seeding rates beyond 300 seeds m^{-2} in the current project, emergence was always excellent and winter kill was minimal – higher seeding rates (i.e. 400+ seeds m^{-2}) can provide a buffer under such circumstances and improve winter wheat yield stability over the long-term. Seeding rate did not affect thousand kernel weights in any years; however, test weight was always affected in a similar manner as grain yield (i.e. increased with seeding rate in 2014 and 2016 but decreased in 2015). Due to the inconsistent results; test weight was similar across seeding rates when averaged over the 3-year period.

Seed treatments are a reasonably low cost tool that can provide protection against seed decay/seedling diseases and can help winter wheat cope with early season stresses thereby increasing the probability of overwintering successfully. Seed treatments can be particularly important if using seed with poor vigour or high levels of disease. The response to seed treatments in these trials was small but relatively consistent. Early season NDVI was higher with seed treatments in both 2014 and 2016 which indicated improved establishment and/or more vigorous early season growth. Averaged across years, using treated seed increased NDVI by 5%, from 0.377 to 0.395. While not part of the current project, seed-applied fungicides resulted in approximately 2x the number of established plants in 2012-13 when winter wheat was planted into extremely dry soils and emergence did not occur until spring. Mean yields were increased by 2% in 2013-14, by 3% in 2014-15 and by 3% in 2015-16 when foliar fungicides were not applied (but not when foliar fungicides were applied). This resulted in a significant overall yield increase of 2.2%, or 100 kg ha^{-1} (1.5 bus ac^{-1}) when averaged over the three years. In the similar demonstration conducted in 2012-13, seed-applied fungicide resulted in an 859 kg ha^{-1} (13 bus ac^{-1}) or 16% yield increase. Seed treatment effects on seed quality were occasionally observed with significant increases in both test weight and thousand kernel weights in 2015 and a small but significant increase in test weight when averaged over all three years.

Table 14. Main effect (seeding rate, seed treatment and fungicide) means for winter wheat NDVI, yield, test weight and thousand kernel weight (3 year average). Main effect means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test; *P* ≤ 0.05).

Main Effect	NDVI (0-1)	Grain Yield (kg/ha)	Test Weight (g/0.5 l)	Seed Size (g/1000 seeds)
Fungicide				
3) Untreated	0.390 a	4279 b	391.3 b	30.7 b
4) Treated	0.383 a	4882 a	398.3 a	33.3 a
S.E.	0.0128	589.3	2.19	0.49
Seed Treatment				
3) Untreated	0.377 b	4524 b	394.3 b	31.9 a
4) Treated	0.395 a	4624 a	395.3 a	32.2 a
S.E.	0.0120	587.2	2.15	0.46
Seeding Rate				
4) 200 seeds m^{-2}	0.351 b	4541 a	394.4 a	32.2 a
5) 300 seeds m^{-2}	0.399 a	4611 a	394.9 a	31.9 a
6) 400 seeds m^{-2}	0.408 a	4589 a	395.0 a	32.0 a
S.E.	0.0123	587.4	2.15	0.46

Winter wheat in southeast Saskatchewan is commonly affected by both leaf spot diseases and fusarium head blight; therefore, once the crop is established, foliar fungicides are often required to achieve top winter wheat yields. Previous field trials evaluated flag-leaf versus anthesis applications and found that a single application at heading frequently provided adequate protection against leaf disease while also suppressing FHB; however, dual applications can be beneficial when disease pressure early in the season is high. In the current demonstration, plots that were treated with fungicide were spayed at both crop stages and, of the inputs evaluated, foliar fungicides provided the most consistent and greatest benefits with yield increases ranging from 5% in 2015 to 20% in 2016. Averaged over the three-year period, fungicide applications increased winter wheat yields by 14% or 603 kg ha^{-1} (8.9 bus ac^{-1}). Fungicide application increased test weight by 0.8% (2015) to 2.8% (2016) and by 1.8% when averaged over the three years. Similarly, fungicide also increased thousand seed weight each year with the magnitude ranging from 2.2% (2015) to 12.9% (2016) and averaging 8.5% over the three years.

Overall, seeding rates, seed treatments and foliar fungicides contributed to winter wheat establishment and yield/quality maintenance. Adequate seeding rates improve overall stand establishment and can buffer against winter kill and/or variable establishment. Minimum rates of 300 seeds m^{-2} are recommended and previous research suggests that rates as high as 400-450 seeds m^{-2} may be justified to enhance yield stability under varying environmental conditions. Winter cereals also respond relatively consistently to seed treatments, likely a result of the more stressful early season conditions compared to spring seeded crops under typical conditions. While the yield benefits associated with seed treatments in the current project were small, they were relatively consistent and preceding work showed dramatic improvements in stand establishment and yield under harsher conditions. Foliar fungicide applications do not impact winter wheat establishment or build yield potential; however, they were critical for maintaining that potential and minimizing disease induced yield or quality loss.

Supporting Information

12. Acknowledgements:

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13. Appendices

Table A-1. Least squares means for fungicide, seed treatment and seeding rate effects (individual treatments) on the NDVI of winter wheat. Data were analyzed separately for each site and values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, $P \leq 0.05$).

Foliar Fungicide	Seed Treatment	Seeding Rate	IH-2014	IH-2015	IH-2016
		seeds/m^2			
no	no	200	0.308 fh	0.414 ab	0.311 f
no	no	300	0.388 abcd	0.406 abc	0.384 bcd
no	no	400	0.375 abcd	0.423 ab	0.428 a
no	yes	200	0.333 efg	0.417 ab	0.331 ef
no	yes	300	0.396 abcd	0.427 a	0.409 abc
no	yes	400	0.398 abcd	0.426 a	0.438 a
yes	no	200	0.328 dgh	0.396 abc	0.302 f
yes	no	300	0.368 bcef	0.417 ab	0.370 cde
yes	no	400	0.380 abce	0.380 c	0.410 abc
yes	yes	200	0.343 cdfg	0.393 bc	0.336 def
yes	yes	300	0.415 a	0.401 abc	0.411 ab
yes	yes	400	0.398 abe	0.405 abc	0.439 a
S.E.	–	–	0.023	0.011	0.018

Table A-2. Least squares means for fungicide, seed treatment and seeding rate effects (individual treatments) on grain yield of winter wheat. Data were analyzed separately for each site and values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

Foliar Fungicide	Seed Treatment	Seeding Rate	IH-2014	IH-2015	IH-2016
		seeds/m^2			
no	no	200	4444 e	3459 b	4657 d
no	no	300	4742 cd	3145 c	4870 c
no	no	400	4618 de	3268 bc	4824 cd
no	yes	200	4654 de	3430 b	4834 c
no	yes	300	4721 cd	3469 b	4898 c
no	yes	400	4741 cd	3243 bc	4996 c
yes	no	200	5203 bc	3437 b	5661 b
yes	no	300	5333 ab	3471 b	5792 ab
yes	no	400	5340 ab	3435 b	5958 a
yes	yes	200	5291 b	3795 a	5623 b
yes	yes	300	5548 a	3477 b	5868 a
yes	yes	400	5361 ab	3425 b	5861 a
S.E.	–	–	163.6	93.9	96.3

Table A-3. Least squares means for fungicide, seed treatment and seeding rate effects (individual treatments) on test weight of winter wheat. Data were analyzed separately for each site and values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, $P \leq 0.05$).

Foliar Fungicide	Seed Treatment	Seeding Rate	IH-2014	IH-2015	IH-2016
		seeds/m^2			
no	no	200	390.7 b	396.3 f	384.3 c
no	no	300	391.9 b	394.5 g	385.2 c
no	no	400	393.7 b	395.0 g	384.8 c
no	yes	200	391.1 b	398.3 cd	385.0 c
no	yes	300	392.0 b	397.5 def	385.9 c
no	yes	400	393.6 b	396.8 ef	386.3 c
yes	no	200	398.4 a	398.9 bc	394.6 b
yes	no	300	399.7 a	397.8 cde	396.6 ab
yes	no	400	399.3 a	398.2 cd	397.0 a
yes	yes	200	398.4 a	402.1 a	394.6 b
yes	yes	300	401.3 a	399.9 b	397.2 a
yes	yes	400	398.9 a	399.8 b	396.8 ab
S.E.	–	–	1.55	0.45	1.11

Table A-4. Least squares means for fungicide, seed treatment and seeding rate effects (individual treatments) on thousand kernel weight of winter wheat. Data were analyzed separately for each site and values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, $P \leq 0.05$).

Foliar Fungicide	Seed Treatment	Seeding Rate	IH-2014	IH-2015	IH-2016
		seeds/m^2			
no	no	200	31.7 bc	31.1 bc	29.9 c
no	no	300	31.4 bcd	30.7 c	28.8 c
no	no	400	30.4 d	30.8 c	29.3 c
no	yes	200	32.1 b	32.1 abc	30.0 c
no	yes	300	30.8 cd	32.0 abc	29.4 c
no	yes	400	31.2 bcd	32.0 abc	29.9 c
yes	no	200	34.0 a	31.9 abc	34.1 a
yes	no	300	34.3 a	31.1 bc	33.6 ab
yes	no	400	35.3 a	32.4 ab	32.8 ab
yes	yes	200	34.4 a	32.3 ab	32.6 b
yes	yes	300	34.8 a	32.7 a	33.3 ab
yes	yes	400	34.5 a	32.3 ab	33.2 ab
S.E.	–	–	0.47	0.49	0.60

Figure A-1. Winter wheat from Indian Head in 2014. No fungicide on left and fungicide (flag plus anthesis) applied on right (300 treated seeds/m^2 in both cases).

Figure A-2. Winter wheat from Indian Head in 2015. No fungicide on left and fungicide (flag plus anthesis) applied on right (300 treated seeds/m^2 in both cases).

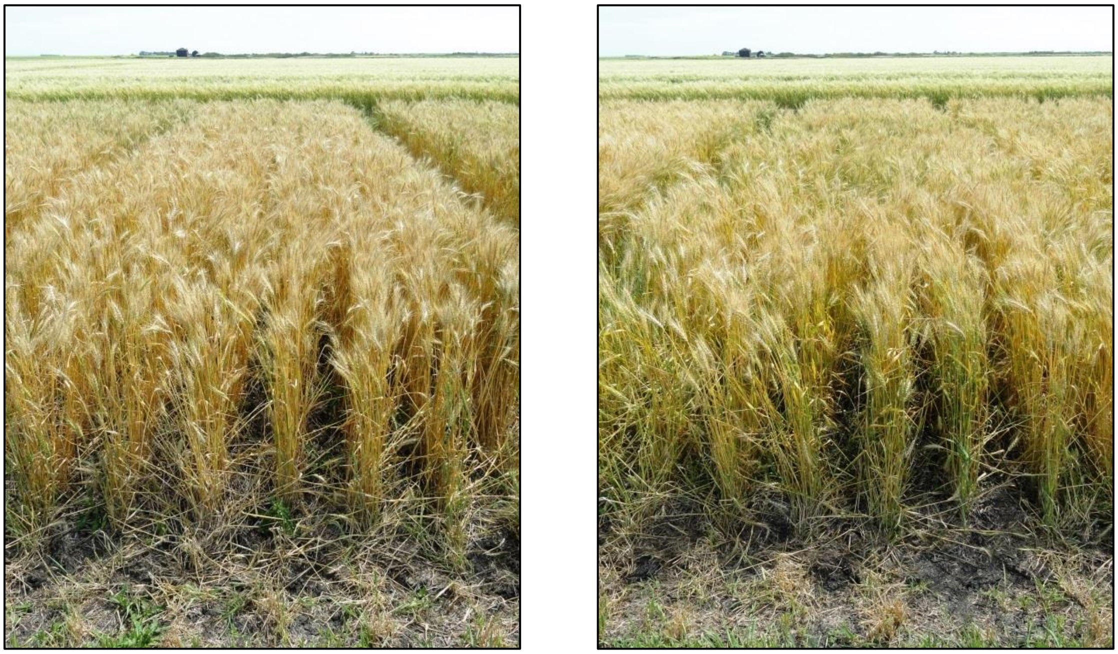

Figure A-3. Winter wheat from Indian Head in 2016. No fungicide on left and fungicide (flag plus anthesis) applied on right (300 treated seeds/m^2 in both cases).

Abstract

14. Abstract/Summary:

Winter wheat trials were conducted over three growing seasons (2014-2016) at Indian Head to demonstrate the relative contributions of seeding rates, seed treatment and foliar fungicides on winter wheat establishment, yield and quality. With the range of seeding rates tested and under the conditions encountered, seeding rate effects were relatively small; however, 200 seeds m^{-2} was normally insufficient to maximize yields. The exception was in 2015 where, with a dry spring but wetter summer, lower seeding rates delayed maturity and, unexpectedly, resulted in higher yields. Test weight was also generally lower when seeding rates were below optimal. Seed treatments provided small but consistent benefits with respect early season growth (NDVI), yield, and, to a lesser extent, grain quality. Averaged over the three years, seed treatments resulted in a 2.3% (1.5 bu ac^{-1}) yield increase compared to seed that was not treated with a seed-applied fungicide. While (spring/summer applied) foliar fungicides will not improve winter wheat establishment or build additional yield potential; they are important for preventing yield or quality loss associated with disease. Of the inputs evaluated in this demonstration, foliar fungicides provided the most consistent and greatest benefits with yield gains ranging from 5-20% and averaging 14% or 603 kg ha^{-1} (8.9 bus ac^{-1}). Foliar fungicide applications also consistently increased test weight and thousand kernel weight.
