2014 Annual Report
for the

Agricultural Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Winter Wheat Establishment and Disease Management

(Project #20130315)

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Project Identification

1. **Project Title:** Winter Wheat Establishment and Disease Management
2. **Project Number:** 20130312
3. **Producer Group Sponsoring the Project:** Indian Head Agricultural Research Foundation
4. **Project Location(s):** Indian Head, Saskatchewan, R.M. #156
   Scott Saskatchewan, R.M. #380
5. **Project start and end dates (month & year):** September 2012-January 2014
6. **Project contact person & contact details:**

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Objectives and Rationale

7. **Project objectives:**

The objectives of this project were 1) to demonstrate the effects of foliar fungicide applications at different crop stages on winter wheat disease levels and yield, 2) to demonstrate the effects of using seed treatments and/or higher seeding rates to improve winter wheat establishment and 2) to investigate potential interactions between plant populations, seed treatments and foliar fungicide applications for winter wheat.

8. **Project Rationale:**

One of the greatest challenges in winter wheat production is successful establishment and overwintering of the crop. Common problems that are encountered include narrow windows for planting, dry or cool soil conditions during and following planting and winterkill, particularly when snow cover is limited. One of the more obvious and effective methods of improving winter wheat establishment is to use higher seeding rates; however the benefits to increased seeding rates ultimately need to be weighed against higher seed costs. Recent work conducted as part of the winter wheat DIAP project showed that seed treatments were also effective for improving plant stands, winter survival and yield; however the positive effect for seed treatment on yield was only observed at low seeding rates. Winter wheat response to foliar fungicide applications is not well documented in western Canada; however, foliar fungicides may provide an economic method for control of leaf and head diseases in situations where moisture conditions are favourable and yield potential is high. Recent field demonstrations and producer accounts suggest winter wheat is quite responsive to foliar fungicide; however, producers must recognize the need to choose an appropriate product and application timing for the specific disease that is being targeted.

Methodology and Results

9. **Methodology:**

Two separate field demonstrations were established at both Indian Head and Scott, Saskatchewan in the fall of 2013. The purpose of Demonstration #1 was to measure the individual and combined benefits of seeding rates, seed treatments and foliar fungicides on winter wheat establishment and yield. In Demonstration #2, the purpose was to separate the effects of different timings of fungicide applications to determine which fungicide timing provides the greatest benefits while demonstrating the need to choose appropriate products and timings for the specific diseases being targeted. Similar demonstrations were also conducted in 2012-13 at Indian Head with funding from Ducks Unlimited and therefore results from these are also included in the current report. All treatments were replicated four times and arranged in either an RCBD or split plot design with fungicide as the main plots in Demonstration #1 in 2014. The treatments evaluated in the two demonstrations are described below.

Demonstration 1 (Seeding rates, seed treatments and foliar fungicides)

1. 200 seeds m^2 / untreated seed / check
2. 300 seeds m^2 / untreated seed / check
3. 400 seeds m^2 / untreated seed / check
4. 200 seeds m^2 / treated seed* / check
5. 300 seeds m^2 / treated seed / check
6. 400 seeds m^2 / treated seed / check
7. 200 seeds m^2 / untreated seed / foliar fungicide**
8. 300 seeds m^2 / untreated seed / foliar fungicide
9. 400 seeds m^2 / untreated seed / foliar fungicide
10. 200 seeds m^2 / treated seed / foliar fungicide
11. 300 seeds m^2 / treated seed / foliar fungicide
12. 400 seeds m^2 / treated seed / foliar fungicide

*325 ml/ac Raxil Pro

**Twinline at flag-leaf and Prosaro at anthesis

Demonstration #2 (Timing of Foliar Fungicides)

1. Check (no foliar fungicide applied)
2. 202 ml/ac Twinline/Tilt applied at flag-leaf stage
3. 324 ml/ac Prosaro applied at anthesis
4. Dual application (both products applied)

Winter wheat at all sites was direct seeded as early in the fall as possible with all fertilizer applied at the time of planting. Weeds were controlled using registered herbicide options and fungicides were applied according to the demonstration protocols. The plots were terminated with pre-harvest glyphosate at maturity and straight-combined when dry. At Indian Head (2013) and Scott (2014), spring plant densities were determined in Demonstration #1 by counting the number of plants in two separate 1 m sections of crop row and converting the average values to plants m^{-2}. Normalized difference vegetation index (NDVI) was measured using a handheld GreenSeeker sensor at the start of stem elongation in both years at the Indian Head. NDVI is an indirect measure of the canopy density and above-ground biomass. In Demonstration #2, leaf disease severity was rated using the McFadden scale (Table 13; Appendices). These ratings were completed similar to the time of the anthesis fungicide application at Scott (2014) but later, at the milk stage, at Indian Head in both years. Consequently, these ratings would not take into account any impacts of the later fungicide application at Scott on leaf disease, but they would at Indian Head. Fusarium head blight was assessed by rating the percent spike area affected for a minimum of 50 heads per plot at the milk stage and calculating FHB index (field average), incidence (percent of heads affected) and severity (spike area affected within infected heads). These measurements were completed *in situ* at Indian Head while at Scott the heads were collected and rated indoors at a later date. Yields were determined from the harvested grain samples which were cleaned and corrected to 14% seed moisture content. Dockage and test weights were determined using CGC methodology and test weights are expressed as g 0.5 L^{-1}. At both locations in 2014, seed size was determined by mechanically counting and weighing a minimum of 500 seeds and the values are expressed as g 1000 $seeds^{-1}$ (TKW). Weather data were estimated from the nearest Environment Canada weather station at each location. All data were statistically analysed using the Mixed procedure of SAS 9.3. For

Demonstration #1, data from each location were analysed separately with the effects of seeding rate, seed treatment and fungicide and their interactions considered fixed. Data from Demonstration #2 was combined across locations and analysed together with the effects of site, fungicide and the interaction considered fixed. In addition, for individual sites and on average, the treated plots as a whole were compared to the check using contrast statements. All pertinent agronomic information including dates of field operations and data collection activities are provided in Table 1.

Table 1. Selected agronomic information for winter wheat fungicide and seed treatment demonstrations and Indian Head and Scott, Saskatchewan.

Factor / operation	Indian Head 2012-13	Indian Head 2013-14	Scott 2013-14
Previous Crop	Canola (LL)	Canola (LL)	—
Pre-emergent herbicide	n/a	PrePass XC (28-Sep-13)	glyphosate (9-Sep-13)
Cultivar	Moats	Moats	AC Radiant
Seeding Date	14-Sep-12	23-Sep-13	11-Sep-13
Row spacing	30 cm	30 cm	25 cm
kg N-P_2O_5-K_2O-S ha^{-1}	115-35-48-16	115-35-48-16	112-22-17
In-crop herbicide 1	0.34 l/ac MCPA ester 500 + 5g florasulam/ac^{-1} (May-26-13)	0.4 l/ac Buctril M	0.5 l/ac Mextrol 450 (30-May-14)
In-crop herbicide 2	0.2 l/ac Simplicity (Jun-11-13)	0.2 l/ac Simplicity (8-Jun-14)	—
Flag-leaf fungicide	0.2 l/ac Twinline (Jun-26-13)	0.2 l/ac Twinline (24-Jun-14)	0.2 l/ac Tilt 250 (Jun-23-14)
Anthesis fungicide	0.324 l/ac Prosaro (4-Jul-13)	0.324 l/ac Prosaro (11-Jul-14)	0.324 l/ac Prosaro (2-Jul-14)
Plant Density	29-May-13	n/a	12-May-14
NDVI	13-Jun-13	18-Jun-14	n/a
Leaf disease ratings	29-Jul-13	Aug-6-14	Jul-3-14
FHB ratings	29-Jul-13	Aug-6-14	Aug-6-14
Pre-harvest herbicide	0.75 l/ac Matrix (18-Aug-13)	0.7 l/ac Roundup Ultra2 (Aug-20-14)	1.5 l/ac R/T 540 (Aug-12-14)
Harvest date	27-Aug-13	Aug-29-14	Aug-26-14

10. Results:

Growing season weather conditions

Mean monthly temperatures and precipitation amounts are presented relative to the long-term averages for Indian Head and Scott in Tables 2 and 3, respectively. At Indian Head in 2013, May was slightly warmer than average and dry while June was slightly cooler than normal with above average precipitation. Overall July was cool and slightly drier than normal; however, conditions were relatively warm and humid during early heading at the start of the month. August was very dry with close to normal temperatures. In 2014 at Indian Head, May was once again drier than normal with well above average temperatures. June was extremely wet and slightly cooler than average, July was dry and hot, and August was also very wet with close to normal temperatures. The very wet conditions in June and were conducive to the development of both leaf and head disease. At Scott, temperatures and precipitation amounts were close to normal for much of the growing season, although June was slightly cooler than normal and July received 178% of the long-term normal precipitation.

Table 2. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2013 and 2014 growing seasons at Indian Head, SK.

Year	May	June	July	August	Avg. / Total
	---------------------------- Mean Temperature (°C) ----------------------------				
2014	14.4	14.4	17.3	17.4	15.9
2013	11.9	15.3	16.3	17.1	15.2
Long-term	10.8	15.8	18.2	17.4	15.6
	------------------------------ Precipitation (mm) ------------------------------				
2014	36.0	199.2	7.8	142.2	385
2013	17.1	103.8	50.4	6.1	177
Long-term	51.8	77.4	63.8	51.2	244

Table 3. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2014 growing season at Scott, SK.

Year	May	June	July	August	Avg. / Total
	---------------------------- Mean Temperature (°C) ----------------------------				
2014	9.3	13.9	17.4	16.8	14.4
Long-term	10.8	15.3	17.1	16.5	14.9
	------------------------------ Precipitation (mm) ------------------------------				
2014	23.1	60.4	128	30.1	241.6
Long-term	36.3	61.8	72.1	45.7	215.9

Demonstration #1: Seeding rates, seed treatments and fungicides

Indian Head 2013

The seeding rate / seed treatment demonstration at Indian Head in 2013 had fewer treatments than those in 2014 with only two seeding rates (200 vs. 400 seeds m^{-2}) and no foliar fungicide component. However, the results from this demonstration were more dramatic than anticipated and formed the basis for the more in-depth field demonstrations conducted in 2013. The overall tests of fixed effects (seeding rate, seed treatment) appear in the Appendices (Table 14). The main effects of both seeding rate and treatment were significant for all variables ($P < 0.01$) and the interaction between these factors was significant for plant density ($P = 0.02$) and test weight ($P = 0.05$) but not NDVI or yield ($P = 0.14$-0.51).

At Indian head in 2012-13, the winter wheat did not emerge in the fall (due to very dry soil conditions) and plant densities were assessed in the spring after emergence was complete. The use of a seed treatment resulted in more than double the number of plants emerging in the spring from 115 plants m^{-2} (38% of viable seeds planted) on average to 257 plants m^{-2} (86%) with a fungicide seed treatment (Table 4). While the rate by treatment interaction was significant for spring plant density, the effects of seed treatment were similar regardless of seeding rate and, by far, the strongest populations were achieved with a combination of higher seeding rates and a seed treatment. The NDVI measurements are an indirect measure of the above-ground biomass of the crop canopy and were affected by both seed treatment and rate – early season NDVI increased by 31% with a seed treatment and by 21% by doubling the seeding rate. Both factors also had a substantial impact on seed yield with seed treatments increasing yields by 859 kg ha^{-1} or 15% while doubling the seeding rate from 200 to 400 seeds m^{-2} increased yield by 949 kg ha^{-1} or 17%. Winter wheat test weight was significantly increased with both seed treatment (24%) and by seeding rate (16%); however, the interaction between these factors was such that, when a seed treatment was applied, there was little effect of seeding rate on test weight (Table 15). This indicates that the observed effects on test weight were primarily a function of the actually number of plants established, regardless of whether this was achieved with a seed treatment or higher seeding rate.

Table 4. Mean winter wheat response variables as affected by fungicide, seed treatment and seeding rate (main effects) at Indian Head, SK in 2013 [Z]. Main effect means followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

Main Effect	Spring Density (plants/m^2)	NDVI	Yield (kg/ha)	Test Weight (g/0.5 L)
Seed Treatment				
1) Untreated	115 b	0.216 b	5567 b	399.9 b
2) Treated [Y]	257 a	0.283 a	6426 a	409.5 a
S.E.	12.5	0.015	323.0	2.27
Seeding Rate				
1) 200 seeds m^{-2}	127 b	0.227 b	5522 b	401.2 b
2) 400 seeds m^{-2}	244 a	0.272 a	6471 a	407.8 a
S.E.	12.5	0.015	323.0	2.27

[Z] All plots received 0.2 l/ac Twinline at the flag leaf stage and 0.324 l/ac Prosaro 250 EC at anthesis
[Y] 325 ml/100 kg seed Raxil Pro

Indian Head 2014

In 2013-14, this demonstration was expanded to include an additional, more typical, seeding rate of 300 seeds m^{-2} and also a foliar fungicide component to investigate potential interactions between seeding rate, seed treatment and foliar fungicides. The overall tests of fixed effects for this site-year are presented in Table 16 in the Appendices. Foliar fungicide affected yield (P = 0.014), test weight and TKW (P < 0.01) but, as expected, not NDVI (fungicide treatments had not yet been applied at time of NDVI measurements). Seed treatment affected early season NDVI (P = 0.006) and yield (P = 0.044) but not test weight or TKW (P = 0.64-0.67). Seeding rate affected NDVI (P < 0.001), yield (P = 0.02) and, to a lesser extent, test weight (P = 0.053) but had no impact on TKW (P = 0.71). The effects of all two and three-way interactions were generally not significant with the exception of the fungicide by seeding rate (F x R) effect on TKW (*P* = 0.023).

With strong emergence in the fall despite being seeded relatively late, the winter wheat establishment conditions at Indian Head in 2013-14 were much more typical than in the previous season. The use of a seed treatment resulted in a small but significant increase in NDVI of 6% relative to untreated seed while doubling the seeding rate from 200 to 400 seeds m^{-2} resulted in a larger increase of nearly 19% (Table 5). These results are more typical of what growers might expect to encounter under more normal seeding conditions as opposed to the more dramatic effects of seed treatment observed the previous season. Grain yields were also increased significantly with both seed treatment (2.1%) and by doubling the seeding rate (2.4%), but the increases were nowhere near the magnitude observed the previous year under less favourable conditions for emergence. Of the factors evaluated, foliar fungicide had the greatest impact on winter yield with an overall average increase of 14% when fungicide was applied at both the flag-leaf stage and anthesis. Test weight was not affected by seed treatment at Indian Head in 2014 but was there was a marginally significant reduction in test weight at the lowest seeding rate relative to the two higher rates. The application of foliar fungicides resulted in an average test weight increase of 18% and a 10.6% increase in TKW. The significant fungicide by seeding rate (F x R) interaction for TKW was due to a slight reduction in TKW with increasing seeding rate that was observed in the absence of foliar fungicide but not when fungicides were applied (Table 6). All individual treatment means for Indian Head, 2014 are provided in the Appendices (Table 17).

Table 5. Least squares means for main effects of fungicide, seed treatment and seeding rate on winter wheat at Indian Head, SK in 2014. Main effect means followed by the same letter do not significantly differ (Fisher's protected LSD test; *P* ≤ 0.05).

Main Effect	NDVI	Yield (kg/ha)	Test Weight (g/0.5 L)	TKW (g/1000 seeds)
Fungicide				
1) Untreated	0.372 a	4654 b	392.2 b	31.2 b
2) Treated [Z]	0.367 a	5346 a	399.3 a	34.5 a
S.E.	0.020	142.9	1.21	0.25
Seed Treatment				
3) Untreated	0.358 b	4947 b	395.6 a	32.8 a
4) Treated [Y]	0.380 a	5053 a	395.9 a	32.9 a
S.E.	0.016	104.1	1.12	0.23
Seeding Rate				
3) 200 seeds m^{-2}	0.328 b	4898 b	394.6 b	33.0 a
4) 300 seeds m^{-2}	0.392 a	5086 a	396.2 a	32.8 a
5) 400 seeds m^{-2}	0.388 a	5015 ab	396.4 a	32.8 a
S.E.	0.017	107.1	1.16	0.26

[Z] 0.2 l/ac Twinline at the flag leaf stage and 0.324 l/ac Prosaro 250 EC at anthesis

[Y] 325 ml/100 kg seed Raxil Pro

Table 6. Foliar fungicide and seeding rate effects on winter wheat thousand kernel weight (TKW) at Indian Head, SK in 2014. Values followed by the same letter do not significantly differ (Fisher's protected LSD test; *P* ≤ 0.05)

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

Scott 2014

The results of the overall tests of fixed effects for Scott 2014 are provided in the Appendices (Table 18). Spring plant densities affected both seed treatment and seeding rates ($P < 0.001$), yield was affected by foliar fungicide ($P < 0.001$) and seed treatment ($P = 0.034$) but not seeding rate ($P = 0.205$). Test weight and TKW were both affected by foliar fungicide ($P < 0.001$) but not seed treatment (P = 0.54-0.85) or seeding rate (P = 0.10-0.23). The only significant interaction between factors was a three way (F x T x R) interaction for plant density; however, this may have been due to chance as the T x R interaction was not significant and fungicides had not yet been applied at the time plant densities were measured.

Similar to Indian Head in 2012, conditions were dry at seeding and through the remainder of the fall at Scott in 2013. Under these conditions, seed treatments resulted in a significant increase in the number of plants established, with an average increase of 30 plants m^{-2}, or 30% relative to untreated seed. As expected, higher seeding rates also resulted in more plants established with an average of 91 plants m^{-2} at the 200 seeds m^{-2} rate increasing to 125-133 seeds m^{-2} when seeding rates of 300-400 seeds m^{-2} were used. Consistent with the previously discussed sites, seed treatments resulted in significantly higher grain yields and the magnitude of the increase was 408 kg ha^{-1}, or 9%. At this location, the effect of seeding rate was not significant and, with no interactions between seed treatment and rate; the benefits of the seed treatments appeared to be independent of seeding rate. Again, the single factor that had the greatest impact on winter wheat yield was foliar fungicide with an average overall increase of 29% with fungicide relative to the unsprayed plots. While test weight or TKW were not affected by seeding rate or seed treatment, they were increased by 3.3 and 9.1%, respectively, with foliar fungicide applications. All individual treatment means are provided in Table 19 of the Appendices.

Table 7. Least squares means for main effects of fungicide, seed treatment and seeding rate on winter wheat at Scott, SK in 2014. Values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test; *P* ≤ 0.05).

Main Effect	Spring Density (plants/m^2)	Yield (kg/ha)	Test Weight (g/0.5 L)	TKW (g/1000 seeds)
Fungicide				
3) Untreated	113 a	4144 b	384.9 b	35.0 b
4) Treated [Z]	120 a	5342 a	397.6 a	38.2 a
S.E.	14.6	427.5	2.17	0.66
Seed Treatment				
5) Untreated	101 b	4539 b	390.9 a	36.6 a
6) Treated [Y]	131 a	4947 a	391.6 a	36.6 a
S.E.	14.6	427.5	2.17	0.66
Seeding Rate				
6) 200 seeds m^{-2}	91 b	4617 a	390.7 a	36.8 a
7) 300 seeds m^{-2}	125 a	4632 a	390.4 a	36.2 a
8) 400 seeds m^{-2}	133 a	4981 a	392.6 a	36.7 a
S.E.	15.1	437.3	2.24	0.67

[Z] 0.2 l/ac Twinline at the flag leaf stage and 0.324 l/ac Prosaro 250 EC at anthesis
[Y] 325 ml/100 kg seed Raxil Pro

Demonstration #2: Foliar fungicide application timings

Again, the purpose of Demonstration #2 to more thoroughly investigate winter wheat response to varying foliar fungicide products and application times to determine and demonstration which of these provide the greatest benefit. With a relatively simple design and identical treatments at all sites, all data from Demonstration #2 was combined and analyzed together. The overall effects of fixed effects (site, treatment, site x treatment) are presented in the Appendices (Table 20). The variables included in the analyses were leaf disease ratings, fusarium head blight (FHB) index, incidence and severity, grain yield, test weight and TKW. All variables except for FHB incidence (the percentage of heads infected) and FHB severity (average spike area affected amongst infected heads) were affected by fungicide treatment ($P \leq 0.05$). With the exception of leaf disease (where the timings of the ratings differed amongst sites) and FHB index, there were no interactions between site and treatment indicating that the response to the treatments was generally similar at all sites. Since all of the data were analyzed and presented together, the results will be discussed one factor at a time.

Leaf disease severity was rated according to the McFadden scale (Table 13) on a scale of 0-12 whereby, at a rating of 12, 26-50% of the flag leaf is affected by disease. At Indian Head, where the plots were rated during the milk stage (late enough to take into account effects of both fungicide applications), disease severity levels were always highest in the check. In 2013, mean ratings were similar amongst all of the treated plots while, in 2014, leaf disease severity was lowest when fungicide application was lowest when a fungicide was applied at anthesis and intermediate when only the flag-leaf application was applied. This may be due to the wet conditions (and higher disease pressure) that occurred relatively late in the season at Indian Head in 2014 compared to the previous year which was relatively wet early in the season but became much drier into late June / early July. At Scott, only the treatments that received a flag leaf application of fungicide showed significantly reductions in leaf disease; however, the ratings at this site were completed at a time when benefits to the later applications would not yet be expected. At Indian Head with the ratings completed later, the later of the two fungicide applications typically resulted equal or even superior protection of the flag leaf late in the season. Contrasts comparing the combined fungicide treatments to the check were significant ($P < 0.001$) in all cases.

Table 8. Mean winter wheat leaf disease severity as affected by foliar fungicide treatments. Least squares means followed by the same letter do not significantly differ (Fisher's protected LSD test, $P \leq 0.05$).

Treatment	Indian Head (13)	Indian Head (14)	Scott (14)	Average
	-------------------------------- McFadden Scale (1-12) ---------------------------------			
1) Check	10.2 b	10.9 a	7.5 def	9.5 a
2) Flag Leaf	7.6 de	9.6 c	6.9 fg	8.0 b
3) Anthesis	7.5 de	7.9 d	7.3 efg	7.6 c
4) Dual	6.8 g	7.7 de	6.8 g	7.1 d
Std. Error	0.18	0.17	0.21	0.11
	-- (Pr. > *F*) --			
Check vs Rest	**<0.001**	**<0.001**	**<0.001**	**<0.001**

The FHB index is the product of the overall percentage of infected heads (FHB incidence) and the percent area affected amongst the infected heads (FHB severity) and therefore is an appropriate indicator of the overall severity of fusarium head blight within the plots. Overall, the fusarium pressure was highest at Indian Head in 2014 followed by Indian Head in 2013 and then Scott in 2014 (Table 9). At Indian Head in 2013, FHB was present but at relatively low levels and the treatment effects were not statistically significant for FHB index, incidence (Table 21), or severity (Table 22). There was however, a slight numerical reduction when fungicide was at anthesis. In 2014, under higher disease pressure, FHB index was significantly reduced from 7.8 to 2.9-3.8 with an appropriately timed fungicide application (early heading / anthesis). While FHB incidence was not significantly affected by the fungicide treatments (Table 21), the average severity was reduced from over 70% to approximately 50% with fungicide applied at heading. As expected, fungicide applied at the flag-leaf stage does not target and did not affect FHB index, incidence or severity. At Scott, there was very little visual evidence of FHB infection and, consequently, there no significant treatment effects or notable trends in this data at that location.

Table 9. Mean winter wheat fusarium head blight (FHB) index as affected by foliar fungicide treatments. Least squares means followed by the same letter do not significantly differ (Fisher's protected LSD test, P ≤ 0.05).

Treatment	Indian Head (13)	Indian Head (14)	Scott (14)	Average
	---------- FHB Index ----------			
1) Check	1.5 bc	7.8 a	0.04 d	3.13 a
2) Flag Leaf	1.6 bc	7.6 a	0.28 d	3.17 a
3) Anthesis	1.1 c	2.9 bc	0.07 d	1.59 b
4) Dual	0.7 cd	3.8 b	0.21 d	1.34 b
Std. Error	0.34	1.09	0.09	0.383
	---------- (Pr. > *F*) ----------			
Check vs Rest	0.335	**0.023**	0.132	**0.020**

Mean winter wheat yields for the fungicide treatments at each of the individual sites are presented in Table 10; however, the site by treatment interaction was not significant for yield and therefore the response to fungicide treatments was similar at all sites. Yields were high at all locations and, focussing solely on grain yield, all fungicide applications resulted in a significant increase averaging 19% across the three locations. Averaged across all of the treatments where fungicides were applied, the mean increase where 15% ($P < 0.001$), 11% ($P = 0.011$) and 37% ($P < 0.001$) at Indian Head 2013, 2014 and Scott 2014, respectively. The absolute values of the mean increases ranged from 867-1412 kg ha^{-1} and there were no significant differences amongst any of the treatments where a fungicide was applied nor were there any indications of a benefit of a dual over a single application of fungicide.

Table 10. Mean winter wheat grain yield as affected by foliar fungicide treatments. Least squares means followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

Treatment	Indian Head (13)	Indian Head (14)	Scott (14)	Average
	---------- Grain Yield (kg/ha) ----------			
1) Check	6000 cd	5294 d	3831 e	5042 b
2) Flag Leaf	6747 ab	5855 abc	5112 cd	5905 a
3) Anthesis	6850 ab	5733 bcd	5425 cd	6003 a
4) Dual	7004 a	6074 abc	5193 cd	6090 a
Std. Error	---------- 425.5 ----------			246.5
	---------- (Pr. > *F*) ----------			
Check vs Rest	**<0.001**	**0.011**	**<0.001**	**<0.001**

Test weight was affected by site ($P < 0.001$) and fungicide treatment ($P < 0.001$) but again with no site by treatment interaction ($P = 0.183$; Table 20). Mean test weights for each of the treatments for the individual and combined sites are presented in Table 11. Averaged across all sites, the flag-leaf application on its own resulted in a slight but significant (0.8%) increase in test weight and a tendency for the highest test weights when fungicide was applied during heading (1.6%). Again, the check versus rest contract was significant in all possible cases (*P* < 0.001-0.025).

Table 11. Mean winter wheat test weight as affected by foliar fungicide treatments. Least squares means followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

Treatment	Indian Head (13)	Indian Head (14)	Scott (14)	Average
	-------------------------------- Test Weight (g 0.5 l^{-1})	----------------------------------		
1) Check	405.2 b	395.0 d	388.9 e	396.4 c
2) Flag Leaf	406.1 b	397.8 c	395.0 cde	399.6 b
3) Anthesis	410.6 a	400.1 c	396.3 cde	402.5 ab
4) Dual	411.0 a	400.1 c	397.1 cd	402.6 a
Std. Error	1.32	0.93	2.68	1.046
	-- (Pr. > *F*)	--		
Check vs Rest	**0.009**	**<0.001**	**0.025**	**<0.001**

Thousand kernel weights (TKW) were measured at both locations in 2014 and the results were similar to those observed for test weight with an overall increase with fungicide that was most profound in the treatments where a fungicide was applied at heading. Averaged across the two sites, the flag leaf application on its resulted in a 6% increase in TKW while the application at heading resulted in an 8% increase and the mean increase in TKW with a dual application was 10% over the check.

Table 12. Mean winter wheat thousand kernel weight as affected by foliar fungicide treatments. Least squares means followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

Treatment	Indian Head (13)	Indian Head (14)	Scott (14)	Average
	--------------------- Thousand Kernel Weight (g 1000 $seeds^{-1}$)	-----------------------		
1) Check	—	32.5 d	34.6 bc	33.5 c
2) Flag Leaf	—	33.5 cd	37.6 a	35.5 b
3) Anthesis	—	34.7 b	37.8 a	36.2 ab
4) Dual	—	35.0 b	38.7 a	36.8 a
Std. Error	—	0.39	0.48	0.31
	-- (Pr. > *F*)	--		
Check vs Rest	—	**<0.001**	**<0.001**	**<0.001**

Extension and Acknowledgement

At Indian Head, the winter wheat site and these trials in particular were a formal stop at the Indian Head Crop Management Field Day on July 22. 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 N fertility and disease management, which were the subject of 2013-14 ADOPT projects. The tour was attended by over 200 producers and industry representatives and signs were in place to identify treatments and acknowledge the support of the Agricultural Demonstrations of Technologies and Practices (ADOPT) program. At Scott, these trials were shown at WARC's annual summer field day on July 17 which was attended by approximately 175 producers and agronomists / industry representatives with Brian Beres and Lyze Boivert invited to discuss the practices being demonstrated. Results from this project will be made available in the 2014 IHARF Annual Report (available online) and also made available through a variety of other media (i.e. oral presentations, popular agriculture press, fact sheets, etc.).

11. Conclusions and Recommendations

This project has demonstrated the potential merits of seed treatments and foliar fungicides for optimizing stand establishment and minimizing the impacts of leaf and head disease on winter wheat yield and quality. Focussing 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 yield gains. Seed treatments are a reasonably low cost tool that protect against seed decay and diseases and can help the crop get off to as strong a start as possible thereby increasing the likelihood of successful overwintering. The response to seed treatments in these trials was remarkably strong with significant impacts on crop establishment (plant density and/or NDVI) and grain yield at all three sites. While the response observed at the two sites in 2014 was probably more typical, the very strong response at Indian Head in 2013 was particularly interesting. At this site, winter wheat was planted into extremely dry soil and did not emerge (or possibly even germinate) until the following spring. Under these conditions, plant densities were doubled with seed treatments and grain yields were increased by 15%. At Scott, the yield increase was 9% and at Indian Head in 2014 it was 2%. Our results support the recommendation that winter wheat producers seed at rates of approximately 300 seeds m^{-2} or higher and consider treated seed to increase the likelihood of strong establishment and overwintering, particularly under stressful conditions. Once the crop is established, foliar fungicides may be required for the winter wheat yield potential by reducing the impact of leaf and head diseases on yield, growth and quality. In these particular sites, yield increases with foliar fungicide ranged from 11-37% and there were no differences in yield amongst any of the treatments where a fungicide was applied. Fungicides applications tended to result in higher test weights and thousand seed weights, with the most consistent benefits observed when applied at anthesis. Furthermore, while both fungicide application times tended to reduce leaf disease, only the later of the two can reduce FHB infection and reduce the potential for grade reduction in pressure is high. Consequently, unless disease pressure is particularly high early in the season and already progressed to the upper canopy at the time of flag leaf emergence, producers may be better off deferring application until heading and choosing a product that is also registered for control of fusarium head blight. There were no cases where a dual application was a significant improvement over a single application and such products (i.e. Prosaro, Caramba, etc.) also protect against leaf disease. Consequently, under moderate disease pressure, fungicides applied at early heading are likely to provide the most consistent yield and quality benefits.

Supporting Information

12. Acknowledgements:

The project was supported by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement. Acknowledgement of the Saskatchewan Ministry of Agriculture's support for this demonstration will be included as part of all written reports and oral presentations that arise from this work. The crop protection productions evaluated in this demonstration were provided in-kind by BASF and Bayer CropScience and seed was sourced and provided in-kind by Ducks Unlimited. In 2013 at Indian Head, financial support for the field demonstrations was provided by Ducks Unlimited.

13. Appendices

Table 13. McFadden, W. 1991. Etiology and epidemiology of leaf spotting diseases in winter wheat in Saskatchewan. Ph.D. thesis, University of Saskatchewan, Saskatoon, 151 pp.

Leaf Level	0[Z]	1	2	3	4	5	6	7	8	9	10	12
Upper (flag)	0	0	0	0	0	0	0	0-1	2-5	6-10	11-25	26-50
Mid	0	0	0	0	0-1	2-5	6-10	6-10	11-25	26-50	>50	>50
Lower	0	0-1	2-5	6-10	11-25	26-50	>50	>50	>50	>50	>50	>50

[Z] Percentage of leaf area with lesions in the upper, middle and lower leaf canopies

Table 14. Type III tests of fixed effects for seed treatments, seeding rates and their interactions on winter wheat at Indian Head, SK in 2013. Data were analyzed using a mixed model with seed treatment, seeding rate and the interaction considered fixed.

Variable	Seed Trt. (T)	Seeding Rate (R)	T x R
	------------------------	Pr. > *F*	------------------------
Plant Density	**<0.001**	**<0.001**	**0.019**
NDVI	**<0.001**	**0.003**	0.507
Yield	**0.004**	**0.002**	0.139
Test Weight	**<0.001**	**<0.001**	**0.045**

Table 15. Least squares means for seed treatment and seeding rate effects (individual treatments) on selected winter wheat at Indian Head in 2013. 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	Spring Density (plants/m^2)	NDVI	Yield (kg/ha)	Test Weight (g/0.5 L)
no	no	200	78 c	0.198 c	4913 b	395.3 c
no	no	400	151 b	0.234 b	6220 a	404.4 b
no	yes	200	178 b	0.257 b	6132 a	407.8 ab
no	yes	400	337 a	0.309 a	6722 a	411.2 a
S.E.	–	–	16.4	0.018	358.7	2.44

Table 16. Type III tests of fixed effects for site and fungicide, seed treatment and seeding rate and their interactions on winter wheat at Indian Head, SK in 2014. Data were analyzed using a mixed model with the effects of fungicide, seed treatment, seeding rate and all interactions considered fixed.

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* ----------						
NDVI	0.842	**0.006**	**<0.001**	0.621	0.680	0.906	0.373
Yield	**0.014**	**0.044**	**0.017**	0.968	0.951	0.815	0.282
Test Weight	**0.007**	0.674	**0.053**	0.836	0.137	0.758	0.817
TKW	**0.002**	0.644	0.708	0.741	**0.023**	0.783	0.100

Table 17. Least squares means for fungicide, seed treatment and seeding rate effects (individual treatments) on winter wheat at Indian Head, SK in 2014. 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	NDVI	Yield (kg/ha)	Test Weight (g/0.5 L)	TKW (g/1000 seeds)
no	no	200	0.308 fh	4444 e	390.7 b	31.7 bc
no	no	300	0.388 abcd	4742 cd	391.9 b	31.4 bcd
no	no	400	0.375 abcd	4618 de	393.7 b	30.4 d
no	yes	200	0.333 efg	4654 de	391.1 b	32.1 b
no	yes	300	0.396 abcd	4721 cd	392.0 b	30.8 cd
no	yes	400	0.398 abcd	4741 cd	393.6 b	31.2 bcd
yes	no	200	0.328 dgh	5203 bc	398.4 a	34.0 a
yes	no	300	0.368 bcef	5333 ab	399.7 a	34.3 a
yes	no	400	0.380 abce	5340 ab	399.3 a	35.3 a
yes	yes	200	0.343 cdfg	5291 b	398.4 a	34.4 a
yes	yes	300	0.415 a	5548 a	401.3 a	34.8 a
yes	yes	400	0.398 abe	5361 ab	398.9 a	34.5 a
S.E.	–	–	0.023	163.6	1.55	0.47

Table 18. Type III tests of fixed effects for site and fungicide, seed treatment and seeding rate effects and their interactions on winter wheat at Scott, SK in 2014. Data were analyzed using a mixed model with the effects of fungicide, seed treatment, seeding rate and all interactions considered fixed.

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* ----------						
Plant Density	0.356	**<0.001**	**<0.001**	0.809	0.089	0.655	**0.032**
Yield	**<0.001**	**0.034**	0.205	0.996	0.810	0.544	0.077
Test Weight	**<0.001**	0.540	0.227	0.877	0.654	0.441	0.849
TKW	**<0.001**	0.850	0.099	0.986	0.527	0.155	0.793

Table 19. Least squares means for fungicide, seed treatment and seeding rate effects (individual treatments) on winter wheat at Scott, SK in 2014. 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	Spring Density (plants/m^2)	Yield (kg/ha)	Test Weight (g/0.5 L)	TKW (g/1000 seeds)
no	no	200	91 de	4020 c	383.1 b	34.7 b
no	no	300	109 cd	3714 c	382.5 b	34.7 b
no	no	400	91 de	4086 c	387.9 b	35.6 b
no	yes	200	90 de	4045 c	384.7 b	35.5 b
no	yes	300	153 ab	4480 bc	385.3 b	34.6 b
no	yes	400	142 abc	4516 bc	386.1 b	34.9 b
yes	no	200	63 e	4574 bc	396.8 a	38.4 a
yes	no	300	121 bcd	5106 ab	396.5 a	37.7 a
yes	no	400	136 abc	5735 a	398.6 a	38.4 a
yes	yes	200	121 bcd	5827 a	398.3 a	38.8 a
yes	yes	300	119 bcd	5230 ab	397.3 a	37.9 a
yes	yes	400	162 a	5586 a	397.8 a	37.9 a
S.E.	–	–	19.3	517.3	2.78	0.76

Table 20. Type III tests of fixed effects for site and fungicide treatment effects on selected winter wheat response variables. Data were analyzed using a mixed model with site-year, treatment and their interaction considered fixed.

Variable	Site-Year (S)	Treatment (T)	S X T
	------ Pr. > *F* ------		
Leaf Disease	**<0.001**	**<0.001**	**<0.001**
FHB Index	**<0.001**	**0.002**	**0.013**
FHB Incidence	**<0.001**	0.093	0.092
FHB Severity	**<0.001**	0.117	0.096
Yield	**0.035**	**<0.001**	0.170
Test Weight	**<0.001**	**<0.001**	0.807
TKW	**<0.001**	**<0.001**	0.183

Table 21. Mean winter wheat fusarium head blight (FHB) incidence as affected by foliar fungicide treatments. Least squares means followed by the same letter do not significantly differ (Fisher's protected LSD test, P ≤ 0.05).

Treatment	Indian Head (13)	Indian Head (14)	Scott (14)	Average
	------ FHB Incidence (%) ------			
1) Check	0.27 a	0.10 bc	0.01 f	0.12 ab
2) Flag Leaf	0.25 a	0.12 b	0.03 ef	0.13 a
3) Anthesis	0.15 abcde	0.06 de	0.01 f	0.07 b
4) Dual	0.12 abcdef	0.08 cd	0.03 ef	0.08 ab
Std. Error	0.061	0.012	0.011	0.02
	------ (Pr. > *F*) ------			
Check vs Rest	0.199	0.235	0.145	0.222

Table 22. Mean winter wheat fusarium head blight (FHB) severity as affected by foliar fungicide treatments. Least squares means followed by the same letter do not significantly differ (Fisher's protected LSD test, $P \leq 0.05$).

Treatment	Indian Head (13)	Indian Head (14)	Scott (14)	Average
	---------------------------------- FHB Severity (0-100) ------------------------------------			
1) Check	6.2 cd	77.6 a	1.75 d	28.5 a
2) Flag Leaf	6.6 c	65.6 ab	7.0 cd	26.4 ab
3) Anthesis	6.9 c	52.7 b	1.75 d	20.5 ab
4) Dual	6.8 c	48.1 b	5.25 cd	20.0 b
Std. Error	0.73	8.41	2.1	2.90
	-- (Pr. > *F*) --			
Check vs Rest	0.450	**0.031**	0.231	0.074

Abstract

14. Abstract/Summary:

Winter wheat field demonstrations were conducted at Indian Head in 2012-13 and 2013-14 and at Scott in 2013-14 to evaluate seeding rates, seed treatments and foliar fungicide effects on winter wheat establishment growth, yield and quality. At all three sites, significant benefits to both seed treatments and foliar fungicides were detected. Where actual spring plant densities were measured, seed treatments increased populations by 30-100% and, in both years at Indian Head, NDVI values (an indirect measure of above-ground biomass) at the start of stem elongation were higher when treated seed was used. Seed treatments, on average resulted in yield increases of 2-15% depending on the site with the most profound results at Indian Head in 2013 when the crop was seeded into extremely dry soil and did not emerge in the fall. In these particular trials, failure to apply foliar fungicides also resulted in significant yield losses due to leaf and head disease. On average, winter wheat yields were 15-37% higher when foliar fungicides were applied. Separate field trials demonstrated the effects of timing of fungicide application on winter wheat disease levels, yield and quality. These showed that the flag-leaf and anthesis fungicide timings resulted in similar yield increases; however, while fungicide applied at anthesis still provided reasonable protection against leaf disease, the flag-leaf application did not reduce FHB infection or provide the potential quality improvements of the later application. Therefore, unless disease pressure is high and symptoms are already progressing to the upper canopy at the early flag-leaf stage, a single application at early heading will likely be the most cost effective option for winter wheat producers. These trials were shown as part of both the IHARF and WARC summer field days and will be made available through a variety of media including annual reports and oral presentations.