2015 Annual Report
for the

**Agricultural Demonstration of Practices and Technologies (ADOPT) Program**

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

(Project #20140304)


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## Project Identification

1. **Project Title:** Options for improved winter wheat establishment and disease management
2. **Project Number:** 20140304
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-2015
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 use of seed treatments, higher seeding rates and foliar fungicide to improve winter wheat establishment, yield and quality and 2) to demonstrate foliar fungicide timing effects on winter wheat yield and quality.

8. **Project Rationale:**

One of the greatest challenges for Saskatchewan winter wheat producers 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 in years or areas in fields where snow cover is limited. One fairly 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. Recent research in western Canada showed that seed treatments could also be effective for improving plant stands, winter survival and yield. This positive effect was primarily observed at lower seeding rates (i.e. 200 seeds/$m^2$). Under warm, humid conditions, winter wheat can be susceptible to both leaf spot diseases and fusarium head blight; however, foliar fungicide applications are often economical under such circumstances, particularly when yield potential is high. Recent field trials and producer accounts suggest winter wheat is quite responsive to foliar fungicide; though producers must recognize the need to choose an appropriate product and application timing for the specific disease they are targeting.

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## Methodology and Results

9. **Methodology:**

Two separate field demonstrations were established at Indian Head (2013-2015) and Scott (2014), Saskatchewan. The purpose of the first demonstration was to measure the individual and combined benefits of higher seeding rates, seed treatments and foliar fungicide applications on winter wheat establishment, yield and quality. The second demonstration was designed to compare the effects of contrasting timings of fungicide applications to determine which provides the greatest benefits while demonstrating the need to choose appropriate products and timings for the specific diseases being targeted. The demonstrations conducted at Indian Head in 2012-13 were funded by Ducks Unlimited with slightly different protocols; however, the treatments and objectives were similar and these results are also included in the current report. All treatments were replicated four times and the design was a split plot for Demonstration #1 (Seeding Rate x Seed Treatment x Fungicide) and an RCBD for Demonstration #2 (Fungicide Timing). The treatments which were evaluated are described below.

*Demonstration 1 (Seeding Rates, Seed Treatments and Foliar Fungicides for Winter Wheat)*

1. 200 seeds $m^2$ / untreated seed / no foliar fungicide
2. 300 seeds $m^2$ / untreated seed / no foliar fungicide
3. 400 seeds $m^2$ / untreated seed / no foliar fungicide
4. 200 seeds $m^2$ / treated seed / no foliar fungicide
5. 300 seeds $m^2$ / treated seed / no foliar fungicide
6. 400 seeds $m^2$ / treated seed / no foliar fungicide
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

*Demonstration #2 (Timing of Foliar Fungicides for Winter Wheat)*

1. Check (no foliar fungicide applied)
2. Flag-leaf application
3. Anthesis application
4. Dual application (both timings combined)

Pertinent agronomic information is provided in Table 1. 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 herbicides and fungicides were applied according to 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 values to plants $m^{-2}$. Normalized difference vegetation index (NDVI) was measured using a handheld GreenSeeker during stem elongation in all years at Indian Head but not at Scott. NDVI is an indirect measure of the canopy density and above-ground biomass. In Demonstration #2 at Indian Head, leaf disease severity was rated at the early milk stage using the McFadden scale (Table 14). Fusarium head blight was assessed at all sites by rating the percent spike area affected for a minimum of 50 heads per plot at the early milk stage and calculating FHB index which is the average percent spike area affected of all 50 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 14.5% seed moisture content. Dockage (for correcting yields) and test weights were determined using CGC methodology and test weights are expressed as g 0.5 $L^{-1}$. At all locations except Indian Head in 2013, 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 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, the treated plots as a whole were compared to the untreated control using single degree-of-freedom contrast statements.

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

| Factor / Field Operation | Indian Head 2012-13 | Indian Head 2013-14 | Scott 2013-14 | Indian Head 2014-15 |
|---|---|---|---|---|
| Previous Crop | Canola (LL) | Canola (LL) | — | Canola (LL) |
| Pre-emergent herbicide | n/a | PrePass XC (28-Sep-2013) | glyphosate (9-Sep-2013) | PrePass XC (21-Sep-2013) |
| Cultivar | Moats | Moats | AC Radiant | Moats |
| Seed Treatment | Raxil Pro | Raxil Pro | Raxil T | Raxil Pro-Shield |
| Seeding Date | 14-Sep-2012 | 23-Sep-2013 | 11-Sep-2013 | 22-Sep-2014 |
| Row spacing | 30 cm | 30 cm | 25 cm | 30 cm |
| kg $N-P_2O_5-K_2O-S$ $ha^{-1}$ | 115-35-48-16 | 115-35-48-16 | 112-22-17 | 115-30-48-16 |
| In-crop herbicide 1 | 0.34 l/ac MCPA ester 500 + 5g florasulam/$ac^{-1}$ (26-May-2013) | 0.4 l/ac Buctril M (8-Jun-2014) | 0.5 l/ac Mextrol 450 (30-May-2014) | 0.17 l/ac Prestige XC A + 0.8 l/ac Prestige XC B (25-May-2015) |
| In-crop herbicide 2 | 0.2 l/ac Simplicity (11-Jun-2013) | 0.2 l/ac Simplicity (8-Jun-2014) | — | 0.2 l/ac Simplicity (25-May-2014) |
| Flag-leaf fungicide | 0.2 l/ac Twinline (26-Jun-2013) | 0.2 l/ac Twinline (24-Jun-2014) | 0.2 l/ac Tilt 250 (23-Jun-2014) | 0.2 l/ac Twinline (10-Jun-2015) |
| Anthesis fungicide | 0.324 l/ac Prosaro (4-Jul-2013) | 0.324 l/ac Prosaro (11-Jul-2014) | 0.324 l/ac Prosaro (2-Jul-2014) | 0.324 l/ac Prosaro (25-Jun-2014) |
| Pre-harvest herbicide | 0.75 l/ac Matrix (18-Aug-2013) | 0.7 l/ac Roundup Ultra 2 (20-Aug-2014) | 1.5 l/ac R/T 540 (12-Aug-2014) | 0.67 l/ac Roundup Transorb HC (8-Aug-2015) |
| Harvest date | 27-Aug-2013 | 29-Aug-2014 | 26-Aug-2014 | 13-Aug-2015 |

## 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 2012-13, winter wheat did not germinate until early May which was slightly warmer than average and dry; however, moisture conditions improved dramatically in June and through July. In 2013-14 at Indian Head, the winter wheat became well established in the fall and, while May and July were drier than normal, June was extremely wet 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 events until late June at which point the winter wheat was starting to head out and much of the yield potential had been set. At Scott, growing season temperatures and precipitation amounts were close to normal, however June was slightly cooler than average while July was wet with 178% of the long-term average precipitation.

**Table 2. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2013-15 growing seasons at Indian Head, SK.**

| Year | May | June | July | August | Avg. / Total |
|---|---|---|---|---|---|
| | ----- Mean Temperature (°C) ----- | | | | |
| 2015 | 10.3 | 16.2 | 18.1 | 17.0 | 15.4 |
| 2014 | 10.2 | 14.4 | 17.3 | 17.4 | 14.8 |
| 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) ----- | | | | |
| 2015 | 15.6 | 38.3 | 94.6 | 58.8 | 192 |
| 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 & fungicides*

*Effects on Emergence & Early Season Growth*

Overall tests of fixed effects for spring plant density and NDVI are presented in Tables 4 and 5, respectively. These tests are used to determine whether a factor or interaction between factors had an impact on a particular response variable. Values ≤ 0.05 were considered significant and suggest that we are at least 95% confident that the treatment had an effect on the corresponding response variable.

At the sites where absolute plant densities were measured (IH-2013 and Scott-2014), the effects of both seed treatment (T) and seeding rate (R) were highly significant ($P < 0.001$). The response was such that, higher populations were achieved with both increased seeding rates and with the use of a seed treatment (Table 6). Increasing seeding rates from 200 to 400 seeds $m^{-2}$ resulted in a 46-92% increase in the number of plants established the following spring. Seed treatments resulted in a 30% increase in plants at Scott (2014) and a dramatic 123% increase at Indian Head in 2013 (Table 6). In the latter case, it is worth noting that the winter wheat did not germinate in the fall (due to extremely dry soil conditions) and no emergence was noted until the following May.

**Table 4. Tests of fixed effects for fungicide, seed treatment, seeding rate and their interactions on winter wheat plant density.**

| 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-2013 | — | **<0.001** | **<0.001** | — | — | **0.019** | — |
| IH-2014 | — | — | — | — | — | — | — |
| IH-2015 | — | — | — | — | — | — | — |
| Scott-2014 | 0.356 | **<0.001** | **<0.001** | 0.809 | 0.089 | 0.655 | **0.032** |

At Indian Head in 2014 and 2015, absolute plant populations were not measured; however, as a relative measure of establishment and early season growth, NDVI was measured using a GreenSeeker™ sensor in all three years at Indian Head. Both higher seeding rates and seed treatment resulted in higher NDVI values at Indian Head in 2013 and 2014; however, no treatments affected NDVI at Indian Head in 2015 (Tables 5 and 6). In 2014 at Indian Head, while NDVI increased when the seeding rate was increased from 200 to 300 seeds $m^{-2}$, there was no further increase going from 300 to 400 seeds $m^{-2}$.

**Table 5. Tests of fixed effects for fungicide, seed treatment, seeding rate and their interactions on winter wheat spring NDVI.**

| 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-2013 | — | **<0.001** | **0.003** | — | — | 0.507 | — |
| 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 |
| Scott-2014 | — | — | — | — | — | — | — |

**Table 6. Least squares means for main effects of fungicide, seed treatment and seeding rate on winter wheat establishment and early season growth. Data were analyzed separately for each site and main effect means followed by the same letter do not significantly differ (Fisher's protected LSD test; $P \leq 0.05$).**

| Main Effect | IH-2013 | Scott-2014 | IH-2013 | IH-2014 | IH-2015 |
|---|---|---|---|---|---|
| Fungicide | -------------- plants/m$^2$ -------------- | | ---------------------------- NDVI ---------------------------- | | |
| 1) Untreated | — | 113 a | — | 0.372 a | 0.419 a |
| 2) Treated [Z] | — | 120 a | — | 0.367 a | 0.399 a |
| S.E. | — | 14.6 | — | 0.020 | 0.007 |
| Seed Treatment | | | | | |
| 1) Untreated | 115 b | 101 b | 0.216 b | 0.358 b | 0.411 a |
| 2) Treated [Y] | 257 a | 131 a | 0.283 a | 0.380 a | 0.406 a |
| S.E. | 12.5 | 14.6 | 0.015 | 0.016 | 0.005 |
| Seeding Rate | | | | | |
| 1) 200 seeds m$^{-2}$ | 127 b | 91 b | 0.227 b | 0.328 b | 0.405 a |
| 2) 300 seeds m$^{-2}$ | — | 125 a | — | 0.392 a | 0.413 a |
| 3) 400 seeds m$^{-2}$ | 244 a | 133 a | 0.272 a | 0.388 a | 0.405 a |
| S.E. | 12.5 | 15.1 | 0.015 | 0.017 | 0.006 |

*Effects on Grain Yield*

Tests of fixed effects on winter wheat yield along with the main effects means are presented in Tables 7 and 8. Yields were affected by both fungicide ($P$ < 0.001-0.014) and seed treatment ($P$ = 0.004-0.044) at all four sites while seeding rate affected yield at Indian Head in all three years ($P$ = 0.002-0.017) but not at Scott ($P$ = 0.205) (Table 7).

**Table 7. Tests of fixed effects for fungicide, seed treatment, seeding rate and their interactions on winter wheat grain yield.**

| 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-2013 | – | **0.004** | **0.002** | – | – | 0.139 | – |
| 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** |
| Scott-2014 | **<0.001** | **0.034** | 0.205 | 0.996 | 0.810 | 0.544 | 0.077 |

Foliar fungicides increased winter wheat yield in all possible cases in this demonstration; however, the extent of the increases ranged from only 5% at Indian Head in 2015 to as high as 29% at Scott in 2014 (Table 8). Seed treatment also had a positive effect on winter wheat yield at all sites but the magnitude was generally much smaller ranging from only 2% (106 kg ha$^{-1}$) at Indian Head in 2014 to 15% at Indian Head in 2013. At Scott in 2014, the increase with seed treatment was also quite high (9%) while it was more modest at Indian Head in 2015 (3%). Focussing on seeding rates, yields did not significantly differ across seeding rates at Scott but doubling the seeding rate (200 to 400 seeds $m^{-2}$) increased yields by approximately 17% and 3% at Indian Head in 2013 and 2014. Unexpectedly, the yields observed at the 200 seeds $m^{-2}$ rate at Indian Head in 2015 were approximately 5% higher than those at the two higher rates (Table 8). This was likely due to extremely dry conditions from April through late June combined with the delay in maturity that is often observed at sub-optimal seeding rates. Moisture conditions dramatically improved from the 3rd week of June onwards at Indian Head in 2015 and, in general, later seeded or maturing crops had an advantage at this site. Averaged across all sites in Demonstration #1, higher seeding rates resulted in a 6% yield increase while seed treatments resulted in a 7% increase and foliar fungicides increased yields by 16%. With the exception of the F x T x R interaction at Indian Head in 2015, no interactions were detected suggesting that the observed responses to individual factors were largely independent of each other.

**Table 8. Least squares means for main effects of fungicide, seed treatment and seeding rate on winter wheat grain yield. Data were analyzed separately for each site and main effect means followed by the same letter do not significantly differ (Fisher's protected LSD test; $P \leq 0.05$).**

| Main Effect | Scott-2014 | IH-2013 | IH-2014 | IH-2015 |
|---|---|---|---|---|
| Fungicide | | kg/ha | | |
| 1) Untreated | 4144 b | — | 4654 b | 3336 b |
| 2) Treated | 5342 a | — | 5346 a | 3507 a |
| S.E. | 427.5 | — | 142.9 | 54.4 |
| Seed Treatment | | | | |
| 1) Untreated | 4539 b | 5567 b | 4947 b | 3369 b |
| 2) Treated | 4947 a | 6426 a | 5053 a | 3473 a |
| S.E. | 427.5 | 323.0 | 104.1 | 54.4 |
| Seeding Rate | | | | |
| 1) 200 seeds $m^{-2}$ | 4617 a | 5522 b | 4898 b | 3530 a |
| 2) 300 seeds $m^{-2}$ | 4632 a | — | 5086 a | 3390 b |
| 3) 400 seeds $m^{-2}$ | 4981 a | 6471 a | 5015 ab | 3343 b |
| S.E. | 437.3 | 323.0 | 107.1 | 59.5 |

*Effects on Test Weight & Seed Size*

Results from the tests of fixed effects and main effect means for test weight are presented in Tables 9 and 10 while those for TKW are in Tables 11 and 12. Winter wheat test weight was affected by foliar fungicide at 3/3 sites ($P$ < 0.001-0.007) by seed treatment at 2/4 sites and by seeding rate at 3/4 sites. Focussing on fungicides, the effect on test weight was small but always positive and significant with increases ranging from 0.8-3.3% and averaging 2%. At the two sites where test weights were significantly higher with seed treatments, the increase was 0.5-2.4% while the average increase across all sites was 0.8%. Higher seeding rates had a positive effect at two sites (+ 0.5-1.6%), no effect at one site and a slight negative effect (- 0.4%) at one site. Averaged across all four sites, increasing the seeding rate from 200 to 400 seeds $m^{-2}$ resulted in a net increase in test weight of approximately 0.6%.

**Table 9. Tests of fixed effects for fungicide, seed treatment, seeding rate and their interactions on winter wheat test weight.**

| 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-2013 | — | **<0.001** | **<0.001** | — | — | **0.045** | — |
| 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** |
| Scott-2014 | **<0.001** | 0.540 | 0.227 | 0.877 | 0.654 | 0.441 | 0.849 |

**Table 10. Least squares means for main effects of fungicide, seed treatment and seeding rate on winter wheat test weight. Data were analyzed separately for each site and main effect means followed by the same letter do not significantly differ (Fisher's protected LSD test; *P* ≤ 0.05).**

| Main Effect | Scott-2014 | IH-2013 | IH-2014 | IH-2015 |
|---|---|---|---|---|
| Fungicide | ---------- g/0.5 l ---------- | | | |
| 1) Untreated | 384.9 b | — | 392.2 b | 396.4 b |
| 2) Treated | 397.6 a | — | 399.3 a | 399.4 a |
| S.E. | 2.17 | — | 1.21 | 0.217 |
| Seed Treatment | | | | |
| 1) Untreated | 390.9 a | 399.9 b | 395.6 a | 396.8 b |
| 2) Treated | 391.6 a | 409.5 a | 395.9 a | 399.1 a |
| S.E. | 2.17 | 2.27 | 1.12 | 0.21 |
| Seeding Rate | | | | |
| 1) 200 seeds $m^{-2}$ | 390.7 a | 401.2 b | 394.6 b | 398.9 a |
| 2) 300 seeds $m^{-2}$ | 390.4 a | — | 396.2 a | 397.4 b |
| 3) 400 seeds $m^{-2}$ | 392.6 a | 407.8 a | 396.4 a | 397.4 b |
| S.E. | 2.24 | 2.27 | 1.16 | 2.43 |

While there were fewer significant effects relative to test weight, TKW (or seed size) was still affected by fungicide at 3/3 sites and seed treatment at 1/3 sites (Table 11). Foliar fungicides consistently increased TKW with the change ranging from 2.2% at Indian Head in 2015 to 10.6% at this same location in 2014 and a similarly large increase at Scott in 2014 of 9.1%. Averaged across the three sites where TKW was measured, foliar fungicide applications increased winter wheat TKW by 7.3%. The only site where seed treatments affected TKW was Indian Head in 2015 where their use resulted in a 2.9% increase relative to untreated seed. The average increase in TKW with seed treatment was 1.1% across all three sites. Again, seeding rate did not significantly affect TKW at any sites and the actual values observed across seeding rates were very similar at all sites.

**Table 11. Tests of fixed effects for fungicide, seed treatment, seeding rate and their interactions on winter wheat thousand kernel weight.**

| 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-2013 | — | — | — | — | — | — | — |
| 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 |
| Scott-2014 | **<0.001** | 0.850 | 0.099 | 0.986 | 0.527 | 0.155 | 0.793 |

**Table 12. Least squares means for main effects of fungicide, seed treatment and seeding rate on winter wheat thousand kernel weight. Data were analyzed separately for each site and main effect means followed by the same letter do not significantly differ (Fisher's protected LSD test; *P* ≤ 0.05).**

| Main Effect | Scott-2014 | IH-2013 | IH-2014 | IH-2015 |
|---|---|---|---|---|
| Fungicide | g/1000 seeds | | | |
| 1) Untreated | 35.0 b | — | 31.2 b | 31.4 b |
| 2) Treated | 38.2 a | — | 34.5 a | 32.1 a |
| S.E. | 0.66 | — | 0.25 | 0.20 |
| Seed Treatment | | | | |
| 1) Untreated | 36.6 a | — | 32.8 a | 31.3 b |
| 2) Treated | 36.6 a | — | 32.9 a | 32.2 a |
| S.E. | 0.66 | — | 0.23 | 0.20 |
| Seeding Rate | | | | |
| 1) 200 seeds $m^{-2}$ | 36.8 a | — | 33.0 a | 31.9 a |
| 2) 300 seeds $m^{-2}$ | 36.2 a | — | 32.8 a | 31.6 a |
| 3) 400 seeds $m^{-2}$ | 36.7 a | — | 32.8 a | 31.9 a |
| S.E. | 0.67 | — | 0.26 | 0.25 |

*Demonstration #2: Timing of Foliar Fungicides for Winter Wheat*

Again, the purpose of Demonstration #2 was to provide information on winter wheat response to contrasting fungicide timings and make recommendations regarding which timings are likely to provide the greatest benefit(s). Unlike the previous trials, response data in this case were combined and the overall test of the fixed effects site, fungicide treatment and their interaction are presented in Table 13. All of the variables measured were affected by both site ($P$ < 0.001) and fungicide treatment ($P$ < 0.001-0.002) while the interaction was significant for leaf disease, FHB index, grain yield and TKW ($P$ < 0.001-0.013) but not test weight ($P$ = 0.097). A significant site by fungicide treatment interaction indicates that the observed effects varied across sites.

**Table 13. Tests of fixed effects (site and fungicide timing) on winter wheat response variables. Unless otherwise indicated, results are for all four sites (Indian Head 2013-15 and Scott 2014).**

| Variable | Site-Year (S) | Treatment (T) | S X T |
|---|---|---|---|
| | ---------- | Pr. > *F* | ---------- |
| Leaf Disease[Z] | **<0.001** | **<0.001** | **<0.001** |
| FHB Index[Y] | **<0.001** | **0.002** | **0.013** |
| Yield | **<0.001** | **<0.001** | **<0.001** |
| Test Weight | **<0.001** | **<0.001** | 0.097 |
| TKW[X] | **<0.001** | **<0.001** | **0.002** |

[Z] Scott 2014 excluded (data not available)
[Y] Indian Head 2015 excluded (no FHB observed)
[X] Indian Head 2013 excluded (data not available)

Leaf disease severity was assessed using a scale of 0-12 where, at the maximum value, 26-50% of the flag leaf and over half of the mid and lower canopy is affected by disease (Table 14). Ten plants from each plot were rated at the milk stage which was late enough to take into account effects of both fungicide applications. As expected, 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 a fungicide was applied at anthesis and intermediate when only the flag-leaf application was applied. In 2015 at Indian Head, disease levels in the check were lower than for the previous two seasons and, of the treated plots, leaf disease was highest with flag leaf application, lowest with a dual application and intermediate with a single application at anthesis. The improved leaf disease control with the later application in 2014 and 2015 was likely due to the fact that these seasons tended to be wetter later in the season while 2013 was relatively wet early on but became much drier into late June / early July. Contrasts comparing the combined fungicide treatments to the check were significant ($P < 0.001$) in all three cases.

**Table 14. 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 15. Mean winter wheat leaf disease severity as affected by foliar fungicide treatments. Means followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).**

| Treatment | Indian Head (2013) | Indian Head (2014) | Indian Head (2015) | Scott [Z] (2014) | Average |
|---|---|---|---|---|---|
| | ------------------------------------- McFadden Scale (1-12) --------------------------------------- | | | | |
| 1) Check | 10.2 b | 10.9 a | 9.0 d | — | 10.0 A |
| 2) Flag Leaf | 7.6 f | 9.6 c | 8.3 e | — | 8.5 B |
| 3) Anthesis | 7.5 f | 7.9 ef | 8.0 ef | — | 7.8 C |
| 4) Dual | 6.8 g | 7.7 f | 7.7 f | — | 7.4 D |
| Std. Error | ------------------------- 0.16 ------------------------- | | | — | 0.09 |
| | --------------------------------------------- (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 is a good indicator of the overall severity of FHB within the plots. Overall, pressure was highest at Indian Head in 2014 followed by Indian Head in 2013, then Scott in 2014 and finally Indian Head in 2015 where no FHB symptoms whatsoever were observed (Table 16). At Indian Head in 2013, FHB was present but at relatively low levels and the treatment effects were not statistically significant; however, there was a slight numerical reduction when fungicide was applied at anthesis. In 2014, with higher disease pressure, FHB index was reduced from 7.8 to 2.9-3.8 with fungicide applied at heading / early anthesis. Fungicide applied at the flag-leaf stage does not target and, as expected did not affect FHB index. At Scott, there was very little visual evidence of FHB infection and, consequently, no significant treatment effects or notable trends in this data for that location. At Indian Head in 2015, with the extremely dry weather through May and most of June, no FHB symptoms were observed. Consequently, all FHB index values were zero and data from this site was excluded from the analysis.

**Table 16. Mean winter wheat FHB index as affected by foliar fungicide treatments. Means followed by the same letter do not significantly differ (Fisher's protected LSD test, P ≤ 0.05).**

| Treatment | Indian Head (2013) | Indian Head (2014) | Indian Head [Z] (2015) | Scott (2014) | 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** |

[Z] Indian Head (2005) excluded from analyses due to there being no FHB observed on any plants

Winter wheat yields were affected by site and fungicide treatment with a significant interaction between these factors (Table 13) and treatment means are presented in Table 17. Averaged across treatments, yields were highest at Indian Head in 2013, were considered about average at both sites in 2014, and were below average at Indian Head in 2015. All fungicide treatments resulted in a significant yield increase relative to the check, averaging 16% across the four locations. Averaged across all of the treatments where fungicides were applied, the mean increases were 15% ($P = 0.002$), 11% ($P < 0.001$), 7% ($P < 0.001$) and 30% ($P = 0.003$) at Indian Head 2013, 2014, 2015 and Scott 2014, respectively. At Indian Head in 2014, where both leaf disease and FHB pressure were highest, yields with the dual application were 219-341 kg ha$^{-1}$, or 5%, higher than for either of the single fungicide application treatments. In the other three cases, there was no apparent yield advantage to the dual application versus either of the single applications.

**Table 17. Mean winter wheat grain yield as affected by foliar fungicide treatments. Means followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).**

| Treatment | Indian Head (2013) | Indian Head (2014) | Indian Head (2015) | Scott (2014) | Average |
|---|---|---|---|---|---|
| | ---------- Grain Yield (kg/ha) ---------- | | | | |
| 1) Check | 6000 cd | 5294 e | 3073 h | 4525 f | 4723 B |
| 2) Flag Leaf | 6747 ab | 5855 d | 3291 g | 5801 cde | 5424 A |
| 3) Anthesis | 6850 ab | 5733 d | 3265 g | 6028 b-e | 5469 A |
| 4) Dual | 7004 a | 6074 c | 3280 g | 5805 cde | 5541 A |
| Std. Error | 218.7 | 54.5 | 39.8 | 360.6 | 106.8 |
| | ---------- (Pr. > *F*) ---------- | | | | |
| Check vs Rest | **0.002** | **<0.001** | **<0.001** | **0.003** | **<0.001** |

Test weight was affected by site (*P* < 0.001) and fungicide treatment (*P* < 0.001) but with no site by treatment interaction (*P* = 0.097; Table 13) and means for this variable appear in Table 18. Averaged across all sites, the flag-leaf application on its own resulted in a slight but significant (0.7%) increase in test weight and a tendency for the highest test weights when fungicide was applied during heading (1.3%). Again, the check versus rest contrast was significant in all possible cases (*P* < 0.001-0.024).

**Table 18. Mean winter wheat test weight as affected by foliar fungicide treatments. Means followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).**

| Treatment | Indian Head (2013) | Indian Head (2014) | Indian Head (2015) | Scott (2014) | Average |
|---|---|---|---|---|---|
| | ------ Test Weight (g 0.5 $l^{-1}$) ------ | | | | |
| 1) Check | 405.2 b | 395.0 f | 395.8 ef | 388.9 g | 396.2 C |
| 2) Flag Leaf | 406.1 b | 397.8 cde | 397.7 d | 395.0 c-g | 399.1 B |
| 3) Anthesis | 410.6 a | 400.1 c | 398.4 cd | 396.3 c-g | 401.4 A |
| 4) Dual | 411.0 a | 400.1 c | 397.9 cd | 397.1 c-f | 401.5 A |
| Std. Error | 1.31 | 0.92 | 0.58 | 2.71 | 1.05 |
| | ------ (Pr. > *F*) ------ | | | | |
| Check vs Rest | **0.008** | **<0.001** | **<0.001** | **0.024** | **<0.001** |

Thousand kernel weights (TKW) were measured at all sites except Indian Head in 2013. Treatment effects were similar to those observed for test weight, where there was an overall increase with fungicide that was most profound in the treatments which included an anthesis application. Averaged across the three sites, the flag leaf application resulted in a 4.5% increase in TKW while the application at heading resulted in a 6% increase and the increase with a dual application was 7% over the check. The significant site by fungicide interaction was due to the dual and (to a lesser extent) anthesis applications having significantly higher TKW at Indian Head and Scott in 2014 but similar TKW across all treatments that received a fungicide at Indian Head in 2015.

**Table 19. 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, $P \leq$ 0.05).**

| Treatment | Indian Head (2013) | Indian Head (2014) | Indian Head (2015) | Scott (2014) | Average |
|---|---|---|---|---|---|
| | Thousand Kernel Weight (g 1000 seeds$^{-1}$) | | | | |
| 1) Check | — | 32.5 ef | 31.9 f | 34.6 cd | 33.0 C |
| 2) Flag Leaf | — | 33.5 de | 32.5 ef | 37.6 b | 34.5 B |
| 3) Anthesis | — | 34.7 c | 32.9 ef | 37.8 ab | 35.1 AB |
| 4) Dual | — | 35.0 c | 32.3 f | 38.7 a | 35.3 A |
| Std. Error | — | 0.41 | | | 0.24 |
| | (Pr. > *F*) | | | | |
| Check vs Rest | — | **<0.001** | **<0.001** | **<0.001** | **<0.001** |

*Extension and Acknowledgement*

At Indian Head, the site of these field trials was a formal stop at the Indian Head 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. At Scott in 2014, 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. For this event, Brian Beres and Lyze Boivert were invited to discuss the practices being demonstrated. The field trials were not a formal stop at the Indian Head Field Day in 2015 but were visited by industry agronomists and producers on several occasions. 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. Updated results from this project will be continue to be made available in the IHARF Annual Reports (available online) and also made available through a variety of other media (i.e. oral presentations, popular agriculture press, fact sheets, etc.) as opportunities arise. The project is continuing at Indian Head in 2015-16.

## 11. Conclusions and Recommendations

This project has demonstrated the merits of seed treatments and foliar fungicides for optimizing stand establishment and minimizing the impacts of disease on winter wheat yield and quality. Focussing on establishment, increasing seeding rates continues to be 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 / seedling diseases and can help winter wheat cope with early season stresses thereby increasing the probability of overwintering successfully. The response to seed treatments in these trials was quite strong with significant impacts on crop establishment (plant density and/or NDVI) and grain yield at all four sites. The responses observed in 2014 and 2015 were probably more typical of what producers might expect; however, the very strong response at Indian Head in 2013 was certainly noteworthy and demonstrates the impact that seed treatments can have under extremely stressful conditions. At this site, winter wheat was planted into extremely dry soil and did not emerge until the following spring – 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 and 2015 it was 2-3%. Despite the atypical results in 2015 where yields were slightly higher at the lowest seeding rate, our results generally support the recommendation that winter wheat producers should seed at rates of 300 seeds $m^{-2}$ or higher. Additionally, these results suggest that growers should use treated seed to increase the likelihood of strong establishment, particularly when conditions at planting might delay emergence or slow down early season growth.

Once the crop is established, foliar fungicides are often required to achieve top winter wheat yields. In these particular sites, yield increases with foliar fungicide ranged from 7-30%. Indian Head in 2014 was the only case where a dual fungicide application resulted in a significantly higher yield than either of the single applications. Fungicides applications, particularly at anthesis, generally resulted in higher test weights and thousand seed weights. Furthermore, while both fungicide application times tended to reduce leaf disease, only the latter of the two will supress FHB infection. 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 advised to defer fungicide applications until heading and to then choose a product that is also registered for control of fusarium head blight. When overall disease pressure is high, particularly early in the season, a dual application may be justified; however, under moderate disease pressure, fungicides applied at early heading are likely to provide the most consistent yield and quality benefits.

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## Supporting Information

### *12.* Acknowledgements:

In 2014 and 2015, this 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 products evaluated in this demonstration were provided in-kind by BASF and Bayer CropScience and, each year, seed was sourced and provided in-kind by Ducks Unlimited. In 2013, financial support for the field demonstrations was also provided by Ducks Unlimited.

## 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 | Scott-2014 | IH-2013 | IH-2014 | IH-2015 |
|---|---|---|---|---|---|---|
| | | seeds/m$^2$ | ---------- NDVI ---------- | | | |
| no | no | 200 | – | – | 0.308 fh | 0.414 ab |
| no | no | 300 | – | – | 0.388 abcd | 0.406 abc |
| no | no | 400 | – | – | 0.375 abcd | 0.423 ab |
| no | yes | 200 | – | – | 0.333 efg | 0.417 ab |
| no | yes | 300 | – | – | 0.396 abcd | 0.427 a |
| no | yes | 400 | – | – | 0.398 abcd | 0.426 a |
| yes | no | 200 | – | 0.198 c | 0.328 dgh | 0.396 abc |
| yes | no | 300 | – | – | 0.368 bcef | 0.417 ab |
| yes | no | 400 | – | 0.234 b | 0.380 abce | 0.380 c |
| yes | yes | 200 | – | 0.257 b | 0.343 cdfg | 0.393 bc |
| yes | yes | 300 | – | – | 0.415 a | 0.401 abc |
| yes | yes | 400 | – | 0.309 a | 0.398 abe | 0.405 abc |
| S.E. | – | – | – | 0.018 | 0.023 | 0.011 |

**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 | Scott-2014 | IH-2013 | IH-2014 | IH-2015 |
|---|---|---|---|---|---|---|
| | | seeds/m$^2$ | ---------- kg/ha ---------- | | | |
| no | no | 200 | 4020 c | – | 4444 e | 3459 b |
| no | no | 300 | 3714 c | – | 4742 cd | 3145 c |
| no | no | 400 | 4086 c | – | 4618 de | 3268 bc |
| no | yes | 200 | 4045 c | – | 4654 de | 3430 b |
| no | yes | 300 | 4480 bc | – | 4721 cd | 3469 b |
| no | yes | 400 | 4516 bc | – | 4741 cd | 3243 bc |
| yes | no | 200 | 4574 bc | 4913 b | 5203 bc | 3437 b |
| yes | no | 300 | 5106 ab | – | 5333 ab | 3471 b |
| yes | no | 400 | 5735 a | 6220 a | 5340 ab | 3435 b |
| yes | yes | 200 | 5827 a | 6132 a | 5291 b | 3795 a |
| yes | yes | 300 | 5230 ab | – | 5548 a | 3477 b |
| yes | yes | 400 | 5586 a | 6722 a | 5361 ab | 3425 b |
| S.E. | – | – | 517.3 | 358.7 | 163.6 | 93.9 |

**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* ≤ 0.05).**

| Foliar Fungicide | Seed Treatment | Seeding Rate | Scott-2014 | IH-2013 | IH-2014 | IH-2015 |
|---|---|---|---|---|---|---|
| | | seeds/m$^2$ | g/1000 l | | | |
| no | no | 200 | 383.1 b | – | 390.7 b | 396.3 f |
| no | no | 300 | 382.5 b | – | 391.9 b | 394.5 g |
| no | no | 400 | 387.9 b | – | 393.7 b | 395.0 g |
| no | yes | 200 | 384.7 b | – | 391.1 b | 398.3 cd |
| no | yes | 300 | 385.3 b | – | 392.0 b | 397.5 def |
| no | yes | 400 | 386.1 b | – | 393.6 b | 396.8 ef |
| yes | no | 200 | 396.8 a | 395.3 c | 398.4 a | 398.9 bc |
| yes | no | 300 | 396.5 a | – | 399.7 a | 397.8 cde |
| yes | no | 400 | 398.6 a | 404.4 b | 399.3 a | 398.2 cd |
| yes | yes | 200 | 398.3 a | 407.8 ab | 398.4 a | 402.1 a |
| yes | yes | 300 | 397.3 a | – | 401.3 a | 399.9 b |
| yes | yes | 400 | 397.8 a | 411.2 a | 398.9 a | 399.8 b |
| S.E. | – | – | 2.78 | 2.44 | 1.55 | 0.45 |

**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 | Scott-2014 | IH-2013 | IH-2014 | IH-2015 |
|---|---|---|---|---|---|---|
| | | seeds/m$^2$ | ------------------------------ g/1000 seeds | | | ------------------------------ |
| no | no | 200 | 34.7 b | – | 31.7 bc | 31.1 bc |
| no | no | 300 | 34.7 b | – | 31.4 bcd | 30.7 c |
| no | no | 400 | 35.6 b | – | 30.4 d | 30.8 c |
| no | yes | 200 | 35.5 b | – | 32.1 b | 32.1 abc |
| no | yes | 300 | 34.6 b | – | 30.8 cd | 32.0 abc |
| no | yes | 400 | 34.9 b | – | 31.2 bcd | 32.0 abc |
| yes | no | 200 | 38.4 a | – | 34.0 a | 31.9 abc |
| yes | no | 300 | 37.7 a | – | 34.3 a | 31.1 bc |
| yes | no | 400 | 38.4 a | – | 35.3 a | 32.4 ab |
| yes | yes | 200 | 38.8 a | – | 34.4 a | 32.3 ab |
| yes | yes | 300 | 37.9 a | – | 34.8 a | 32.7 a |
| yes | yes | 400 | 37.9 a | – | 34.5 a | 32.3 ab |
| S.E. | – | – | 0.76 | – | 0.47 | 0.49 |


**Abstract**

**14. Abstract/Summary:**

Winter wheat trials were conducted over four site-years to demonstrate seed rate, seed treatment and foliar fungicide effects on winter wheat establishment, yield and quality. In all cases, benefits to both seed treatments and foliar fungicides were detected. Where spring plant densities were measured, seed treatments increased populations by 30-100% and early season NDVI was higher with treated seed in 2/3 possible site-years. Seed treatments, on average, resulted in yield increases of 2-15%. Additionally, failure to apply foliar fungicides resulted in significant yield losses from leaf spot disease and fusarium head blight with 15-30% higher yields when fungicides were applied. Adjacent trials showed that fungicide applied at flag-leaf versus anthesis resulted in similar yield increases; however, while fungicide applied at anthesis still protected against leaf disease, flag-leaf application cannot suppress fusarium head blight. There was one case where dual application resulted in higher yield than either of the single applications.