2015 Annual Report
for the
Agriculture Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Fungicide Application Timing to Increase Yield in Soft White Wheat
Project Number: 20140346
Producer Group Sponsoring the Project: Western Applied Research Corporation

Project Location: AAFC Scott Research Farm, R.M. #380, NE 17-39-21 W3

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Objectives and Rationale

Project Objectives

The objective of this project was to demonstrate the effects of fungicide products and timing on grain yield and quality of soft white wheat.

Project Rationale

Foliar fungicide have been shown to improve crop yields in red spring and durum varieties of wheat, but its effect on soft white wheat is yet to be established. The timing of application in spring wheat and durum has shown a significant effect on the efficacy of the fungicides. Gooding et al. (2000) reported an 11% increase in average grain weight and a 13% increase in overall yield when fungicides were applied to wheat at the flag leaf stage. As producers in the area have experimented with both flag leaf and head emergence timing, it is important to determine the correct application time. Therefore, our goal is to show producers the optimal fungicide application time on soft white wheat to improve overall yield and seed quality.

Methodology and Results

Methodology

This demonstration was conducted at the AAFC Scott Research Farm in 2015. The treatments were arranged in a randomized complete block design with four replicates. On May 11, sadash soft white wheat was seeded at a rate of 300 seeds m^{-2} with an R-Tech drill seeder in a 10 inch row spacing and at a depth of 3-4cm. Fertilizer was applied at seeding according to soil test recommendations and weeds were controlled using a pre-seed burndown and registered in-crop herbicides (See Appendix, Table A.1. for complete details of field maintenance activities). Fungicides and their application timing followed the treatment list and were based at the recommended label rates (Table 1).

Table 1: Treatment list for the 2015 growing season

Treatment	Fungicide	Active Ingredient	Zadoks Timing (Z)
1	Untreated Check	n/a	n/a
2	Twinline	Pyraclostrobin + Metconazole	38[w]
3	Folicur	Tebuconazole	38
4	Prosaro	Prothiaconazole+ Tebuconazole	58[x]
5	Caramba	Metconazole	58
6	Prosaro	Prothiaconazole+ Tebuconazole	60[y]
7	Caramba	Metconazole	60
8	Prosaro	Prothiaconazole+ Tebuconazole	64[z]
9	Caramba	Metconazole	64
10	Twinline & Prosaro	Pyraclostrobin + Metconazole & Prothiaconazole+ Tebuconazole	60
11	Twinline & Caramba	Pyraclostrobin + Metconazole& Metconazole	60
12	Folicur & Prosaro	Tebuconazole & Prothiaconazole+ Tebuconazole	60
13	Folicur & Caramba	Tebuconazole & Metconazole	60

[w] flag leaf; [x] Late heading; [y] Full heading but no flowering; [z] Mid flowering

Figure 1. Wheat developmental stages. From left to right: flag leaf (Z38), late heading (Z58), full heading but no flowering (Z60), mid flower (Z64)

Spring plant densities were assessed at three weeks after seeding to determine similar plant emergence among treatments. These were assessed by counting two 1 m rows in the front and back of the plot for a total of four rows per plot. The average of the four rows was converted to plants per m^{-2} based on 10 inch row spacing. Leaf, stem and/or head disease ratings of incidence and severity were assessed at Zadoks 38, Zadoks 60, and Zadoks 85 using modified versions of Clive James assessment keys and McFadden cereal foliar disease rating scale (Appendix B; Figure B.1 and Table B.1). Disease ratings were calculated by assessing ten random plants throughout each plot then averaging the ratings in similar plots to develop our level of infection. Grain yields were determined after plots were mechanically harvested, cleaned and corrected to 14.5 % seed moisture. Test weights were determined using the Canadian Grain Commission protocols (Canadian Grain Commission, 2014). Percent FDK was also tested by a third party laboratory to determine seed disease infection level.

Statistical Analysis

An analysis of variance (ANOVA) was conducted on all variables using the PROC MIXED in SAS 9.3. Fungicide treatment and timing were considered fixed effect factors and replicates were considered a random effect factor. The assumptions of ANOVA (equal variance and normally distributed) were tested using Levene's test, and Shapiro-Wilks. The data fitted to the ANOVA assumptions. The data was normally distributed; therefore no data transformation was necessary. Treatment means were separated using Fisher's Protected LSD test and considered significant at $P < 0.05$. Contrasts were conducted to determine difference between the untreated check and similar treatments. PROC GLM regression was used on treatments of Prosaro and Caramba at Zadoks 58, 60 and 64. Weather data was collected from the Scott Environment Canada weather station (Table 2).

Weather Conditions

In 2015, the early growing season was very dry with only 4.1 mm and 19.4 mm accumulated precipitation during the month of May and June, respectively. July received 36 % less rainfall compared to the long term average. However, August received 39 % more moisture compared to the long-term average. The mean monthly temperatures were comparable to previous years (Table 2).

Table 2. Mean monthly temperature, precipitation and growing degree day accumulated from May to September 2015 at Scott, SK

Year	May	June	July	August	September	Average /Total
			Temperature (°C)			
2015	9.3	16.1	18.1	16.8	10.9	14.24
Long-term[z]	10.8	15.3	17.1	16.5	10.4	14.0
			Precipitation (mm)			
2015	4.1	19.4	46.4	74.5	49.6	194.0
Long-term[z]	36.3	61.8	72.1	45.7	36.0	215.9
			Growing Degree Days			
2015	140.3	332	405.1	365.8	179.8	1423.0
Long-term[z]	178.3	307.5	375.1	356.5	162.0	1379.4

[z]Long-term average (1981-2010)

Results

Plant Emergence

Plant emergence was not significantly different among treatments (P = 0.6540) (Table 4), indicating a similar plant establishment within the trial. This is important as different plant stands can influence yields. Therefore, any significant differences reported in this study is likely attributed to a fungicide timing or product effect and not caused by a difference in plant density.

Table 4. P values for main effects of fungicide application timing on measured response variable at Scott, SK in 2015.

	Plant Emergence (Plants/ m^{-2})	**Yield** (kg ha^{-1})	**Bushel Weight** (kg hl^{-1})	**FDK** (%)
		p values		
Fungicide	0.6540	0.0088	<.0001	0.0771

Grain Yield, Bushel Weight & FDK

Grain yield was significantly different among fungicide treatments (P = 0.0088), with the greatest yield achieved when fungicides were applied later in the growing season (Figure 2). A yield increase was reported when fungicide was applied at later growth stages (Z58 to Z64) compared to flag leaf stage (Z38). Flag leaf applications (Z38) of Folicur and Twinline resulted in low yields compared to the untreated check (Figure 2). However, Twinline resulted in significant difference (P < 0.05) in bushel weight compared to the untreated check. Overall, Twinline outperformed Folicur, as it had 11 % yield and 1.5 % bushel weight increase compared to the control, whereas Folicur resulted in a 5.9 % yield and a 0 .7 % bushel weight increase compared to the control (Figure 2).

Twinline + Prosaro applied at Z38 and Z60 resulted in a similar yield to Twinline alone and did not result in a significant yield increase compared to the untreated check. This was unanticipated as it had the highest bushel weight (81.9 kg/ hl) compared to all the treatments (Figure 2). In contrast, dual applications at Z38 and Z60 of Twinline + Caramba resulted in a yield and bushel weight increase of 20 % and 4 %, respectively, compared to the untreated control (Figure 2). This may be due to the synergistic effect of the dual products. The result was consistent with previous studies where dual fungicides were applied on winter wheat. For example, when tebuconazole was applied at Zadoks growth stage Z37 (Zadoks, 1974) and propiconazole applied at Z37 followed by triadimefon + mancozeb at Z55 to control leaf rust and Septoria tritici blotch, they consistently resulted in the lowest disease severities and highest winter wheat yields (Milus, 1994). However, Cromey et al. (2004) found no consistent effects of crop growth stage when the fungicides azoxystrobin and tebuconazole were applied at three alternative growth stages between flag leaf emergence and flowering to control *Didymella exitialis* (anamorph: *Ascochyta* spp.). From this study and previous studies, it can be deduced that, although there may be a synergistic effect of fungicide mixtures on disease control and yield, it may be product dependent as the contrasting studies had a mixture of different active ingredients in the fungicides.

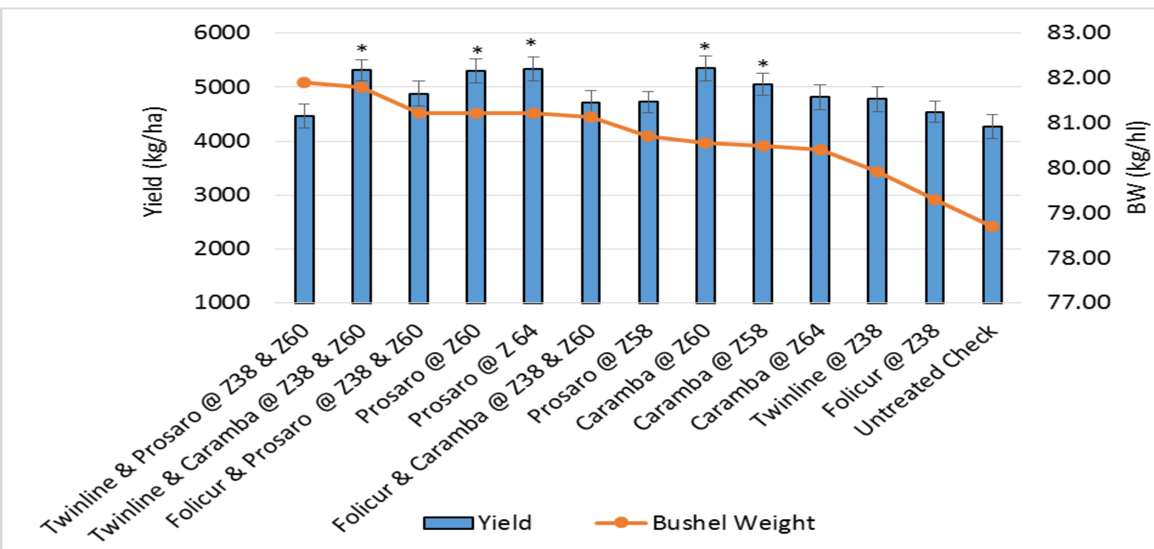

Figure 2. Yield (*columns*) and bushel weight (*line*) of soft white wheat at Scott, SK 2015 (columns with * indicate significant difference compared to the control).

Single applications of Caramba at Z58, Z60, and Z64 indicated that the ideal fungicide applications were between Z58 and Z60, with yields declining after applications at Z64 (Figure 3). However, the yield differences between the three fungicide application timings were not significantly different (Figure 3). Furthermore, Prosaro applied at Z64 resulted in similar yields when applied at Z58 and Z60 (Figure 4). These results indicate that different products may perform better at different application timing. However, applications of Prosaro and Caramba should have occurred at Z38 to confirm the actual effect of application timing on yield across all application timings. Overall, fungicide applications delayed until Z58 to Z64 resulted in greater yields compared to flag leaf application (Z38). This is therefore encouraged unless early disease pressure warrants early application. This is supported by Bockus et al. (1997) who found the optimum timing for fungicide application to be between the boot and the fully headed growth stages. Also, Duczek and Jones-Flory (1994) found the optimum timing of fungicide application to be between extension of the flag leaf and the medium milk growth stages. Again, Wiersma and Motteberg (2005) found that across cultivars, the optimum timing for foliar fungicide application was Z60 rather than Z39. These timings relates to our Z58-60 and Z38, respectively.

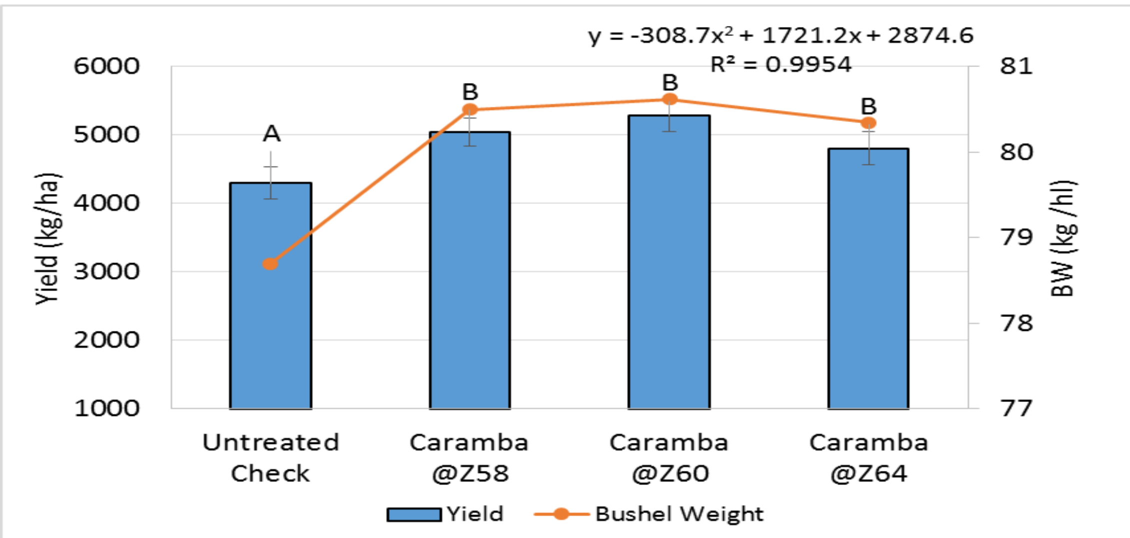

Figure 3. The effect of Caramba application timing on soft white wheat yield (*columns*) and bushel weight (*line*) at Scott, SK 2015. Main effect means followed by the same letter do not significantly differ (Fisher's protected LSD test; $P \leq 0.05$).

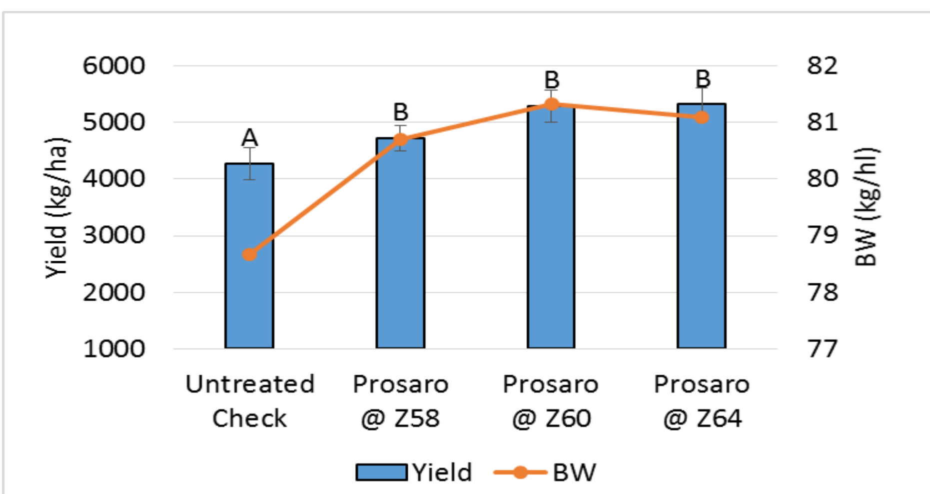

Figure 4. The effect of Prosaro application timing on soft white wheat yield (*columns*) and bushel weight (*line*) at Scott, SK 2015. Main effect means followed by the same letter do not significantly differ (Fisher's protected LSD test; $P \leq 0.05$).

There were no significant differences on percent Fusarium Damaged Kernel (% FDK) levels among treatments (Table 4). This might be because of the dry conditions at the onset of the study. The dry conditions may have slowed the development of diseases, resulting in very low disease severity. This can be corroborated by a study which states that the environment has a major influence on the development of plant disease epidemics, as temperature and moisture are especially critical to the development, reproduction, and survival of plant pathogens (Campbell and Madden, 1990). Although there was little disease development, the effect of fungicide on seed quality and grain yield was persistent throughout the trial. These results coincide with Kelley (2001), who found that over a period of six years, the fungicide propiconazole significantly increased winter wheat yield 77 % of the time. Similarly, Wegulo et al. (2009) showed that up to 42 % yield loss was prevented by applying foliar fungicides to winter wheat. Therefore, these studies suggest that in years with little risk of disease, fungicide applications may be cost-effective, because of yield benefits associated with fungicides.

Conclusions and Recommendations

These results suggest that fungicide application to soft white wheat can result in yield benefits even when environmental conditions do not favor disease development. Timing of fungicide application between Z58 to Z64 and dual applications at Z38 and Z60 generally resulted in a higher yield increase compared to a single application at Z38 and the untreated check. Therefore, based on this study, if disease is not prevalent and only a single application is affordable, then spraying should occur between Z58 to Z64 to ensure a yield benefit. However, fungicide application may offer potential advantage of reducing the risk of grade reduction when high levels of diseases are encountered. In cases where leaf disease symptoms develop early and have potential to cause significant damage, the earlier fungicide application may be warranted. Overall, this study shows that there are non-fungal benefits associated with fungicide applications as yield and seed quality increased, despite the low disease incidence and low seed contamination (% FDK). Further research should focus on early applications (Z38) as well as delayed (Z58 to Z65) for all the studied products, as no one product as applied during this range of development. Applications over these developmental stages will provide a clearer insight as the importance of timing and product efficacy for non-fungal benefits.

Supporting Information

Acknowledgements

We would like to thank the Ministry of Agriculture for the funding support on this project. We would also like to acknowledge the support of Herb Schell and our summer staff for their technical assistance with project development and implementation. This report will be distributed through WARC's website and included in WARC's annual report.

Appendices

Appendix A – Agronomic information for the demonstration
Appendix B – Clive James (1971). A Manual of Assessment Keys for Plant Diseases
– McFadden cereal foliar disease rating scale

Abstract

Abstract/Summary

The application of foliar fungicide have been shown to improve yields in red spring and durum wheat varieties, but its effect on soft white wheat is yet to be established. The timing of application on spring wheat and durum was shown to significantly affect fungicide efficacy. As producers in NW SK have experimented with both flag leaf and head emergence timing, especially in other wheat varieties, it is important to determine the correct application time for soft white wheat varieties as well. Therefore, this study was done to demonstrate to producers the optimal fungicide application time in soft white wheat, in order to improve overall yield and seed quality. The experiment was set up as a randomized complete block design (RCBD) with four replications. As expected there was no significant differences in plant population among treatments (P = 0.6540). Percentage FDK levels were also not significantly different among treatments. However, there were significant differences in grain yield (P = 0.0088) and bushel weight (P <.0001) among treatments. From this study, it can be concluded that fungicide applications at the flag leaf stage (Z38) may provide disease control but is less likely to result in a bushel weight and yield benefits. Dual fungicide applications have shown promise on yield benefits, but this is a costly option and it may not be profitable, except where there is disease pressure. This study also shown that there are non-fungal benefits associated with fungicide applications in years when disease incidence and seed contamination (% FDK) are low. Results from this demonstration will be distributed through WARC's website and included in WARC's annual report.

Appendix A
Agronomic information for 2015 demonstration

Table A.1. Agronomic information for Fungicide Application Timing to Increase Yield in Soft White Wheat trial at Scott, Saskatchewan, 2015.

Seeding Information	2015
Seeder	R-Tech Drill, 10 inch row spacing, knife openers
Seeding Date	May 11, 2015
Cultivar	Soft white wheat - Sadash
Seeding Rate	300 seeds m^{-2}
Stubble Type	Canola
Fertilizer applied	100 lbs N ac^{-1} as Urea, (balanced with MAP and AS in blend)-Mid-rowed 40 lbs P_2O_5 ac^{-1} as MAP/AS with seed
Plot Maintenance Information	
Pre-plant herbicide	Roundup ¾ L/ac + Pardner 0.4 L/ac (May 18, 2015)
In-crop herbicide	Buctril M 0.4 L/ac + Axial 0.48 L/ac (June 10, 2015)
Treatment Application	Fungicides applied according to the treatments
Desiccation	Glyphosate @ 1L/ac (August 20, 2015)
Data Collection	
Emergence Counts	May 29, 2015
Harvest Date	September 01, 2015

Appendix B

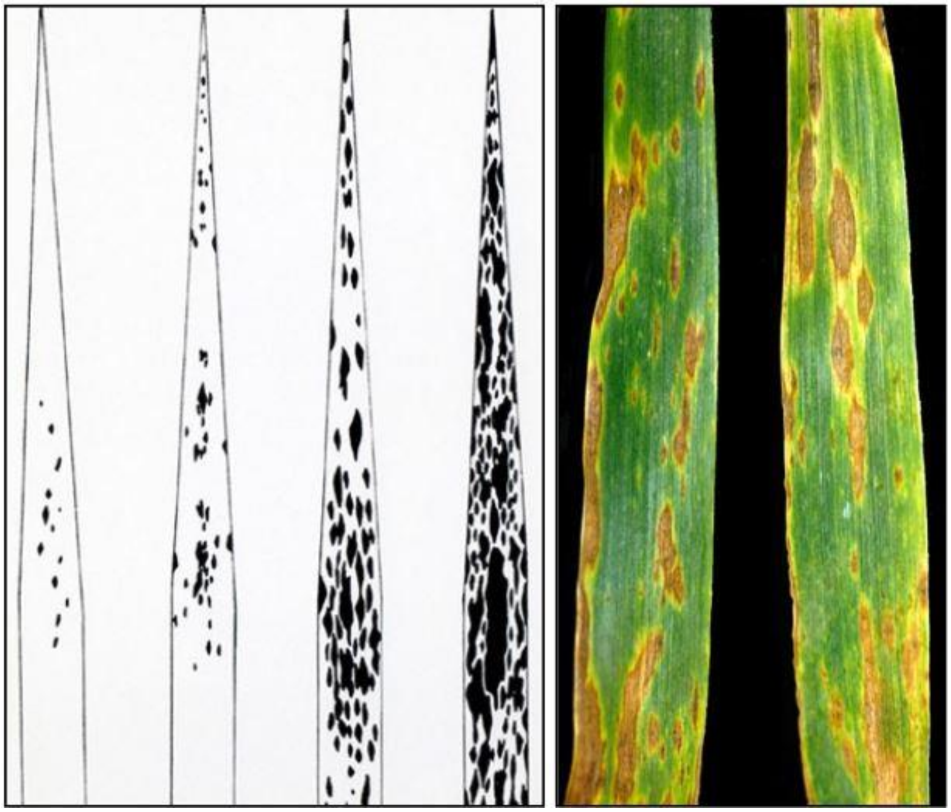

Figure B.1. A Manual of Assessment Keys for Plant Diseases (*Clive James, 1971. A manual of assessment keys for plant diseases. APS Press (Key 1.6.10))*

McFadden cereal foliar disease rating scale

Table B.1. 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

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