Using Cultivar Selection and Fungicide as Management Tools to Control Disease on Hard Red Winter Wheat, Langdon

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Winter wheat can offer growers some management alternatives that can be economically competitive with spring planted crops in some environments. Winter wheat can be more competitive against weeds and is planted in the fall so that a grower's work load can be more evenly distributed over a greater time period. This only fits well when resources are available to timely complete harvest of spring planted crops and plant the winter wheat. In the counties along the Canadian border winter wheat does not always profitably compete with hard red spring wheat (HRSW) and canola. This research project was design to evaluate management strategies that make winter wheat more competitive with HRSW and canola. The objective of the studies was to evaluate several cultivars and two fungicide management options that minimizes the negative effects of disease and increases both yield and profitability.

MATERIALS AND METHODS

Two sets of studies were conducted at the North Dakota State University Langdon Research Extension Center. The first set was conducted in 2003, 2004 and 2005 (**Flag** leaf timing) followed by a second set in 2007, 2008 and 2009 (**Anthesis** timing). The objectives for each of the studies were similar. Some of the variables were changed for the second study (Table 1) and comparisons within each study are relevant but between studies are not statistically relevant in most cases. In each year prior to the initiation of the Flag study, the plot area was fallowed until July and then planted to soybean or flax to provide for snow catch and minimize winter injury. Both sets of trials were designed as a randomized complete block with split plot arrangements and four replicates. Cultivars were the whole plot factor and treatments were the subplot factor. For both sets of studies the target planting date was mid September. Seven 15 cm wide rows twenty feet long were planted with a notill double disk type drill into standing residue to maximize the snow catch and increase chances of winter survival. Additional plots were planted between the treated and untreated plots to minimize spray drift to adjacent plots. Cultivars evaluated in the Flag study included Elkhorn, Jerry, Ransom, Roughrider, and Seward. The cultivars planted in the Anthesis study included CDC Falcon, Jagalene, Jerry, Ransom, and Wesley. Fertilizer was fall applied for the Flag study and equally split between spring and fall application for the Anthesis both by broadcast method. Soil and applied nitrogen were adjusted to meet target nitrogen levels of 150 lb/acre.

To encourage the development of Fusarium head blight in the Anthesis studies a *Fusarium* grain inoculum was hand-broadcast in equal amounts on the plot area, three weeks prior to heading. In the Flag study, the fungicide evaluated was pyraclostrobin which is marketed by BASF under the trade name Headline (2.09EC). Headline is very effective against foliar disease on small grain and was applied at 6 fl oz /acre. For the Anthesis studies the fungicide applied was Prosaro (421 SC 3.57 lb/gal. formulation of prothioconazole/tebuconazole, 19% +19% w/w) which is manufactured and marketed by Bayer CropScience). Prosaro is especially effective against

Fusarium head blight but is also effective against most foliar diseases on wheat. The Prosaro fungicide was tank mixed with Induce adjuvant (Helena Chemical Co.) and applied at 6.5 fl oz /acre and 0.125%v/v, respectively. The fungicide treatments were applied with a CO_2-pressurized backpack sprayer. The boom was equipped with three nozzles spaced 20 inches apart. For the first study the principal target was to protect the flag leaf from foliar disease. The flag leaf provides the majority of photosynthesis contribution to yield. The boom was equipped with XR8001 nozzles oriented vertically delivering 9.2 GPA of spray solution. In the Anthesis study, the principal target was to protect the grain head, and secondarily to protect the flag leaf. For this study the boom was equipped with XR8001 nozzles mounted on a double swivel, angled downward from horizontal and oriented forward and backward. This unit delivered 18.4 GPA. Both spray systems were operated at 40 psi. Headline applications in the Flag study were made immediately after the flag leaf was completely emerged from the leaf sheath, Feekes growth stage (GS) 10.0. For the Anthesis study the Prosaro fungicide application was made after the main stem head was fully extended and flowering was initiated which occurs at Feekes GS 10.51. The application timing for the Anthesis study occurred about 10 calendar days after the boot GS timing. The heading dates for all the cultivars did not occur simultaneously so the fungicide applications for the Anthesis study were applied on two separate dates coinciding with anthesis of the cultivars in the study. Five leaves per plot were sampled from the both studies 20 days after flower initiation and visually assessed to determine the necrotic and infected area per leaf. For the 2007 study, because a severe infestation of leaf rust developed, an additional set of five leaves per plot was also sampled 12 days after flower initiation and evaluated to determine the percent diseased and necrotic area (from the F1 leaf which is the last leaf emerging before the flag emerges). This sampling was recorded as **Early**. Twenty days after the fungicide application in the Anthesis studies (soft dough growth stage, Feekes 11.2) twenty heads were sampled, removed and evaluated to determine FHB incidence (number of spikes infected) and head severity (number of infected kernels per head divided by total kernels per head). *Fusarium* head blight index is the summation of the incidence*severity. The plots were harvested with a Hege plot combine and the sample processed to determine yield, test weight, and protein. A sub sample of the grain was ground and sent to North Dakota State University to determine the presence of the toxin deoxynivalenol (DON) when FHB was present. North Dakota State University Extension recommended production practices for hard red winter wheat for Northeast North Dakota were followed. Data was analyzed with the general linear model (GLM) in SAS. Fischer's protected least significant differences (LSD) were used to compare means at the 5% probability level (Tables 2 and 7).

RESULTS AND DISCUSSION

Parameters and data from the Flag studies are reported in Tables 1 and 2-5 and the Anthesis studies in Tables 1 and 6-10. No significant winter kill was observed in any year for any of the cultivars. **Foliar diseases.** Primary diseases were Septoria leaf spot caused by *Stagonospora nodorum* in 2003 and tan spot caused by *Pyrenophora tritici-repentis* in 2004, 2005 and 2007. Leaf Rust, *Puccinia triticina* (formerly *recondita* f. sp. *tritici*) arrived late in the season in 2003, 2004 and 2005 and early in 2007 but only affected a few cultivars. Jagalene is susceptible to leaf rust infection and was severely affected in 2007. Powdery mildew caused by the pathogen *Blumeria graminis* f. sp. tritici, was present in the lower canopy in 2009. Powdery mildew has not been present very often. Bacterial blight and leaf spot, caused by the genus *Xanthomonas*,

was present in 2009. The bacterial diseases are transmitted by rain splash. Two major rain splash events occurred in late June and early July in 2009. Fungicide is not effective against bacterial pathogens. Generally foliar disease pressure caused by fungal pathogens was low in 2003 (Table 2), 2007, 2009 (Table 8) and very low in 2004 and 2008. Foliar disease developed near the end of the crop maturation and affected yields only slightly in most of the study years. Overall, the application of Headline had minimal affect on yield in 2003 and 2005 (Table 4). Yield averaged over all the cultivars was increased in 2004 from 78.6 to 85.6 bu /acre. A significant interaction (environment*cultivar* treatment) was measured for leaf disease (Table 6). Headline substantially reduced leaf disease for all cultivars except Seward in 2003. In 2004 only Roughrider had enough leaf disease to benefit from the Headline application. In 2005 all cultivars had substantially less leaf disease after the application of Headline. The early leaf disease, measured in 2007, only significantly affected cultivars CDC Falcon and Jagalene which are both susceptible to leaf rust. A significant environment*cultivar interaction was measured for late leaf disease in the Anthesis study. Differences among cultivars were small in 2007 at very high levels of necrosis and 2008 at very low levels of necrosis (Table 9). However in 2009, differences between cultivars were substantial reflecting some level of cultivar resistance to the bacterial and powdery mildew pathogen present in this environment. A cultivar*treatment interaction was measured in 2007 for the early leaf disease (Table 11). Significant differences by treatment were measured for Jagalene and Wesley. The late leaf data was included to contrast the differences between the two leaf stages in the relative short time period.

Head diseases. Fusarium head blight had the most effect on yield in 2005 and the Headline did not improve yield significantly. The application timing, GS 10.0, is too early to have a significant impact on FHB. Systemic fungicides usually provide protection for about 10 days. An environment*treatment interaction was measured for FHB head severity and index (Table 10). The application of Prosaro reduced head severity in 2007 but had no effect in 2008. The Prosaro did reduce FHB index in both years. The increased susceptibility of cultivar Jagalene was evident in 2007 and cultivar Wesley in 2007 and 2008 by FHB index (Table 9). The application of Prosaro also reduced FHB index on cultivars Jagalene and Wesley in 2007 and Wesley in 2008 (Table 11). Differences in DON accumulation were measured by cultivar and treatment (Table 8). The greatest resistance to DON accumulation was cultivar Ransom followed by CDC Falcon and Jerry. Jagalene and Wesley were most susceptible to DON accumulation. Overall the Prosaro application reduced DON levels by 47 percent in the Anthesis study. The levels of DON were affected by the Prosaro application in 2007 reducing the DON levels significantly on Jagalene, Jerry and Ransom. Wesley headed several days earlier than the other cultivars and differences between Wesley and the other cultivars could be the result of escape rather than differences in susceptibility.

Agronomic differences. Yields and grain qualities reflect the environmental conditions that occurred during the **Flag** study. Yields were excellent in 2003, acceptable in 2004 and disappointing in 2005 when head scab was present but not managed (Table 4). Both Jerry and Ransom had greater yields than the other cultivars in 2003 and 2004 (Table 5). In 2005 the two cultivars had numerically but not significantly greater yields. The test weights of Roughrider and Seward were greatest in 2003 and 2005. Jerry had the next greatest test weight in 2005. Roughrider and Ransom had the greatest test weights in 2004 when disease pressure was low. Both cultivars are susceptible to lodging and this was reflected in less test weight when the two

events (lodging and lower test weight) coincided. Protein was only determined in 2004 and 2005. Ransom and Seward had lower protein in 2004. Roughrider had greatest protein in 2005 followed by Elkhorn, Jerry and Ransom. In the **Anthesis** study, yield differences were measured by cultivar and environment (Table 9). Yield was lower in 2007 for cultivars most affected by disease, Jagalene, CDC Falcon and Wesley. Ransom had lower yields when conditions that were present that permitted lodging. Ransom is the most susceptible of the cultivars to lodging. Jagalene, Wesley, and CDC Falcon are shorter and more resistant to lodging. The application of Prosaro increased yield by an average of 23.7 bushels in 2007, 8.9 bushels in 2008 and 7.5 bushels in 2009 (Table 10). Test weight was increased significantly in all years and substantially in 2007 by 3.1 lb. /bushel. The application of Prosaro increased test weight on all cultivars in 2007 (Table 11). Test weight of Jagalene and Wesley were increased in 2008 and 2009. Ransom had increased test weight in 2008 and CDC Falcon and Jerry had increased test weight in 2009. Wesley had greater protein than Jagalene, Ransom and CDC Falcon (Table 8). Proteins were also greater in 2008 than the other environments. The application of Prosaro only increased protein in 2008 by 0.3% and decreased it by 0.3% in 2009 (Table 10). Fungicide treatment was effective when disease was present and the application timing and the fungicide chemistry corresponded to the specific disease and the susceptibility of the cultivar. Economics responses also are reflected by the aforementioned conditions. Jerry had the greatest tolerance to the disease present in the studies and would be the most profitable cultivar to plant when fungicide is not an option. The cultivar Ransom has weaker straw strength and is taller than the other cultivars.

Table 1. Contrasting differences between the two sets of studies.

Study Set 1	Study Set 2
Years conducted 2003, 2004 and 2005	Years conducted 2007, 2008 and 2009
Headline (6 fl. oz./acre)	Prosaro (6.5 fl. oz./acre)
Application Timing Feekes GS 10.0 (boot)	Application Timing Feekes GS 10.51(anthesis)
Cultivars Elkhorn, Jerry, Ransom, Roughrider, and Seward	Cultivars CDC Falcon, Jagalene, Jerry, Ransom, and Wesley
Primary target – leaf disease	Primary target – head disease
The ground was fallowed until July and planted to soybean or flax to provide for snow catch and minimize winter kill.	Planted into mature flax stubble all years

Table 2. Source of variation and confidence levels for yield, test weight, protein and leaf disease for winter wheat, Langdon 2003, 2004 and 2005.

Source of variation	Yield	Test weight	Protein	Leaf Disease
Cultivar	0.0034	0.1756	0.0873	0.1590
Treatment	0.1161	0.9487	0.0614	0.2007
Cult [a]*trt [b]	0.7593	0.0277	0.0474	0.3132
Environment	<0.0001	<0.0001	<0.0001	<0.0001
Cult*env [c]	<0.0001	0.0001	<0.0001	<0.0001
Trt*env	0.0096	0.1453	0.6976	<0.0001
Cult*trt*env	0.4385	0.8446	0.4872	0.0087
%C.V.	4.9	1.1	2.2	39.3

[a] Cult = cultivar, [b] trt = treatment and [c] env = environment.

Table 3. Yield, test weight, protein and leaf disease by winter wheat cultivar, averaged across all treatments and environments, fungicide treatment averaged across cultivars and environments or environment averaged across cultivars and treatments Langdon 2003, 2004 and 2005.

Cultivar	Yield (bushels/acre)	Test weight (lb/bushel)	Protein (%)	Leaf disease (%)
Elkhorn	67.9	55.8	13.4	20.6
Jerry	84.3	56.5	13.3	27.6
Ransom	80.5	56.3	12.8	34.8
Roughrider	66.6	57.6	13.6	33.5
Seward	68.5	56.7	12.4	15.4
LSD $_{(0.05)}$	8.5	NS	NS	NS
Headline	75.6	56.6	13.2	11.2
Untreated	71.5	56.6	13.0	41.6
LSD $_{(0.05)}$	NS	NS	NS	NS
2003	100.7	60.0	na	23.1
2004	82.1	54.9	12.2	7.0
2005	37.8	54.9	14.0	49.1

Table 4. Yield by environment and treatment averaged across all cultivars Langdon 2003, 2004 and 2005.

Environment	Treatment	Yield (bushels/acre)	Leaf Disease (%)
2003	Headline	101.9	13.3
	Untreated	99.5	33.0
2004	Headline	85.6	2.3
	Untreated	78.6	11.6
2005	Headline	39.1	18.0
	Untreated	36.5	80.2
LSD $_{(0.05)}$		0.6	1.4

Table 5. Test weight and protein by environment and cultivar averaged across all treatments Langdon 2003, 2004 and 2005.

Environment	Cultivar	Yield (bu/acre)	Test weight (lb/bushel)	Protein (%)	Leaf Disease (%)
2003	Elkhorn	90.3	59.9		19.6
	Jerry	116.4	59.5		35.1
	Ransom	110.6	59.4		26.5
	Roughrider	92.3	60.8		27.3
	Seward	94.0	60.3		7.3
2004	Elkhorn	79.4	53.4	12.7	2.1
	Jerry	93.9	54.8	12.6	2.9
	Ransom	89.6	55.8	11.9	4.9
	Roughrider	72.6	56.1	12.4	18.9
	Seward	75.1	54.3	11.7	6.0
2005	Elkhorn	34.1	54.1	14.1	40.1
	Jerry	42.5	55.3	14.1	44.9
	Ransom	41.3	53.6	13.8	73.0
	Roughrider	34.9	55.8	14.9	54.4
	Seward	36.4	55.7	13.2	33.0
$LSD_{(0.05)}$		0.3	1.6	0.1	3.6

Table 6. Leaf disease incidence by environment, cultivar and treatment Langdon.

Environment	Cultivar	Treatment	Leaf Disease (%)
2003	Elkhorn	Headline	6.9
		Untreated	32.3
	Jerry	Headline	26.5
		Untreated	43.8
	Ransom	Headline	9.5
		Untreated	43.5
	Roughrider	Headline	18.0
		Untreated	36.5
	Seward	Headline	5.4
		Untreated	9.2
2004	Elkhorn	Headline	1.6
		Untreated	2.6
	Jerry	Headline	2.3
		Untreated	3.5
	Ransom	Headline	2.7
		Untreated	7.1
	Roughrider	Headline	3.1
		Untreated	34.7
	Seward	Headline	1.9
		Untreated	10.2
2005	Elkhorn	Headline	8.6
		Untreated	71.6
	Jerry	Headline	11.2
		Untreated	78.6
	Ransom	Headline	52.2
		Untreated	93.9
	Roughrider	Headline	11.8
		Untreated	97.0
	Seward	Headline	6.1
		Untreated	60.0
$LSD_{(0.05)}$			7.1

Table 7. Source of variation and confidence levels for yield, test weight, protein, leaf disease Fusarium head blight and deoxynivalenol accumulation (DON) in the grain for winter wheat, Langdon 2007, 2008 and 2009.

Source of variation	Yield	Test weight	Protein	Leaf Disease		Fusarium head blight			
				Early	Late	Incidence	Head Severity	Index	DON
Cultivar	0.7123	0.6850	0.0198	<0.0001	0.6635	0.0426	0.1785	0.2009	<0.0001
Treatment	0.1119	0.2210	0.8198	0.1637	0.3537	0.1258	0.6069	0.3817	<0.0001
Cult [a]*trt [b]	0.1859	0.2064	0.4193	0.0303	0.3113	0.9052	0.3372	0.2828	0.0134
Environment	<0.0001	0.0001	<0.0001		<0.0001	<0.0001	0.0129	<0.0001	
Cult*env [c]	<0.0001	0.2210	0.0084		<0.0001	0.0496	0.3276	0.0279	
Trt*env	0.0009	<0.0001	0.0086		<0.0001	0.2188	0.0083	0.0001	
Cult*trt*env	0.0664	<0.0001	0.1117		0.5553	0.4406	0.2320	0.0286	
%C.V.	9.2	1.1	3.5	9.1	19.2	32.4	35.4	64.2	36.7

[a] Cult = cultivar, [b] trt = treatment and [c] env = environment.

Table 8. Yield, test weight, protein, leaf disease; Fusarium head blight incidence, head severity, and index; and deoxynivalenol accumulation (DON) in the grain by winter wheat cultivar, averaged across all treatments and environments, fungicide treatment averaged across cultivars and environments or environment averaged across cultivars and treatments Langdon 2007, 2008 and 2009.

Cultivar	Yield	Test weight	Protein	Leaf Disease		Fusarium head blight			
				Early	Late	Incidence	Head Severity	Index	DON
	(bu/a)	(lb/bu)	(%)	(%)	(%)	(%)	(%)		(ppm)
CDC Falcon	105.7	60.3	11.5	71.5	50.5	32.0	9.0	1.2	1.1
Jagalene	94.2	59.5	12.2	93.6	40.5	44.8	12.3	4.1	2.6
Jerry	100.9	59.7	12.5	52.8	43.3	35.7	11.1	1.8	1.1
Ransom	92.6	59.2	12.2	65.8	48.6	25.7	7.8	0.7	0.4
Wesley	98.8	58.7	13.0	67.9	40.7	62.8	13.8	6.8	2.2
LSD (0.05)	NS	NS	0.8	7.9	NS	21.3	NS	NS	0.5
Treatment									
Prosaro	104.9	60.2	12.29	68.8	40.9	31.1	9.9	1.6	1.0
Untreated	92.0	58.7	12.24	71.8	48.5	49.3	11.7	4.3	1.9
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.4
Environment									
2007	81.8	59.7	11.9		84.3				
2008	104.4	60.9	13.0		4.0				
2009	109.9	57.7	11.9		45.8				

Table 9. Yield, leaf disease and Fusarium head blight index by environment and cultivar averaged across all treatments Langdon 2007, 2008, and 2009.

		Yield	Late Leaf Disease	FHB Index
Environment	Cultivar	(bushels/acre)	(%)	
2007	CDC Falcon	89.7	81.5	1.5
2008		109.4	6.0	0.9
2009		117.9	63.9	
2007	Jagalene	59.1	90.2	7.2
2008		110.3	1.5	1.1
2009		113.2	29.7	
2007	Jerry	95.6	85.5	2.6
2008		100.4	2.8	0.9
2009		106.7	41.5	
2007	Ransom	89.5	80.4	1.0
2008		99.3	4.5	0.4
2009		89.0	61.1	
2007	Wesley	75.3	83.8	10.5
2008		102.8	5.4	3.1
2009		118.3	32.9	
$LSD_{(0.05)}$		3.5	3.9	1.3

Table 10. Yield, test weight, protein, leaf disease, Fusarium head blight head severity and index by cultivar and treatment averaged across all environments Langdon.

					Late	Fusarium head blight	
Environment	Treatment	Yield	Test weight	Protein	Leaf Disease	Head Severity	Index
		(bu/acre)	(lb/bu)	(%)	(%)	(%)	
2007	Prosaro	93.0	59.2	11.9	74.2	9.9	2.3
	untreated	70.7	56.1	11.9	94.3	14.0	6.8
2008	Prosaro	108.9	61.2	13.1	4.5	10.0	0.8
	untreated	100.0	60.7	12.8	3.5	9.3	1.7
2009	Prosaro	112.8	60.1	11.8	43.9		
	untreated	105.3	59.3	12.1	47.9		
$LSD_{(0.05)}$		1.4	0.5	0.1	1.5	0.8	0.5

Table 11. Test weight, protein, leaf disease, Fusarium head blight index and deoxynivalenol accumulation (DON) in the grain by environment, cultivar and treatment Langdon.

Cultivar	Treatment	Test weight	Leaf disease		FHB	
			early	late [a]	Index	DON
		(lb/bu)	(%)	(%)		(ppm)
2007						
CDC Falcon	Prosaro	60.0	69.8	66.3	0.4	1.1
	untreated	57.1	73.3	96.8	2.6	1.2
Jagalene	Prosaro	59.1	89.0	81.5	3.0	1.6
	untreated	52.3	98.2	99.0	11.4	3.6
Jerry	Prosaro	59.3	55.1	75.3	1.5	0.3
	untreated	58.3	50.6	95.7	3.7	1.8
Ransom	Prosaro	59.7	69.1	77.6	0.4	0.1
	untreated	59.0	62.4	83.2	1.6	0.7
Wesley	Prosaro	58.1	61.3	70.5	6.1	2.1
	untreated	53.9	74.5	97.1	14.9	2.4
2008						
CDC Falcon	Prosaro	61.6			0.7	
	untreated	61.6			1.0	
Jagalene	Prosaro	62.5			1.2	
	untreated	61.6			1.0	
Jerry	Prosaro	60.3			0.8	
	untreated	60.3			1.0	
Ransom	Prosaro	60.3			0.1	
	untreated	59.8			0.8	
Wesley	Prosaro	61.2			1.5	
	untreated	60.3			4.8	
2009						
CDC Falcon	Prosaro	61.3				
	untreated	60.1				
Jagalene	Prosaro	61.2				
	untreated	60.0				
Jerry	Prosaro	60.3				
	untreated	59.7				
Ransom	Prosaro	58.2				
	untreated	57.9				
Wesley	Prosaro	59.8				
	untreated	58.9				
$LSD_{(0.05)}$		0.4	7.1		2.6	0.4

[a] Column included to contrast changes over eight days (12 versus 20 days after fungicide application).