Project Title: Investigating the effects of nitrogen rates, timing and fungicide applications interactions on wheat

Project Location(s): Scott Saskatchewan, R.M. #380 Legal land description: SE-19-39-20-W3

Project start and end dates (month & year): May 2021 to December 2021

Project Collaborators:

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Objective:

The objective of this trial was to demonstrate the effects of nitrogen timing and rate on fungicide efficacy in spring wheat.

Methodology:

The trial was arranged as a randomized complete block design (RCBD) with four replicates of twelve treatments at Scott, SK in 2021 (Table 1). Nitrogen (N) was side-banded at seeding and/or foliar applied 3 days prior to seeding. Pre-seed N was applied as a dribble band foliar application with ammonium nitrate (UAN; 28-0-0). N applied at seeding was side-banded as untreated urea (46-0-0). Total N applied ranged from 30 lbs/ac to 230 lbs/ac of actual N (Table 1). Phosphorus (P), potassium (K) and sulphur (S) were side-banded at seeding to be non-limiting. A fungicide application of Prosaro was applied according to the treatment list at 75% head emergence to 50% heads in flower on July 7th, 2021. The wheat variety selected was AAC Viewfield, and was direct seeded into canola stubble with 10-inch row spacing on May 17th, 2021. The wheat was sprayed with Axial Ipak on June 13th for weed control. The wheat was desiccated on August 16th, 2021 with Glyphosate, Heat LQ and Merge and straight-cut harvested on August 30th, 2021.

Table 1. Treatment list for the Nitrogen Rate and Fungicide Interactions in Wheat study at Scott, SK.

Trt #	Foliar Pre-seed* lb N/ ac	Side-banded** lb N/ ac	Total N *** lb N/ ac	Fungicide App (Y/N)
1	0	0	0	N
2	0	30	30	N
3	0	80	80	N
4	30	100	130	N
5	80	100	180	N
6	130	100	230	N
7	0	0	0	Y
8	0	30	30	Y
9	0	80	80	Y
10	30	100	130	Y
11	80	100	180	Y
12	130	100	230	Y

*Pre-seed nitrogen (UAN, 28-0-0) was sprayed approximately 3 days prior to seeding
**Nitrogen (Urea, 46-0-0) was side-banded at seeding
***All application rates are based on actual N lb/ac

Data Collection:

Soil samples were collected in the spring of 2021 at two depth increments (0-6 inches and 6-24 inches). Plant densities were determined by counting numbers of emerged plants on 2 x 1 meter row lengths per plot at three weeks after planting (WAP). Leaf disease ratings were assessed between tiller and heading growth stages by rating 10 leaves per plot using the rating scale in Figure 1. Fusarium head blight (FHB) ratings were visually assessed between late milk (Zadok 77) and soft dough (Zadok 85), where 10 heads were rated from each plot using the rating scale in Figure 2. Disease incidence and severity were calculated based on visual ratings (Figure 3). Maturity ratings were recorded at physiological maturity (hard dough) when kernel moisture from the lower third of the spike is less than 40% and the seed is no longer easily severed when pinched between thumbnail and fingernail. Yields were determined from cleaned harvested grain samples and corrected to 14% moisture content. Grain protein were collected as indicators of seed quality. Individual plots were combined into treatments and sent to Seed Solutions Seed Labs in Swift Current for a percent fusarium damaged kernels (FDK) analysis. Weather data was collected from a Government of Canada on-site weather station and growing degree days were based on 5ºC.

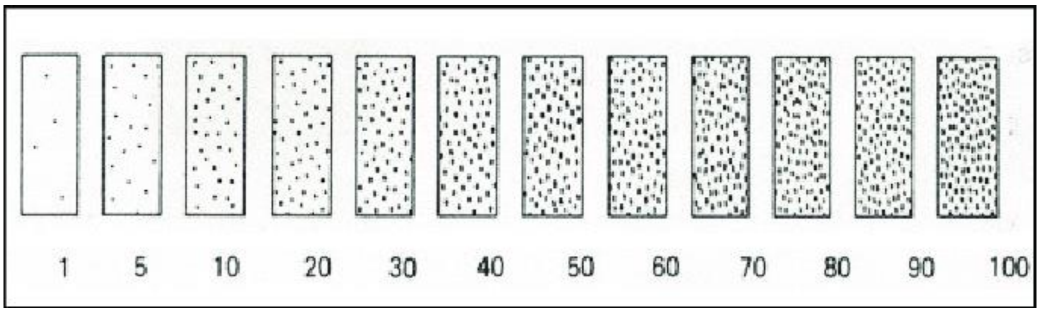

Figure 1. Rating scale used to assess amount of leaf disease on wheat between the tiller and heading growth stages for the Nitrogen Rate and Fungicide Interactions in Wheat study at Scott, SK 2021.

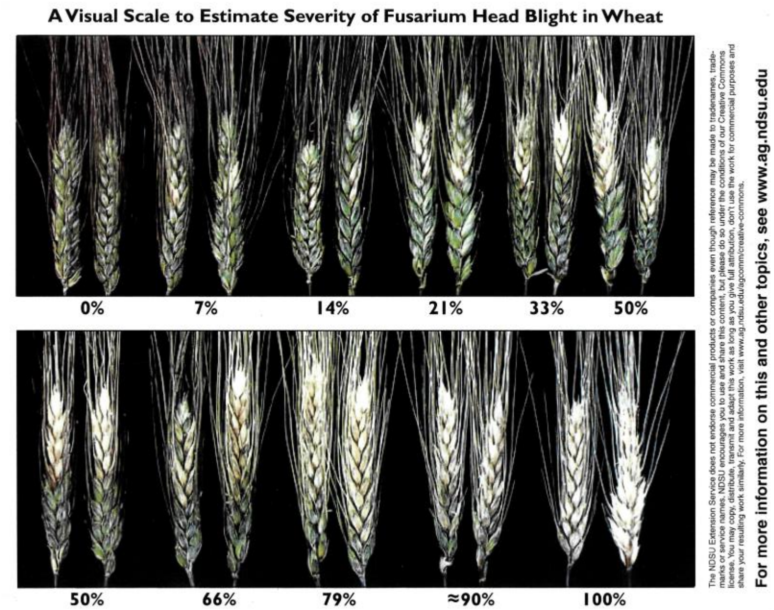

Figure 2. Visual scale to estimate severity of Fusarium Head Blight (FHB) for the Nitrogen Rate and Fungicide Interactions in Wheat study at Scott, SK 2021.

FHB Incidence (%)
FHB Incidence = (# of diseased spikes / total # of spikes sampled) * 100

FHB Severity (%)
FHB Severity = (sum of the proportion of diseased spikelets per diseased spike / total number of diseased spikes sampled) * 100

Figure 3. Calculations to determine percentage of fusarium head blight incidence and severity for the study of comparing fungicide products relative to price in wheat at Scott, 2021 (Paul et al. 2005).

<u>Statistical Analysis:</u>

Data was analyzed using the Mixed procedure of SAS with the effects of treatment (timing x rate x fungicide) considered fixed and replicate effects considered random. The residuals were tested for normality and equal variance to meet the assumptions of ANOVA. Individual treatment means were separated using Fisher's protected LSD test. Overall treatment effects and differences between individual means were considered significant at $P \leq 0.05$. The data was also analyzed for analysis of covariance using Proc GLM. Yield data was considered acceptable with an analysis of covariance was less than 15. Analysis of Covariance is presented in Appendix A. Nitrogen rate was analyzed using a polynomial regression (model y= x x*x) with Proc GLM with the measured data as a response variable and total nitrogen as an independent variable.

Weather:

The 2021 growing season started out quite dry and relatively cool in April with only 0.7 mm of precipitation and an average temperature of 3.6 °C (Table 2). May received 43.9 mm of precipitation, which was well over the long-term average of 38.9 mm. The average temperatures of the growing season remained 0.7°C above the long-term average. In June, temperatures remained close to the long-term average, but precipitation was significantly lower with only 43.8 mm of rain versus the long-term average of 69.7 mm. The month of July received even less precipitation (10.4 mm) compared to the long-term average (69.4 mm) while having higher temperatures (19.6 °C) compared to the long-term average (17.3 °C). The end of August received some much-needed precipitation, totaling 51.3 mm compared to the long-term average of 48.7 mm. Overall, there were 108.2 more growing degree days in the 2021 growing season than the long-term average. Overall, the 2021 season experienced 101 mm less precipitation and was 0.7°C warmer than the long-term average.

Table 2. Mean monthly temperature, precipitation and growing degree day accumulated from April to August 2021 at Scott, SK.

Year	April	May	June	July	August	Average/Sum
Temperature (°C)						
2021	3.6	8.9	17.3	19.6	17.2	13.3
Long-term^z	3.8	10.8	14.8	17.3	16.3	12.6
Precipitation (mm)						
2021	0.7	43.9	43.8	10.4	51.3	150.1
Long-term^z	24.4	38.9	69.7	69.4	48.7	251.1
Growing Degree Days						
2021	24.4	125.6	368.1	453.5	376.7	1348.3
Long-term^z	44.0	170.6	294.5	380.7	350.3	1240.1

^{z}Long-term average (1985 - 2014)

Results

Soil Sample

Soil test results showed low levels of phosphorus (6 ppm) and high levels of potassium (246 ppm). Sulfur showed low levels in the 0-6 inch increment (20 lbs/ac) and very high levels in the 6-24 inch increment (>360 lbs/ac). Nitrogen levels were 13 lbs/ac in the 0-6 inch increment and 18 lbs/ac in the 6-24 inch increment. Total N was 31 lbs/ac, which is classified as low to medium. The pH levels ranged from 5.5 (0-6 inch) to 7.7 (6-24 inch).

Plant Densities

Plant densities were not significantly influenced by fertilizer timing (foliar pre-seed vs. side-banded), total nitrogen (0, 30, 80, 130, 180, 230 lb N/ac) or the absence or presence of fungicide (Table A1). Plant densities were generally higher with low to moderate nitrogen rates (0 to 80 lb/ac of total nitrogen) compared to the total higher nitrogen rates of 130, 180 and 230 lb/ac. Timing of application had a slight effect on overall emergence. High rates of nitrogen applied at seeding caused a slight reduction in plant establishment compared to the foliar pre-seed application (Table 3). Excessive nitrogen rates (>80 lb/ac) applied at seeding likely caused salt burn and resulted in diminished plant establishment. Overall, there were minor differences amongst all fertilizer rates and placement with all densities exceeding 15 plants/ft^2.

Table 3. Overall individual treatment means of spring wheat plant density with fixed effects of fertilizer timing, rate and fungicide application in Scott, 2021.

Trt #	Foliar pre-seed lb N/ ac	Side-banded lb N/ ac	Total Nitrogen lb N/ ac	Fungicide (Y/N)	Crop Density Plants/ft^2
1	0	0	0	N	16.3
2	0	30	30	N	16.4
3	0	80	80	N	16.4
4	30	100	130	N	15.7
5	80	100	180	N	15.1
6	130	100	230	N	16.2
7	0	0	0	Y	16.6
8	0	30	30	Y	17.0
9	0	80	80	Y	15.4
10	30	100	130	Y	16.1
11	80	100	180	Y	15.9
12	130	100	230	Y	16.3

Flag Leaf and Fusarium Head Blight Disease Severity & Incidence

Flag leaf incidence ratings ranged between 55 to 85% when averaged across all twelve treatments indicating that the majority of plants sampled had disease present. The highest disease incidence ratings of 76% and 75% occurred when nitrogen rates were applied at the highest rate (230 lb N/ ac) and the lowest rate (0 lb N/ac). Total N applied between 80 to 180 lb N/ac resulted in the same disease incidence of 67.5%, while 30 lb N/ac resulted in the lowest disease incidence of 53.8%. Although disease was present within the majority of the wheat sampled; the overall severity of the diseases was relatively low < 9%. There were also no clear trends in terms of nitrogen rates, timing or fungicide application. Visual fusarium head blight ratings for severity and incidence equalled zero with no response to applied nitrogen timing (foliar pre-seed or side-banded), rate (0,30,80,130, 180, 230 lb N/ac) or fungicide application.

Days to Maturity

Wheat maturity was largely influenced by the hot and dry conditions throughout the growing season. Wheat maturity varied by 2.3 days between the earliest and latest maturing treatment and fungicide application had a significant effect on maturity (P=0.0259). Wheat without a fungicide application on average matured around 88 days while wheat sprayed with a fungicide matured around 87 days. Nitrogen rate also tended to have an effect on overall maturity, however, it was not statistically significant. Wheat with a higher total N (> 80 lb N/ac) reached maturity after 88 days while wheat with lower total nitrogen (< 80 lb N/ac) matured ≤ 87 days (Table 4).

Table 4. Overall individual treatment means of spring wheat days to maturity with fixed effects of fertilizer timing, rate and fungicide application in Scott, 2021.

Trt #	Foliar pre-seed lb N/ ac	Side-banded lb N/ ac	Total Nitrogen lb N/ ac	Fungicide (Y/N)	Days to Maturity
1	0	0	0	N	87.8
2	0	30	30	N	87.5
3	0	80	80	N	88.0
4	30	100	130	N	87.3
5	80	100	180	N	88.8
6	130	100	230	N	88.0
7	0	0	0	Y	87.0
8	0	30	30	Y	87.3
9	0	80	80	Y	86.5
10	30	100	130	Y	87.0
11	80	100	180	Y	87.3
12	130	100	230	Y	87.0

Yield

Timing and rate of nitrogen are the most common factors that can influence overall plant growth and seed production. However, spring wheat yield was relatively unchanged with either nitrogen rate, timing or their interaction (Table A1). On average, the foliar pre-seed nitrogen resulted in a similar yield compared to side-banded nitrogen. A further analysis was conducted using a polynomial regression to determine if yield would increase with higher increments of total nitrogen (0, 30, 80, 130, 180, 230 lb/ac). The analysis indicated that yield did not significantly increase with higher increments of nitrogen, as neither a linear (P= 0.3839) or quadratic response (P=0.2263) could be detected (Table A1). However, there was a small yield bump when nitrogen rates where between 30 to 180 lb N/ac while the lowest yields were produced with 230 lb N/ac and 0 lb N/ac (Figure 4). The addition of nitrogen, especially during a drought, is essential for wheat development and growth. Several studies (Abid et al., 2016; Nawaz et al., 2012; Zhang et al., 2007) found that nitrogen contributed to drought tolerance in wheat by maintaining higher photosynthetic activities and antioxidative defense system during vegetative growth periods. There is a limited benefit to nitrogen applications and excessive rates of nitrogen do not provide greater drought tolerance. In fact, excessive rates of nitrogen can cause additional plant stress, particularly in the seedling stage, to ultimately reduce yields. Additionally, supplying excessive nitrogen in a drought is not economical as nutrient uptake is restricted. Nawaz et al. (2012) found that early drought stress significantly reduced the nitrogen uptake by 38% while late drought stress decreased nitrogen uptake by 46%. The phosphorus and potassium uptake were decreased by 49% and 37% under early drought stress, respectively while their uptake was decreased by 51% each under late drought stress. Therefore, supplying moderate amounts of nitrogen will provide increased drought tolerance and yield gains while remaining profitable.

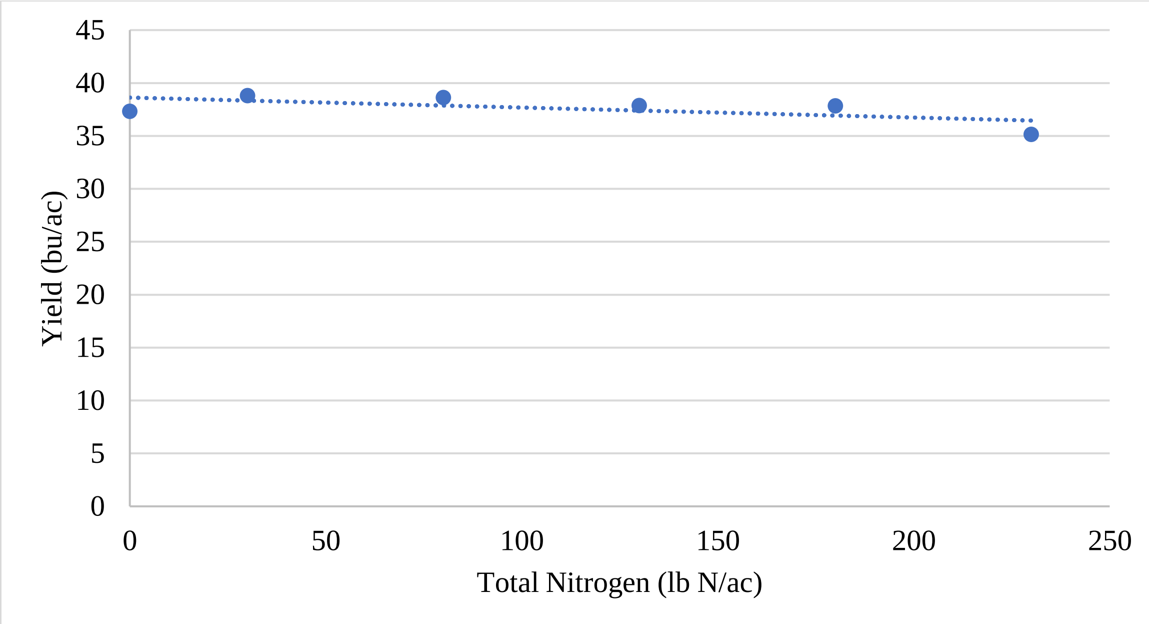

Figure 4. Spring wheat yield response to increased total nitrogen rates (lb N/ac) at Scott, SK 2021.

The fungicide application applied at anthesis had the largest impact on yield and resulted in a significant response (P= 0.0282) (Table A1). Yields on average were 3.4 bu /ac higher in wheat without a fungicide application compared to wheat sprayed with a fungicide (Table 5). Fungicide applications during drought conditions can cause plant toxicity. In particular, tebuconazole, one of the main active ingredients in Prosaro, is commonly known to cause toxicity to plants (phytotoxic) at normal application rates during drought conditions (Pederson, 2007). Symptoms of tebuconazole phytotoxicity may affect all or only parts of the plant (including roots), and can include leaf tissue death to only a subtle growth reduction. The phytotoxic effects of tebuconazole appear to be exacerbated when applied to plants under drought stress (Pederson, 2007). Toxicity from the foliar fungicide application was the largest factor in yield differences between the twelve treatments. Although there were two treatments with no fungicide and high total N (80 and 180 lb N/ac) that yielded on average 4.9 bu/ac higher than others, this was not a result from an interaction between nitrogen and fungicide, but a consequence of the fungicide application (Table 6).

Table 5. Overall tests of fixed effects on wheat yield were analysed using a mixed model analysis conducted at Scott, 2021. Individual treatment means were generated and separated using Tukey's HSD. Different letters indicate a significant difference between treatments**.**

Treatment/ Main Effects	**Yield** Bushels/acre
	---------------------------------- p- value----------------------------------
Fungicide	0.0282
	-----------------------------------Treatment Means ------------------------------------
Absence	39.3[A]
Presence	35.8[B]

Table 6. Overall individual treatment means of spring wheat yield with fixed effects of fertilizer timing, rate and fungicide application in Scott, 2021.

Treatment #	Foliar pre-seed lb N/ ac	Side-banded lb N/ ac	Total Nitrogen lb N/ ac	Fungicide (Y/N)	Yield bu/ac
1	0	0	0	N	36.6
2	0	30	30	N	40.2
3	0	80	80	N	41.4
4	30	100	130	N	38.0
5	80	100	180	N	41.7
6	130	100	230	N	37.6
7	0	0	0	Y	38.0
8	0	30	30	Y	37.4
9	0	80	80	Y	34.9
10	30	100	130	Y	37.8
11	80	100	180	Y	33.9
12	130	100	230	Y	32.7

Protein and Test Weight

An interaction between total nitrogen and fungicide was significant (P=0.0285) for wheat protein content (Table A1). The highest protein content of 15.7% resulted from a fungicide application with 130 lb N/ac while the lowest protein content of 14.1% from no fungicide applied with 130 lb N/ac (Figure 5). Although the lowest protein content occurred when no fungicide was applied, it was not a constant factor as the second and third lowest protein content occurred with a fungicide application with 30 and 0 lb N/ac. In general, there was no clear trend as to the effect of nitrogen rate, timing or fungicide. Overall, all treatments resulted in proteins exceeding 13.0% for grading purposes.

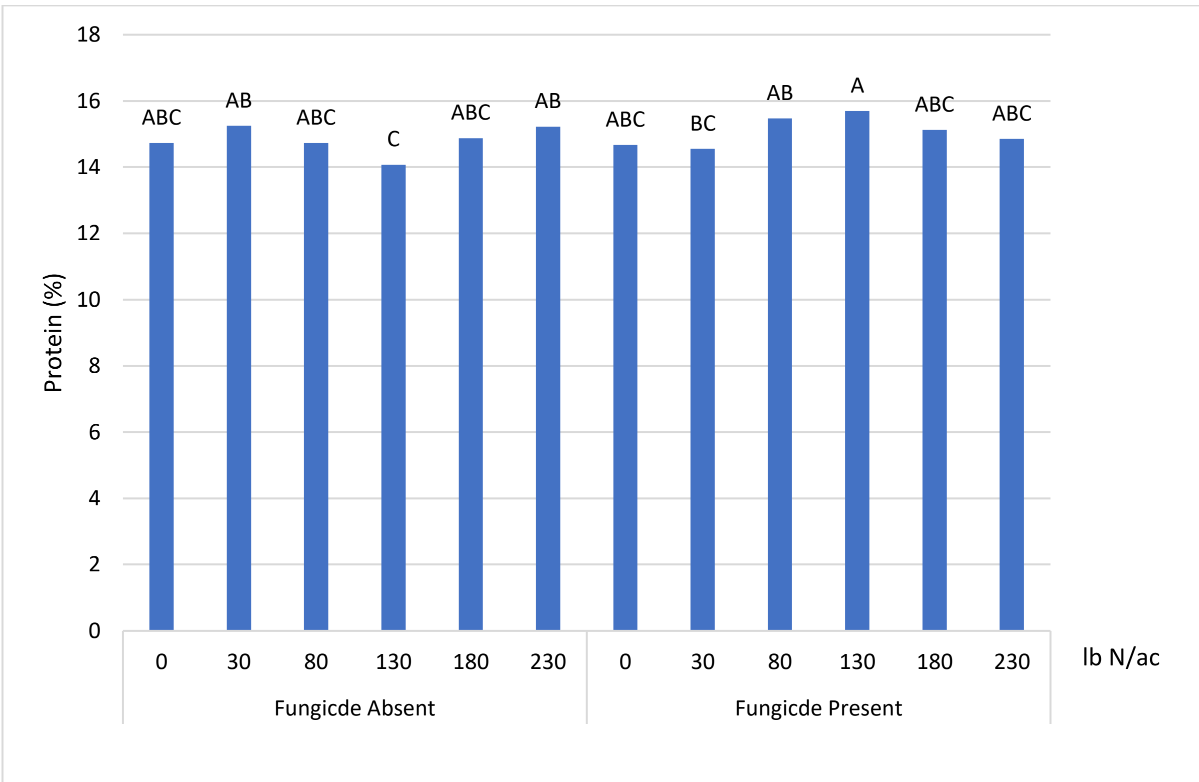

Figure 5. Spring wheat protein response to a fungicide x nitrogen rate (lb N/ac) interaction at Scott, SK 2021.

Test weight of harvested grain was not largely influenced by total nitrogen or the absence or presence of fungicide; however, two trends were noted. The first trend is that lower rates of nitrogen (< 80 lb N/ac) generally resulted in higher test weights compared to higher rates of nitrogen (> 80 lb N/ac). Secondly, wheat without a fungicide application resulted in higher test weights than wheat sprayed with a fungicide.

Table 7. Overall individual treatment means of spring wheat test weight (kg/hl) with fixed effects of fertilizer timing, rate and fungicide application in Scott, 2021.

Treatment #	Foliar pre-seed lb N/ ac	Side-banded lb N/ ac	Total Nitrogen lb N/ ac	Fungicide (Y/N)	Test Weight (kg/hl)
1	0	0	0	N	83.4
2	0	30	30	N	83.7
3	0	80	80	N	83.4
4	30	100	130	N	82.2
5	80	100	180	N	83.2
6	130	100	230	N	82.4
7	0	0	0	Y	83.0
8	0	30	30	Y	83.2
9	0	80	80	Y	81.2
10	30	100	130	Y	82.7
11	80	100	180	Y	81.9
12	130	100	230	Y	81.5

Percent Fusarium Damaged Kernels (% FDK)

The hot and dry conditions throughout the growing season resulted in very low disease pressure and as a result the %FDK ranged from 0 to 0.008% with only two treatments resulting in a disease rating. As there is such minimal % FDK, the effect of nitrogen rate, timing or fungicide or their interaction cannot be determined.

Conclusion:

In general, the presence of a fungicide during the hot and dry conditions was a detriment to wheat production compared to wheat managed without a fungicide. Wheat sprayed with a fungicide had a shorter day to maturity and a yield penalty without the added benefit of disease reduction. The timing of application was less important than the total rate of nitrogen applied. Moderate to high nitrogen rates (30, 80, 130 and 180 lb N/ ac) provide the most consistent benefit to the wheat plants. These four rates in general had the higher plant densities, lowest disease incidence and severity and highest yield production. Wheat grown without nitrogen and at the highest rate of 230 lb N/ac had the greatest disease incidence, disease severity and lowest yields. The effect of fungicide, nitrogen rate and timing had an inconsistent effect on protein and test weights. The extreme hot and dry conditions that persisted throughout the growing season made it difficult to determine the interaction between nitrogen timing, rate and fungicide. However, these conditions highlighted the detrimental effect of a tebuconazole fungicide during drought conditions while showcasing the importance of nitrogen fertilization.

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Appendix A

Table A1. Overall tests of fixed effects of fertilizer timing, rate and fungicide application and their interaction on were analysed using a mixed model analysis conducted at Scott, 2021. Nitrogen rate was analyzed using a polynomial regression (model y= x x*x) with Proc GLM with the measured data as a response variable and total nitrogen as an independent variable.

	Plant Density Plants/ft2	**Flag Leaf Disease** Severity (%)	**Flag Leaf Disease** Incidence (%)	**DTM**	**Yield** Bu/acre	**Protein** (%)	**Test Weight** (kg/hl)
Analysis of Covariance	7.073	70.55	29.44	1.54	12.81	8.38	1.46
Main Effects	-- ***p- value***----------------------------------						
Fungicide (Fg)	0.6443	0.4473	0.1041	0.0259*	0.0282*	0.5635	0.6924
Timing (Tm)	0.8091	0.4006	0.6829	0.6094	0.6176	0.7774	0.7214
Rate (Rt)	0.3813	0.3484	0.5817	0.5923	0.617	0.9666	0.4712
Linear	0.0839	0.7179	0.415	0.9081	0.3839	0.6928	0.4616
Quadratic	0.1612	0.6476	0.2684	0.7678	0.2263	0.7811	0.5268
Fg*Tm	NA	NA	NA	NA	NA	NA	NA
Fg*Rt	0.6491	0.5093	0.2277	0.4923	0.3816	0.0285*	0.0685
Tm*Rt	NA	NA	NA	NA	NA	NA	NA
Fg*Rt*Tm	NA	NA	NA	NA	NA	NA	NA

*Indicates a level of significance at P < 0.05

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