Variation in Response to N and S Among Spring Wheat Genotypes Grown on Irrigated and Non-irrigated Soils

Daniel Kaiser, Dept. of Soil, Water and Climate, U of M

Research Questions

1) Study the effect of sulfur rate on spring wheat grain yield and protein concentration and quality.
2) Determine whether spring wheat varieties differ in the potential response to sulfur fertilizer.
3) Evaluate if plant tissue analysis (flag leaf samples collected at anthesis) can indicate the responsiveness of spring wheat varieties to N or S
4) Determine the economic optimum nitrogen rate for spring wheat grown under irrigation.

Results

Statistical significance, by location, for spring wheat grain yield, grain protein concentration, and the total amount of protein produced per acre is summarized in Table 4. As expected, yield differed consistently among the varieties. Faller produced the greatest yield across sites followed by RBO7, Mayville, Glenn, Vantage, and lastly, Select. The only surprise out of the ranking was Glenn which was one of the top yielding varieties at Crookston. Grain protein concentration was greatest for Vantage and Glenn while Faller producing the least. Total protein produced per acre was greatest for the top yielding variety, Faller, and the varieties with the greatest protein (Glenn and Vantage). The only surprise in the site data was the high protein concentrations measured at Staples. We are in the process of analyzing the grain for total nitrogen to determine if the levels produced were as high as measured on the NIR. Higher levels might be expected if nitrate levels in the irrigation water were high enough to continually feed nitrate in the plant at or post anthesis.

There was no detectable increase in yield from sulfur at the Crookston and Fergus Falls locations (Table 4). In 2014 the 7.5 lb S rate produced a significant yield increase at Staples and there was no further increase to the 15 lb rate. In 2015 grain yield was again increased at Staples but only for the 15 lb S rate. The actual yield increase was less at 4 bu/ac in 2015 than occurred in 2014. Grain protein content was increased by sulfur at Staples and decreased by sulfur at Crookston. The decrease at Crookston was small on a relative basis. At Staples, the 15 lb S rate produced an increase of 0.8% protein. Average protein levels were above 16% so the increase in grain protein concentration would not have resulted in a discount. Grain protein produced on a per acre basis was only impacted by sulfur at Staples.

Asparagine data was collected on samples taken from the 2014 sulfur studies (Table 5). Asparagine is important as it is an indicator of the production of acrylamide. Acrylamide can be produced during baking or frying and can have negative health impacts on humans. Asparagine content in the wheat grain varied among varieties across locations. Glenn typically had the lowest asparagine content followed by Vantage and Faller. Past research on hard red winter wheat has shown that sulfur can reduce the amount of asparagine in the grain. For hard red spring wheat, application of sulfur decreased asparagine content at Staples and Kimball. In both cases the 7.5 lb S rate produced the greatest decrease in asparagine content. It was interesting that the content of asparagine was higher at Staples than the other locations. The higher asparagine content at Staples could have been a result of higher protein content at Staples compared to the other locations. Samples were saved from the 2015 site to test for asparagine content if funds allow.

Figure 1 summarizes flag leaf sulfur concentration by variety across the six locations conducted between 2014 and 2015. One question we were to address is weather there were differences among the varieties in their distribution of sulfur in the flag leaf tissue following application of sulfur fertilizer. The varieties were selected because they showed some differences in preliminary surveys of variety trials. Flag leaf sulfur concentration was impacted by the application of sulfur across the sites but there was no indication that there was a differing effect by variety (no significant interaction between variety and sulfur rate). The lack of impact of variety on sulfur content could be as a result of the rates being used are too high to achieve differences or the fact that the previous research correlated sulfur content of individual varieties with the average sulfur concentration based on location. Grain S concentration was also measured (Figure 2) with similar results as flag leaf S concentration.

A nitrogen trial was conducted under irrigation at Staples with three varieties and six nitrogen rates. Varieties different in their response to grain yield, protein concentration, and protein production per acre (Table 8). Effects of nitrogen by variety are summarized for grain yield, protein concentration, and protein yield per acre in Figures 3, 4, and 5, respectively. Economic optimum nitrogen rates are summarized for a situation with no discount in Table 9. No discount was assumed as the protein concentration, particularly for the 2014 data, was well above the threshold were discounts were expected. It took less N to maximize

continued on page 50

continued from page 49

economic yield in 2014 than in 2015. The primary reason was that additional N was applied by fertigation by mistake in 2014 which inflated the protein concentration values. A recommendation of 200 lb of N per acre would not be out of line with non-irrigated sites. It should be noted that the varieties did differ in their yield potential but the amount of N needed to maximize yield was the same for both 2014 and 2015 studies. This indicates that yield goal may not be an important factor when considering what nitrogen rate should be applied.

Flag leaf nitrogen concentration was measured and the data are reported in Figure 6. There was no indication that the varieties varied in their response to N in the flag leaf tissue. The P value was close to significance but the main effect of variety and nitrogen rate were the only significant factors for the study.

Application and Use

The data from the first year of this project indicate that some changes may be required to the current fertilizer guidelines for wheat. Changes were made when the Fertilizer Guidelines for Wheat in Minnesota publication was updated in 2012. Some changes included a general framework of S guidelines for eroded low organic matter soils (less than2.0% organic matter in the top six inches). An addition year of data would be beneficial to compare the response that occurred at the Staples location to determine if our current suggestion of 25 lbs of S may be greater than what is required to grow wheat on irrigated sandy soils in Minnesota.

There may be some benefit in baking quality with S. However, until protein premium/discounts reflect quality over the quantity there may be a limited impact to the bottom line of a wheat grower. Since this work was being conducted in-kind at the USDA grain quality lab there was no cost for this work included in the budget of this grant. Previous research has demonstrated benefits of S on baking quality. This study provides a better comparison as it includes multiple varieties.

Our goal for comparing the varieties was to determine if tissue sampling could be used to determine responsiveness of varieties to S. Since there was no evidence that a variety by S interaction occurred, it is unlikely that the tissue data had much value in determining whether S would benefit one variety over another. One caution about this work is that since yield was only affected at one location it is hard to draw hard conclusions unless the effect can be replicated. More locations and one or two additional years of funding would greatly benefit this project to determine if similar effect can be replicated across sites and years. Overall, our data from this study and past research indicated that significant caution should be taken when using plant tissue samples for guiding fertilizer application.

Materials and Methods

Small plot sulfur fertilization studies on non-irrigated soils will be established alongside two spring wheat variety trials. The proposed locations are near Crookston or Stephen and Fergus Falls or Kimball. We are currently exploring the possibility for a site closer to Fergus Falls on a soil with an organic matter concentration around 2.0% or less. We will continue to maintain 1 site on a high organic matter soil in the primary spring wheat growing region to ensure no responses have been occurring as a follow up to the previous research.

Six wheat varieties will be selected using the stability analysis conducted for spring wheat flag leaf tissue among varieties in 2011 and 2012. Variety selection will not be based on current planting trends or popularity. Two varieties will be selected that were considered in the high, average, and low response to sulfur categories and that vary in protein and yield potential. The varieties selected are Faller, Vantage, Select, Glenn, Mayville, and RB07. Sulfur rates used will be a non-fertilized control (0 lb S). 7.5, and 15 lbs S per acre. Sulfur will be applied to the soil surface at planting. The source of sulfur will be ammonium sulfate (21-0-0-24). Nitrogen will be applied to balance the rate of nitrogen applied with the high rate of ammonium sulfate. Nitrogen, phosphorus, and potassium will be kept at non-limiting rates according to current recommendations.

An irrigated wheat site will be located at the Central Lakes College Ag and Energy Center at Staples. The irrigated site will consist of a third sulfur site as outlined previously and a nitrogen study. The nitrogen trial will consist of only three of the varieties utilized in the S study (Faller, Mayville, and RB07) and six nitrogen rates (0, 60, 120, 180, 240, and 300 lbs of N per acre). Nitrogen will be applied as urea (46-0-0) and applied at two times with half of the nitrogen applied after seeding but before emergence and the remaining applied near jointing. Additional nutrients (P, K, and S) will be applied as a pre-plant application. The varieties selected were done so based on previous flag leaf tissue data for N similar to selection characteristics outlined the preceding paragraph.

Grain yield will be measured for all plots and a subsample of grain will be collected and analyzed for protein concentration by NIR. Grain samples for the S study will be analyzed for total N and S.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Assuming a wheat price of $6 per bushel, the response at Staples would result in an additional $24 per acre in added crop value across the varieties. If S cost was $0.50 per lb of S, the rate needed to increase yield (15 lb per acre) would cost a grower $7.50 per acre resulting in a net profit of $16.50 per acre and would total $8,250 for a 500 acre operation. When S is deficient, application of S is typically highly profitable for hard red spring wheat.

Even with the low total cost associated with the rate of S needed to increase yield, if a site is not responsive a grower should highly consider using money intended for S for nitrogen especially in years where yield potential and protein discounts are greater. Since there has been no evidence for increased grain protein due to S application in several studies dating back to 2008 S should not play a role in making decisions on fertilizer application for increasing grain protein concentration.

Related Research

A S study was concluded in 2009 which was funded by the Minnesota Wheat Growers that studied the effect of S source, rate, and timing for wheat grown on soils with relatively high concentration of organic matter. This current study provided supporting data for the previous research but focuses on questions received following the previous study on whether we would expect response to S to be greater for varieties which are greater yielding than Glenn which was used in the previous research. We are also following up on information collected in a study funded in 2011 and 2012 that included a survey of flag leaf tissue nutrient concentration. The current research will determine if there is any value in tissue concentration data and whether tissue concentration can help predict a varieties responsiveness to a specific fertilizer.

Recommended Future Research

We are currently evaluating the sulfur guidelines which were modified for wheat. Our research should provide furhter information on the validity of the guidelines. For nitrogen, additional sites would be beneficial to bolster the current guidelines. Nitrogen rate trials on non-irrigated soils are continually needed to fine tune guidelines.

Table 1. Trial location, planting information, and monthly total precipitation for spring wheat S rate studies.

					Monthly Total Precipitation		
Location	County	Soil Type	Soil Texture	Seeding Date	May	June	July
					-----inches-----		
Crookston	Polk	Wheatville	Sandy Loam	28-Apr	2.7	3.7	5.0
Fergus Falls	Otter Tail	Dickey	Fine Sand	1-May	7.5	3.0	1.8
Staples	Wadena	Verndale	Sandy Loam	12-Apr	5.9	1.9	5.0

Table 2. Spring soil test averages across replications for Spring wheat S trials.

	Soil Test (0-6")†				
Location	P	K	SOM	pH	Sulfate-S‡
	-------ppm-------		---%---		--lb/ac--
Crookston	18	146	3.2	7.5	32§
Fergus Falls	31	111	2.8	6.1	40
Staples	19	101	1.9	6.6	40

† P, Bray-P1 phosphorus; K, ammonium acetate potassium; SOM, soil organic matter; pH, soil pH.

‡ 0 to 2 foot soil sulfate-S

§Sample was collected from 0-1'

Table 3. Summary of statistical signficance of main effects of variety (V), sulfur rate (S), and their interaction (VxS) for spring wheat grain yield, protein concentration, and total protein produced per acre.

	Grain Yield†			Grain Protein†			Protein Yield†		
Location	V	S	VxS	V	S	VxS	V	S	VxS
	P>F								
Crookston	<0.001	0.41	0.84	<0.001	0.02	0.48	<0.01	0.30	0.91
Fergus Falls	0.02	0.76	0.59	<0.01	0.66	0.02	0.05	0.79	0.58
Staples	<0.001	0.03	0.35	<0.001	<0.001	0.14	<0.001	<0.002	0.22

continued on page 52

continued from page 51

Table 4. Summary of hard red spring wheat grain yield, grain protein concentration, and protein production per acre for individual varieties at Crookston (CR), Fergus Falls (FF), and Staples (ST) Minnesota during 2015. Average values were calculated for variety and sulfur main effects by and across locations (AVG).

	Grain Yield†				Grain Protein†				Protein Yield†			
Variety	CR	FF	ST	AVG	CR	FF	ST	AVG	CR	FF	ST	AVG
	bushels/ac (@ 13%)				%(@ 12%)				pounds/ac (@ 13%)			
Faller	103a	62a	68bc	78	14.5e	15.1b	15.9d	14.9d	906b	564a	617c	696b
Glenn	100ab	55b	67c	79	16.2a	15.0bc	16.4b	15.6b	985b	499b	635bc	741a
Mayville	87d	67a	73a	74	15.7b	14.7c	16.4b	15.4bc	825c	584a	688a	694b
RB07	94bc	64a	70abc	76	15.5c	15.2ab	16.1cd	15.3c	881b	579a	650bc	699b
Select	95bc	61ab	71ab	75	14.9d	15.6a	16.2c	15.2c	857bc	576a	658ab	683b
Vantage	90cd	68a	51d	71	16.2a	14.9bc	18.5a	16.3a	873bc	602a	540d	691b
S Rate (lb/ac)												
0	94	63	65b	75	15.5a	15.2	16.1c	15.3b	883	571	595c	687
7.5	97	64	66b	76	15.5a	15.0	16.7b	15.5a	908	574	630b	708
15	94	62	69a	76	15.4b	15.0	16.9a	15.6a	872	557	670a	707

† within columns for each main effect, numbers followed by the same letter are not statistically significant at *P* ≤0.05 probability level.

Table 5. Effect of variety and sulfur rate on asparagine content in the wheat grain collected from 2014 at Crookston, Kimball, and Staples

	Grain Yield†			
Variety	CR	K	ST	AVG
	umol/gram (@ 14%)			
Faller	3.5c	3.9c	8.6b	5.2c
Glenn	3.3c	3.1d	5.1c	3.5d
Mayville	4.6b	5.8a	10.4a	6.6ab
RB07	3.7c	5.2b	10.1a	6.3b
Select	5.4a	5.2b	10.3a	6.9a
Vantage	3.1c	3.7c	8.1b	4.9c
S Rate (lb/ac)				
0	3.7	4.7a	9.7a	6.0a
7.5	4.0	4.4b	8.6b	5.5b
15	4.0	4.3b	8.0b	5.3b

† within columns for each main effect, numbers followed by the same letter are not statistically significant at P<0.05 probability level.

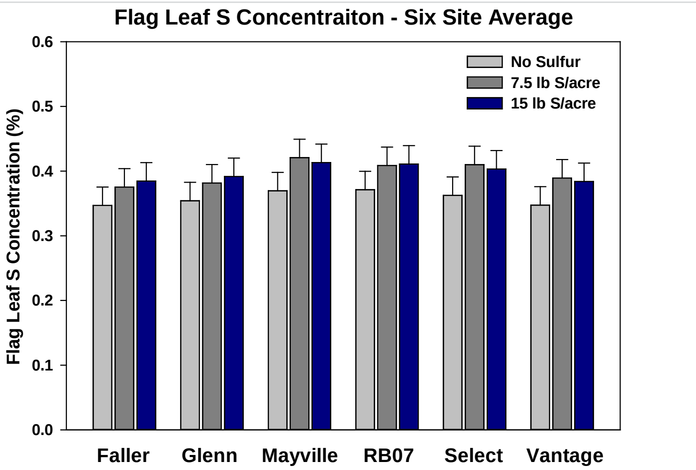


Figure 1. Flag leaf S concentration summarized by variety across six locations from 2014-2015

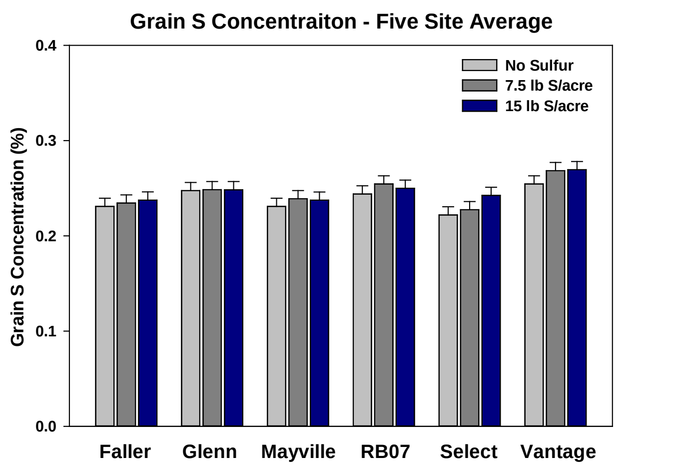


Figure 2. Grain S concentration summarized by variety across six locations from 2014-2015

Table 6. Spring soil test averages across replications for Spring wheat N trial.

Location	P	K	SOM	pH	Nitrate-N‡
	Soil Test (0-6")†				
	-------ppm-------		---%---		--lb/ac--
Staples	17	84	1.5	7.0	34

† P, Bray-P1 phosphorus; K, ammonium acetate potassium; SOM, soil organic matter; pH, soil pH.

‡ 0 to 2 foot soil nitrate-N

Table 7. Summary of statistical signficance of main effects of variety (V), nitrogen rate (N), and their interaction (VxN) for spring wheat grain yield, protein concentration, and total protein produced per acre.

	Grain Yield†			Grain Protein†			Protein Yield†		
Location	V	N	VxN	V	N	VxN	V	N	VxN
	------------------------				P>F				------------------------
Staples	<0.01	<0.001	0.33	<0.001	<0.001	0.75	<0.01	<0.001	0.38

Table 8. Summary of hard red spring wheat grain yield, grain protein concentration, and protein production per acre for individual varieties at Staples Minnesota from 2014-2016. Average values were calculated for data across six nitrogen rates and across years (AVG).

	Grain Yield†				Grain Protein†				Protein Yield†			
	2014	2015	2016	AVG	2014	2015	2016	AVG	2014	2015	2016	AVG
	-------------bushels/ac (@ 13%)-------------				--------------------%(@ 12%)--------------------				--------------pounds/ac (@ 13%)---------------			
Faller	--	62a	--	--	--	14.0b	--	--	--	543b	--	--
Mayville	--	63a	--	--	--	14.7a	--	--	--	577a	--	--
RB07	--	57b	--	--	--	14.7a	--	--	--	527b	--	--

† within columns, numbers followed by the same letter are not statistically significant at $P \leq 0.05$ probability level.

Table 9. Summary of economic optimum nitrogen rates using the maximum return to N model for irrigated HRSW at Staples, MN in 2014 and 2015 assuming no discounts.\

	Ratio of Price N:Price per bushel of corn					
Location	0.00	0.05	0.10	0.15	0.20	0.25
	--------------------lb N/acre------------------					
2014	164	148	130	113	95	78
2015	238	205	171	137	103	70

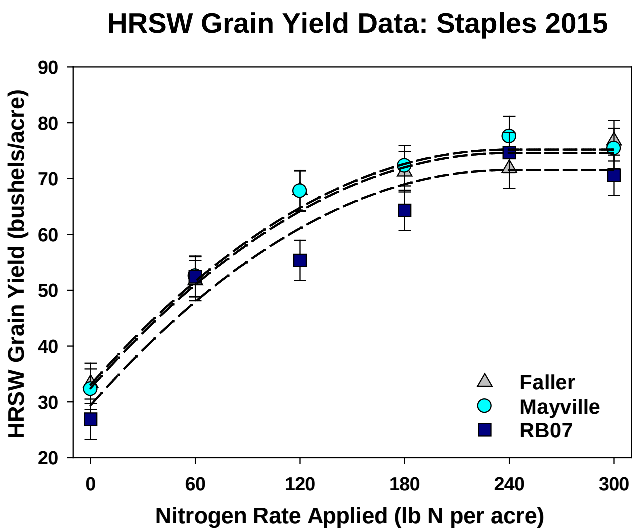


Figure 3. (left) Effect of nitrogen on grain yield of three hard red spring wheat varieties grown under irrigation.

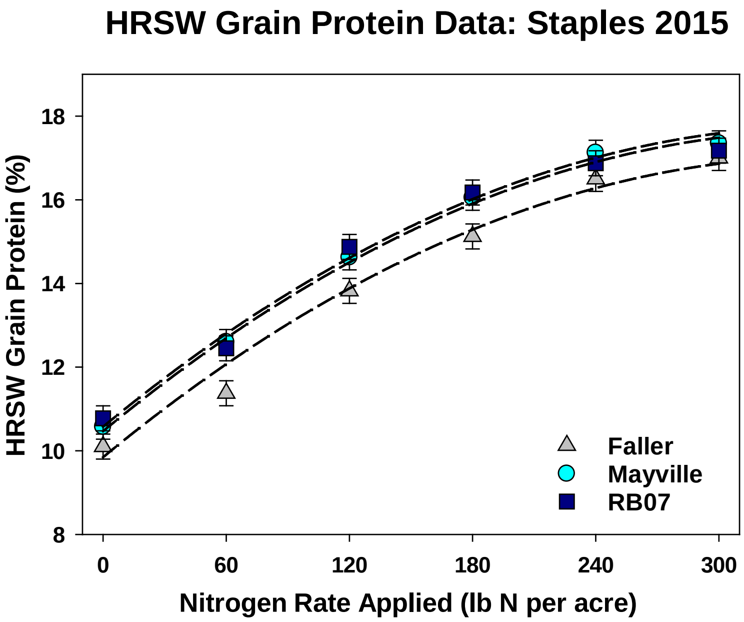
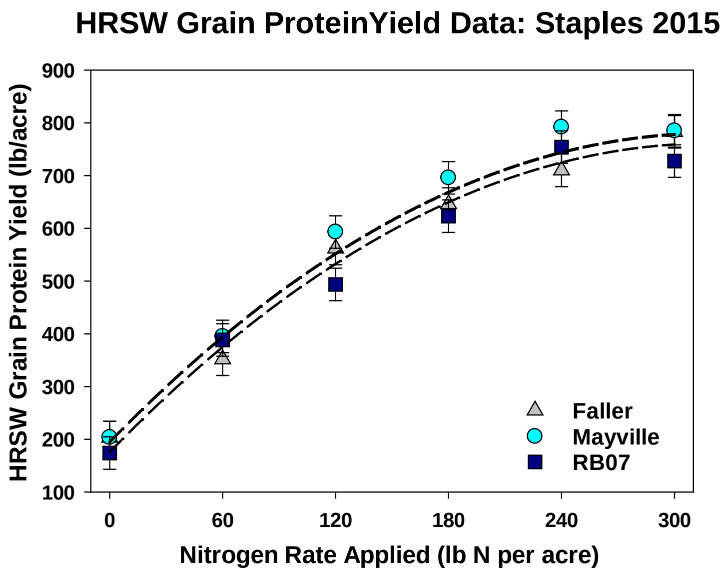


Figure 4. (left) Effect of nitrogen on grain protein concentration of three hard red spring wheat varieties grown under irrigation.

Figure 5. (right) Effect of nitrogen on grain protein yield of three hard red spring wheat varieties grown under irrigation.



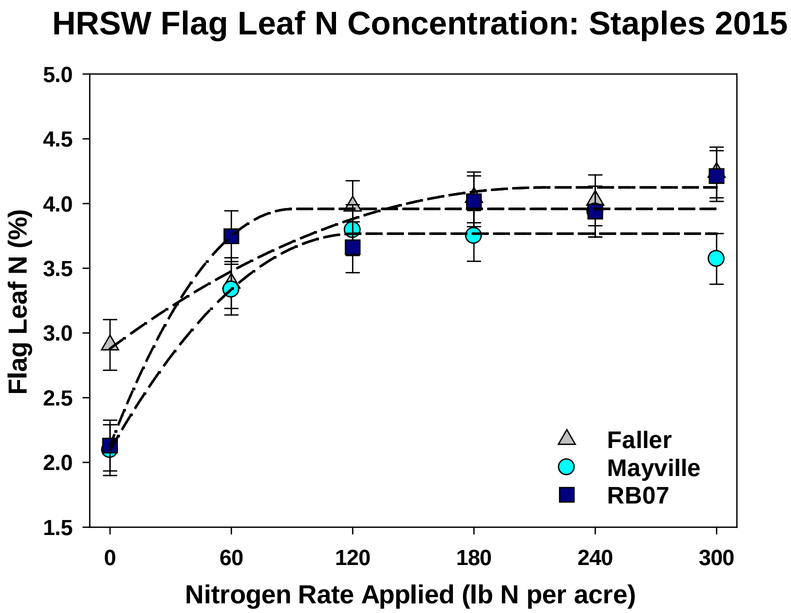


Figure 6. (left) Effect of nitrogen on flag leaf nitrogen concentration at anthesis of three hard red spring wheat varieties grown under irrigation.