Advancing Modern Wheat Nutrition to Sustain Both Yield and the Economics of Production

[1]John H. Grove, [1]Edwin L. Ritchey and [2]Jordan M. Shockley
with much appreciated assistance from Bill Bruening (Small Grain Variety Testing) & Brad Wilks (Wheat Tech Research)

[1]Plant and Soil Sciences; [2]Agricultural Economics Departments
UK Research & Education Center – Grain and Forage Center of Excellence
UK College of Agriculture

Photo courtesy of Brad Wilks

INTRODUCTION/BACKGROUND:

This work is intended to answer certain questions that result from the implementation of a multi-element wheat nutrition program. Nitrogen rate is a fundamental driver of wheat yield and quality. However, the impact/value of S or the micronutrients, which are likely components of a more integrated wheat nutrient management program, is not clear.

PROJECT OBJECTIVES:

The primary goal of this research is to look for and examine (both agronomics and economics), possible interactions between N, sulfur (S) and micronutrients [especially boron (B) and zinc (Zn)].

PROCEDURES:

The main study design included 4 rates of N (40, 80, 120 and 160 lb N/acre), 2 rates of S (0 and 10 lb S/acre), and 2 rates of the micronutrient 'package' (0 and recommended); in complete factorial combination to give a total of 16 (4x2x2) treatments to find all possible interactions. The satellite study design consisted of the 2 rates of S and the 2 rates of the micronutrient package, also in complete factorial combination, to give 4 (2x2) treatments. Four (or more) replications of each treatment, in both main and satellite studies, were used at all locations.

In the 2020-21 season we executed the main study at four sites, and the satellite study at six sites (Table 1) within Kentucky's wheat production regions. One main study site, and the six satellite study sites, were planted and managed by the Wheat Variety Testing Program (Bill Bruening). The other three main study sites were planted and managed by the Wheat Tech (Brad Wilks) research division. Bruening and Wilks were responsible for establishment, pest (weeds insects and diseases) management and grain harvest. Early spring soil samples were taken just prior to treatment applications. Flag leaf tissue was taken at heading. Grain yield data has been received, statistically analyzed, and is discussed just below. Other data (leaf tissue composition) have been determined and are also presented in this report.

RESULTS:

There was no freeze damage at any of the sites. Wheat yield statistics at the six satellite sites are shown in Table 2, and for the four main study sites in Table 3. The results revealed that two (Sites 4 and 7) of the six satellite sites exhibited a statistically significant and positive yield response (+4.8 to 4.9 bu/acre) to the micronutrient (B + Zn) package (Table 2). Two (Sites 2 and 3) of the other four sites exhibited a similar trend in positive response (+3.8 to 4.5 bu/acre) but were not statistically significant. Small yield differences are more statistically detectable with greater treatment replication, and Sites 2 and 3 had the least treatment replication, four, of any of the satellite sites. The sulfur response at the satellite sites was varied. Sites 4 and 5 gave significant positive (+8.6 and 4.5 bu/acre, respectively) responses, while the other four sites gave responses ranging from -2.7 (Site 7) to +1.7 (Site 10) bu/acre that were not statistically significant (Table 2). There were no significant micronutrients by sulfur interaction on grain yield at any satellite (Table 2).

Table 1. Site information.

Site Number	Site Name-Description	Wheat Variety	Planting Date
1	Caldwell – UKREC/GFCE	Pembroke 2021	17 October
2	Webster – Benson Farm	Pembroke 2021	15 October
3	Fulton – Sanger Farm	Pembroke 2021	14 October
4	Woodford – C.O. Little Farm	Pembroke 2021	22 October
5	Fayette – Spindletop	Pembroke 2021	23 October
6	Christian – Wheat Tech (CC)	AgriMAXX 454	20 October
7	Christian – Hunt Farm	Pembroke 2021	16 October
8	Logan – Wheat Tech (RBF)	AgriMAXX 454	15 October
9	Logan – Wheat Tech (OFF)	AgriMAXX 454	23 October
10	Logan – Halcomb Farm	Pembroke 2021	15 October

Table 2. Grain Yield Response – By Trial Site – Part 1.

	------------------------bu/acre, by Site----------------------					
Treatment	Site 2	Site 3	Site 4	Site 5	Site 7	Site 10
- B&Zn	84.6a†	66.3a	84.4b	72.4a	56.6b	71.1a
+ B&Zn	88.4a	70.8a	89.2a	74.7a	61.5a	71.6a
- S	87.4a	68.9a	82.5b	71.3b	60.4a	70.5a
+ S	85.6a	68.2a	91.1a	75.8a	57.7a	72.2a
B&Zn x S	NS	NS	NS	NS	NS	NS
Site Ave. (reps)	86.5 (4)	68.5 (4)	86.8 (7)	73.1 (6)	59.1 (5)	71.4 (7)

†For any treatment – site combination, yield values followed by the same letter are not significantly different at the 90 % level of confidence. NS indicates no significant interaction.

Among the main study sites (Table 3), there was no significant yield response to micronutrient or sulfur addition. All four sites exhibited a significant positive response to nitrogen, ranging from +22.2 bu/acre at Site 1 to +54.7 bu/acre at Site 6 (Table 3). Interestingly, the wheat yield at Site 9, with 40 lb N/acre, was about the same as that at Site 1, with 160 lb N/acre. All sites gave yield increases to 160 lb N/acre, over 120 lb N/acre, though the amount of yield increase was small at Sites 8 and 9 (+4.3 to 5.2 bu/acre, Table 3). No lodging was observed at any site, even at the higher N application rates.

Site 6 also gave several statistically significant interactions on grain yield (Table 3). The S by N and B&Zn by S by N interactions were not easily explained – did not follow an agronomically logical pattern.

Table 3. Grain Yield Response – By Trial Site – Part 2.

Treatment	Site 1	Site 6	Site 8	Site 9
	-----------------bu/acre, by Site-------------			
- B&Zn	92.1a†	101.2a	103.2a	128.4a
+ B&Zn	89.9a	103.2a	101.1a	126.1a
- S	89.7b	102.7a	103.0a	127.1a
+ S	92.3a	101.8a	101.2a	127.4a
40 lb N/A	79.0d	72.3d	89.2d	107.4c
80 lb N/A	89.0c	97.4c	98.0c	121.2b
120 lb N/A	94.9b	112.1b	108.0b	138.1a
160 lb N/A	101.2a	127.0a	113.2a	142.4a
B&Zn x S	NS	NS	NS	NS
B&Zn x N	NS	†0.0363	NS	NS
S x N	NS	†0.0367	NS	NS
B&Zn x S x N	NS	†0.0053	NS	NS
Site Ave. (reps)	91.0 (4)	102.2 (4)	101.7 (4)	127.3 (4)

†For any treatment – site combination, yield values followed by the same letter are not significantly different at the 90 % level of confidence. NS indicates no significant interaction.

Sites 4 and 7 gave significant yield increases to micronutrient addition (Table 2), and these yield increases were associated with significant large increases in flag leaf tissue B and significant but smaller increases in flag leaf tissue Zn (Table 4). At Site 4, flag leaf Zn was significantly reduced by S addition (Table 4). The larger tissue B response suggests that the crop was responding more to B than to Zn (see also Table 8).

Table 4. Flag Leaf B and Zn at Sites 4 (Woodford/Little) and 7 (Christian/Hunt).

	-----Site 4-----		-----Site 7-----	
Treatment	Leaf B	Leaf Zn	Leaf B	Leaf Zn
	ppm	ppm	ppm	ppm
- B&Zn	3.1b†	14.9b	2.7b	13.7b
+ B&Zn	9.7a	16.8a	4.2a	16.1a
- S	6.6a	16.5a	3.3a	14.7a
+ S	6.2a	15.1b	3.6a	15.1a
Site Ave.	6.4	15.8	3.5	14.9

†For any treatment – site combination, tissue values followed by the same letter are not significantly different at the 90 % level of confidence.

Sites 4 and 5 gave significant yield increases to S addition (Table 2). These yield increases were associated with significant large increases in flag leaf tissue S (Table 5). At site 4, micronutrient addition also caused increased flag leaf tissue S (Table 5). The large flag leaf tissue S response was a better indicator of crop yield response to S addition than soil test S (see also Table 8).

Table 5. Flag Leaf S at Sites 4 (Woodford/Little) and 5 (Fayette/Spindletop)

	Leaf S	
Treatment	Site 4	Site 5
	%	%
- B&Zn	0.30b†	0.26a
+ B&Zn	0.33a	0.26a
- S	0.25b	0.23b
+ S	0.39a	0.29a
Site Ave.	0.32	0.26

†For any treatment – site combination, tissue values followed by the same letter are not significantly different at the 90 % level of confidence.

Three main study sites; 1, 8, and 9, did not give a yield response to micronutrients or S (Table 3). All three sites did respond to N (Table 3). Associated flag leaf N concentrations are shown in Table 6. Micronutrient or S addition had no impact on flag leaf N concentrations – only N addition was associated with improved plant N nutrition (Table 6). The 40 lb N/acre addition generally resulted in a flag leaf N tissue concentration of around 3.1%, the 80 lb N/acre rate raised tissue N concentrations by an average of 0.45%, 120 lb N/acre raised tissue N by an additional 0.38%, and 160 lb N/acre increased tissue N a further 0.25% (Table 6), exhibiting a 'diminishing return' to ever greater N rates. At these three main study sites, highest grain yields (Table 3) were associated with tissue N concentrations averaging around 4.1% (Table 6).

Table 6. Flag Leaf N Responses at Sites 1 (Caldwell/UKREC), 8 (Logan/Wheat Tech RBF) and 9 (Logan/Wheat Tech OFF)

	--------Leaf N--------		
Treatment	Site 1	Site 8	Site 9
	%	%	%
- B&Zn	3.68a†	3.59a	3.79a
+ B&Zn	3.64a	3.55a	3.77a
- S	3.64a	3.56a	3.78a
+ S	3.69a	3.58a	3.79a
40 lb N/A	3.08d	3.04d	3.13d
80 lb N/A	3.57c	3.44c	3.60c
120 lb N/A	3.89b	3.79b	4.07b
160 lb N/A	4.12a	4.03a	4.34a
Site Ave.	3.66	3.56	3.78

†For any treatment – site combination, tissue values followed by the same letter are not significantly different at the 90 % level of confidence.

Main study site 6 did not give a significant yield response to the singular effect of micronutrient or S addition (Tables 3 and 7, below). There was a significant yield response to simple N addition, and there were also several interactions (B&Zn by N, S by N, and B&Zn by S by N) in the wheat grain yield response (Table 3). As noted above, the S by N and B&Zn by S by N interactions were not easily explained because these did not follow an agronomically logical pattern. However, the B&Zn by N interaction is familiar and was observed at two locations in the previous year. This interaction was because micronutrient application gave a yield increase at the lowest N rate but not at the higher N rates (Table 7). Looking at the flag leaf composition information, leaf B responded only to micronutrient addition and leaf Zn responded to both micronutrient and N additions (Table 7). Leaf S was significantly increased by added N, but not by added S or added micronutrients (Table 7). Leaf N was significantly decreased by added S and increased by added N (Table 7). However, the interesting observation is that there was a B&Zn by N interaction on leaf N concentration where added micronutrients raised leaf N at the lowest rate of N addition (Table 7). Though the mechanism for this is not clear, it appears that the wheat yield increase to micronutrient addition at the lowest N rate is due to improved N nutrition. No other nutrient response explains the B&Zn by N interaction on grain yield at this site.

Table 7. Grain Yield Flag Leaf Composition Responses at Site 6 (Christian/Wheat Tech CC)

Treatment	Grain Yield	Leaf B	Leaf Zn	Leaf S	Leaf N
	%	ppm	ppm	%	%
- B&Zn	101.2a[†]	2.3b	13.6b	0.25a	3.45a
+ B&Zn	103.2a	3.6a	16.2a	0.25a	3.48a
- S	102.7a	2.9a	15.2a	0.25a	3.51a
+ S	101.8a	2.9a	14.6a	0.26a	3.42b
40 lb N/A	72.3d	2.8a	12.3d	0.21d	2.78d
80 lb N/A	97.4c	2.9a	14.5c	0.24c	3.39c
120 lb N/A	112.1b	3.0a	15.6b	0.27b	3.69b
160 lb N/A	127.0a	2.9a	17.3a	0.30a	4.01a
- B&Zn, 40 lb N	66.8e	NS	NS	NS	2.68e
- B&Zn, 80 lb N	97.9c				3.39c
- B&Zn, 120 lb N	112.6b				3.69b
- B&Zn, 160 lb N	127.6a				4.05a
+ B&Zn, 40 lb N	77.8d				2.88d
+ B&Zn, 80 lb N	96.8c				3.38c
+ B&Zn, 120 lb N	111.7b				3.68b
+ B&Zn, 160 lb N	126.5a				3.97a
Site Ave.	102.2	2.9	14.9	0.25	3.46

[†]For any treatment combination, tissue values followed by the same letter are not significantly different at the 90 % level of confidence. NS indicates no significant interaction.

Table 8, below, summarizes the yield responses to sulfur and boron plus zinc across the ten sites, alongside the soil test data results. Generally, the boron plus zinc treatment had a positive impact on yield. At most sites (2, 4, 6, and 7), this seems largely due to added boron. Neither soil test B or Zn were low at Site 3, so it is not clear what caused the response. Five sites did not exhibit any kind of a response to added B plus Zn, regardless the soil test result.

Responses to added S were less mixed, with seven sites giving no response and three sites showing a positive yield response. Soil test (Mehlich III extractable) S was not especially helpful in predicting the response pattern, partially because the distribution of soil test results was very bimodal. There were two sites with soil test S values around 45 lb S/acre, and all the rest were between 13 and 17 lb S/acre. There were no negative yield responses to applied S this year.

Table 8. Site Responses to S, B and Zn – by Soil Test Result.†

Site	Meh III S lb/A	Response to S	Hot H_2O B lb/A	Meh III Zn lb/A	Response to B & Zn
1	17	yes, positive	0.44	3.7	no
2	47	no	0.42	4.1	trend positive
3	14	no	0.75	6.1	trend positive
4	14	yes, positive	0.38	3.1	yes, positive
5	13	yes, positive	0.47	1.9	no
6	16	no	0.51	6.6	interaction w/N*
7	15	no	0.47	7.9	yes, positive
8	43	no	0.53	5.9	no
9	14	no	0.77	6.2	no
10	13	no	0.56	3.3	no

†Soil test S and B from a 0-12 inch soil sample. Soil test Zn from a 0-4 inch sample.
*Gave a micronutrient by N rate interaction where micronutrients were beneficial at lowest N rate.

CONCLUSIONS:

Site average yields ranged from 59.1 (Site 7) to 127.3 (Site 9) bu/acre. Nitrogen was generally beneficial (4 of 4 sites tested) to yield, while micronutrients were somewhat less so (5 of 10 sites). Sulfur was less beneficial, with 3 of 10 sites giving positive yield responses. An interesting micronutrient by N interaction has again been observed. Soil test information for S, B and Zn were helpful but not definitive as regards predicting whether a significant response to those nutrient elements would occur. Plant tissue composition data do offer some opportunities as regards nutrient stress monitoring, but the sampling times will have to be earlier in the plant's lifecycle in order to be of benefit to the crop currently growing in the field.