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

Report for the 2019-20 Production Season

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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 (B and Zn), which are likely components of a more integrated wheat nutrient management program, is not clear.

Take Home Conclusions from This One/First Season:

Wheat yield at six of nine locations was negatively impacted by the May freeze event, causing site average yields to range from 2.9 (Site 1) to 126.0 (Site 5) bu/A. Nitrogen was generally beneficial (2 of 3 sites tested) to yield, while micronutrients were somewhat less so (5 of 9 sites). Sulfur was even less often beneficial, and quite inconsistent, with 3 of 9 sites giving positive responses and 2 of 9 sites giving significant negative yield responses. 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.

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 in order 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.

Table 1. Site information

Site Number	Site Name-Description	Wheat Variety	Planting Date
1	Fayette—Spindletop	Pembroke 2016	5 October
2	Woodford—C.O. Little Farm	Pembroke 2016	19 October
3	Simpson—Walnut Grove Farm	AgriMAXX 454	24 October
4	Logan—Halcomb Farm	Pembroke 2016	15 October
5	Logan—Wheat Tech RBF	AgriMAXX 454	23 October
6	Fulton—Sanger Farm	Pembroke 2016	9 October
7	Christian—Hunt Farm	Pembroke 2016	10 October
8	Webster—Benson Farm	Pembroke 2016	8 October
9	Caldwell—UKREC/GFCE	Pembroke 2016	15 October

We executed the main study at three 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 two 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. Selected composite grain samples have been sent to Siemer Milling for milling and baking quality assessment. Grain yield data has been received, statistically analyzed, and is discussed just below. Other data (leaf tissue composition and soil test results) have been analyzed and presented in this report.

Results:

Freeze damage was observed at six of the nine sites (Tables 2 and 3). Five of the satellite sites were freeze damaged (Table 2), as was one of the main study sites (Table 3). Despite the damage, the results revealed that three of the six satellite sites exhibited a statistically significant and positive yield response (+1.4 to 1.7 bu/A) to the micronutrient (B + Zn) package (Table 2). The sulfur response at the satellite sites was varied. Site 4 exhibited a significant positive (+3.3 bu/A) response, while Sites 2 and 8 showed statistically significant and negative (-1.8 to -3.5 bu/A) responses (Table 2).

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

	------------------------bu/A, by Site----------------------					
Treatment	Site 1*	Site 2*	Site 4*	Site 6*	Site 7*	Site 8
- B&Zn	2.1b†	20.1b	18.5a	35.0b	26.5a	81.8a
+ B&Zn	3.8a	21.5a	19.6a	36.7a	26.8a	81.9a
- S	2.7a	21.7a	17.1b	35.5a	27.3a	83.6a
+ S	3.2a	19.9b	21.0a	36.2a	26.1a	80.1b
- B&Zn, - S	NS	19.8b	NS	NS	NS	85.2a
- B&Zn, + S		20.4b				78.3b
+ B&Zn, - S		23.6a				81.9ab
+ B&Zn, + S		19.4b				81.9ab
Site Ave. (reps)	2.9 (5)	20.7 (7)	19.0 (7)	35.9 (4)	26.7 (4)	81.9 (4)

*Site yield reduced by May freeze damage.
†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.

There was a significant sulfur by micronutrient interaction at Sites 2 and 8 (Table 2). At Site 2, the benefit of added micronutrients only occurred in the absence of added sulfur (Table 2). At Site 8, neither added sulfur or micronutrients were beneficial, and added sulfur exhibited an especially negative impact on yield in the absence of added micronutrients (Table 2).

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

	------bu/A, by Site------		
Treatment	Site 3	Site 5	Site 9*
- B&Zn	106.0b†	124.7a	59.8a
+ B&Zn	108.5a	127.2b	62.1a
- S	105.1b	125.5a	59.2b
+ S	109.4a	126.5a	62.7a
40 lb N/A	83.7d	115.3c	59.4a
80 lb N/A	103.9c	124.2b	63.2a
120 lb N/A	117.3b	130.8a	61.9a
160 lb N/A	124.1a	133.6a	59.5a
B&Zn by S	NS	NS	NS
B&Zn by N	NS	NS	NS
S by N	NS	NS	NS
B&Zn by S by N	NS	NS	NS
Site Ave. (reps)	107.2 (4)	126.0 (4)	61.0 (4)

*Site yield reduced by May freeze damage.
†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 a significant positive response to micronutrient addition at Sites 3 and 5 and significant positive responses to sulfur at Sites 3 and 9 (Table 3). Sites 3 and 5 showed significant positive responses to nitrogen, while Site 9 did not.

Looking more closely at the three sites with little freeze damage, Sites 3, 5 and 8, gave some greater insight into the responses observed. Site 8, a satellite study site, exhibited a significant negative yield response to S and a significant micronutrient by S interaction (Tables 2 and 4). The interaction was because S application resulted in a very significant yield reduction where no B and Zn were applied but had little impact where B and Zn were applied (Tables 2 and 4). Grain test weight at Site 8 averaged 59.6 lb/bu and there were no significant treatment effects (statistics not shown). Flag leaf tissue N, P, K, Mg and Ca concentrations averaged 3.49, 0.23, 1.55, 0.17 and 0.71%, respectively, while leaf Mn, Fe and Cu concentrations averaged 100, 76 and 5.4 ppm, respectively. None of these tissue parameters were significantly affected by the treatments (statistics not shown).

Table 4. Wheat Crop Responses at Site 8 – Webster County/Benson Farm

Treatment	Grain Yield	Flag Leaf S	Flag Leaf B	Flag Leaf Zn
	bu/A	%	ppm	ppm
- B&Zn	81.8a†	0.32a	4.9b	17.3b
+ B&Zn	81.9a	0.34a	6.5a	19.4a
- S	83.6a	0.33a	5.5a	17.9a
+ S	80.1b	0.32a	5.9a	18.8a
- B&Zn, - S	85.2a	NS	NS	NS
- B&Zn, + S	78.3b			
+ B&Zn, - S	81.9ab			
+ B&Zn, + S	81.9ab			
Site Ave.	81.9	0.33	5.7	18.3

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

Flag leaf tissue S was not influenced by treatments (Table 4) – the Mehlich III soil test S values for Site 8 averaged 22 lb S/A in the 0-4 inch depth increment and 42 lb S/A in the 4-8 inch depth increment. Flag leaf B and Zn were increased significantly by the application of B and Zn (Table 4). Mehlich III soil test B and Zn were 0.85 lb/A and 11.3 lb/A, respectively, in the 0-4-inch depth increment and 0.45 lb/A and 1.5 lb/A, respectively, in the 4-8 inch depth increment. Given the leaf tissue and soil analysis information, an explanation for the yield responses observed at this site is not readily discernable.

Site 3, a main study site, exhibited a significant positive yield response to the micronutrients (+2.5 bu/A), S (+4.3 bu/A), and N (+20.2, +13.4, and +6.8 bu/A to each successive 40 lb N/A increment subsequent to the first 40 lb N/A) (Tables 3 and 5). There was a barely significant micronutrient by N rate interaction that was not explored in Table 3, but is detailed in Table 5, below. The interaction was because micronutrient application tended to give a yield increase at the lower N rates but not at the highest (Table 5). Grain test weight at Site 3 was influenced by N rate, being significantly higher at the two highest N rates (Table 5). Flag leaf tissue composition was affected by the treatments, with added micronutrients decreasing leaf Mg (Table 5) and leaf Cu (Table 6), while increasing leaf B and Zn (Table 6). Added S raised leaf N, K, Mg, and Ca (Table 5), as well as leaf S and Zn concentrations (Table 6). Added N had the greatest impacts across the measured leaf nutrient elements, increasing leaf N, K and Ca (Table 5), as well as leaf S, B, Zn, Mn and Fe (Table 6). Added N caused mixed differences in leaf P and Mg (Table 5) and no significant differences in leaf Cu (Table 6).

Table 5. Wheat Crop Responses at Site 3 – Simpson County/Walnut Grove Farm, Part 1.

Treatment	Grain Yield	Test Weight	Leaf N	Leaf P	Leaf K	Leaf Mg	Leaf Ca
	bu/A	lb/bu	%	%	%	%	%
- B&Zn	106.0b†	59.1a	3.45a	0.340a	2.02a	0.108a	0.571a
+ B&Zn	108.5a	58.9a	3.46a	0.340a	2.04a	0.103b	0.571a
- S	105.1b	59.0a	3.42b	0.340a	1.99b	0.104b	0.562b
+ S	109.4a	59.0a	3.49a	0.340a	2.08a	0.107a	0.580a
40 lb N/A	83.7d	58.4b	2.96d	0.343ab	1.96b	0.108a	0.473d
80 lb N/A	103.9c	58.6b	3.34c	0.336bc	2.03a	0.104ab	0.539c
120 lb N/A	117.3b	59.8a	3.62b	0.350a	2.08a	0.108a	0.606b
160 lb N/A	124.1a	59.2a	3.88a	0.333c	2.05a	0.103b	0.665a
- B&Zn, 40 lb N	81.0f	NS	NS	NS	1.98cd	0.115a	NS
- B&Zn, 80 lb N	102.2d				2.06ab	0.106bcd	
- B&Zn, 120 lb N	115.2c				2.04bc	0.108bc	
- B&Zn, 160 lb N	125.7a				2.01cd	0.103cde	
+ B&Zn, 40 lb N	86.4e				1.95d	0.100e	
+ B&Zn, 80 lb N	105.7d				2.01cd	0.101d	
+ B&Zn, 120 lb N	119.4b				2.13a	0.109b	
+ B&Zn, 160 lb N	122.4ab				2.09ab	0.103cde	
B&Zn by S	NS	NS	NS	NS	NS	NS	NS
S by N	NS	NS	NS	NS	NS	NS	NS
B&Zn by S by N	NS	NS	NS	NS	NS	NS	NS
Site Ave.	107.2	59.0	3.45	0.340	2.03	0.105	0.571

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

Added S had more impact at Site 3, both in terms of yield and flag leaf tissue composition – the Mehlich III soil test S values for Site 3 averaged 12 lb S/A in the 0-4 inch depth increment and 7 lb S/A in the 4-8 inch depth increment. Added B and Zn also raised yield and similarly significantly increased flag leaf B and Zn. Mehlich III soil test B and Zn were 0.98 lb/A and 5.7 lb/A, respectively, in the 0-4-inch depth increment and 0.73 lb/A and 3.8 lb/A, respectively, in the 4-8 inch depth increment. Given the leaf tissue and soil analysis information, the yield response to S was driven by generally lower available soil S. Given the larger leaf tissue B increase, relative to that for leaf Zn, the yield response to micronutrients observed at this site was likely driven by a response to added B. That hypothesis is not supported by Mehlich III soil test B data.

Site 5, another main study site, exhibited a barely significant positive yield response to the micronutrients (+2.5 bu/A) and N (+8.9, +6.6, and +2.8 bu/A to each successive 40 lb N/A increment subsequent to the first 40 lb N/A), but not to added S (Tables 3 and 7). There was another barely significant micronutrient by N rate interaction that was not explored in Table 3, but is detailed in Table 7, below. The interaction was similar to that for Site 3 (Table 5, above), where the micronutrient application tended to give a yield increase at the lower N rates but not at the highest (Table 7). Grain test weight at Site 5 was positively influenced by S application, (Table 7). Flag leaf tissue composition was affected by the treatments, with added micronutrients again decreasing leaf Mg (Table 7), also increasing leaf Ca (Table 7) and leaf S (Table 8), and again increasing leaf B and Zn (Table 8). Added S raised leaf K (Table 7), and leaf S concentrations (Table 8). Added S lowered leaf Ca (Table 7) and leaf B levels (Table 8). Added N again had the greatest impacts across the measured leaf nutrient elements, increasing leaf N, K and Ca (Table 7), as well as leaf S, B, Zn, Mn and Fe (Table 8). Leaf P and Cu concentrations averaged 0.272% and 6.9 ppm, respectively, over the whole experiment and were not affected by any treatment or treatment combination.

Table 6. Wheat Crop Responses at Site 3 – Simpson County/Walnut Grove Farm, Part 2.

Treatment	Leaf S	Leaf B	Leaf Zn	Leaf Mn	Leaf Fe	Leaf Cu
	%	ppm	ppm	ppm	ppm	ppm
- B&Zn	0.296a	2.8b	18.2b	64.8a	56.1a	7.7a
+ B&Zn	0.292a	6.3a	20.1a	63.2a	54.3a	7.0b
- S	0.276b	4.7a	18.6b	64.1a	55.1a	7.0a
+ S	0.312a	4.5a	19.8a	63.9a	55.4a	7.6a
40 lb N/A	0.248d	4.2b	17.8b	51.4d	44.9d	7.4a
80 lb N/A	0.281c	4.6b	19.1b	60.3c	53.1c	7.1a
120 lb N/A	0.307b	4.2b	18.9b	69.2b	58.5b	7.4a
160 lb N/A	0.340a	5.4a	20.8a	75.2a	64.4a	7.4a
- B&Zn, - S	0.283b	NS	NS	NS	NS	NS
- B&Zn, + S	0.310a					
+ B&Zn, - S	0.269c					
+ B&Zn, + S	0.314a					
B&Zn by N	NS	NS	NS	NS	NS	NS
S by N	NS	NS	NS	NS	NS	NS
B&Zn by S by N	NS	NS	NS	NS	NS	NS
Site Ave.	0.294	4.6	19.2	64.0	55.2	7.3

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

Added S had no impact at Site 5 in terms of yield, and less impact on flag leaf tissue composition than at Sites 3 and 8 – the Mehlich III soil test S values for Site 3 averaged 15 lb S/A in the 0-4 inch depth increment and 12 lb S/A in the 4-8 inch depth increment. Added B and Zn raised yield and significantly increased flag leaf B and Zn. Mehlich III soil test B and Zn were 0.88 lb/A and 5.3 lb/A, respectively, in the 0-4-inch depth increment and 0.60 lb/A and 2.6 lb/A, respectively, in the 4-8 inch depth increment. Given the leaf tissue and soil analysis information, the lack of a yield response to S was driven by somewhat higher available soil S. Given the larger leaf tissue B increase, relative to that for leaf Zn, the yield response to micronutrients observed at this site was driven by a response to added B. That is, again, not well supported by Mehlich III soil test B data.

Table 7. Wheat Crop Responses at Site 5 – Logan County/Wheat Tech Office, Part 1.

Treatment	Grain Yield	Test Weight	Leaf N		Leaf K	Leaf Mg	Leaf Ca
	bu/A	lb/bu	%		%	%	%
- B&Zn	124.7a[†]	58.2a	3.58a		1.79a	0.111a	0.536b
+ B&Zn	127.2b	58.2a	3.63a		1.81a	0.106b	0.553a
- S	125.5a	58.1b	3.62a		1.77b	0.108a	0.554a
+ S	126.5a	58.4a	3.59a		1.83a	0.108a	0.536b
40 lb N/A	115.3c	58.1a	3.35d		1.72b	0.111a	0.478d
80 lb N/A	124.2b	58.3a	3.52c		1.84a	0.108a	0.533c
120 lb N/A	130.8a	58.2a	3.69b		1.82a	0.107a	0.556b
160 lb N/A	133.6a	58.4a	3.85a		1.81a	0.108a	0.613a
- B&Zn, 40 lb N	111.7e	NS	NS	- S, 40 lb N	1.74d	NS	NS
- B&Zn, 80 lb N	124.7c			- S, 80 lb N	1.82bc		
- B&Zn, 120 lb N	127.8bc			- S, 120 lb N	1.76cd		
- B&Zn, 160 lb N	134.8a			- S, 160 lb N	1.74d		
+ B&Zn, 40 lb N	118.9d			+ S, 40 lb N	1.70d		
+ B&Zn, 80 lb N	123.7cd			+ S, 80 lb N	1.87ab		
+ B&Zn, 120 lb N	133.9a			+ S, 120 lb N	1.88ab		
+ B&Zn, 160 lb N	132.4ab			+ S, 160 lb N	1.89a		
B&Zn by S	NS	NS	NS		NS	NS	NS
S by N	NS	NS	NS			NS	NS
B&Zn by S by N	NS	NS	NS		NS	NS	NS
Site Ave.	126.0	58.2	3.60		1.80	0.108	0.545

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

Table 8. Wheat Crop Responses at Site 5 – Logan County/Wheat Tech Office, Part 2.

Treatment	Leaf S	Leaf B	Leaf Zn	Leaf Mn	Leaf Fe
	%	ppm	ppm	ppm	ppm
- B&Zn	0.305b	3.5b	18.2b	65.6a	71.6a
+ B&Zn	0.318a	8.2a	20.1a	65.6a	70.1a
- S	0.303b	6.2a	19.3a	66.3a	70.7a
+ S	0.320a	5.6b	19.4a	64.9a	71.0a
40 lb N/A	0.258d	4.9c	17.3d	58.5c	62.9c
80 lb N/A	0.301c	5.8b	19.1c	64.9b	70.8b
120 lb N/A	0.330b	6.1b	20.1b	68.4ab	73.1b
160 lb N/A	0.359a	6.7a	21.1a	70.6a	76.6a
- B&Zn, 40 lb N	NS	3.1	NS	NS	NS
- B&Zn, 80 lb N		3.4de			
- B&Zn, 120 lb N		3.6de			
- B&Zn, 160 lb N		4.0d			
+ B&Zn, 40 lb N		6.6c			
+ B&Zn, 80 lb N		8.1b			
+ B&Zn, 120 lb N		8.6ab			
+ B&Zn, 160 lb N		9.4a			
B&Zn by S	NS	NS	NS	NS	NS
S by N	NS	NS	NS	NS	NS
B&Zn by S by N	NS	NS	NS	NS	NS
Site Ave.	0.312	5.9	19.4	65.6	70.9

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

Table 9, below, summarizes the yield responses to sulfur and boron plus zinc across the nine sites, alongside the soil test data results. The second column indicates whether the site was hurt by freeze damage. The three sites without freeze damage are highlighted in yellow. Generally, the boron plus zinc treatment had a positive impact on yield. At most sites (2, 3, and 5), this seems largely due to added boron. Neither soil test B or Zn were low at Sites 1 and 6, so it is not clear what caused the response. Four sites did not give a response to added B plus Zn, regardless the soil test result.

Table 9. Site Responses to S, B and Zn – by Soil Test Result.†

Site	Freeze Damage	Meh III S lb/A	Response to S	Hot H_2O B lb/A	Meh III Zn lb/A	Response to B and Zn
1	yes	13	no	0.93	3.4	yes, positive
2	yes	12	yes, negative	0.59	7.4	yes, positive
3	no	10	yes, positive	0.53	4.7	yes, positive*
4	yes	12	yes, positive	0.51	8.4	no
5	no	14	no	0.37	5.4	yes, positive*
6	yes	15	no	0.98	6.1	yes, positive
7	yes	18	no	0.45	10.0	no
8	no	32	yes, negative	0.66	11.5	no
9	yes	10	yes, positive	0.62	2.4	no

†Soil test S and B from a 0-8 inch soil sample. Soil test Zn from a 0-4 inch sample.
*Also gave a micros by N rate interaction where micros were beneficial at lower, but not higher, N rates.

Responses to added S were very mixed, with four sites giving no response, three sites showing a positive yield response and two sites where added S gave a significant negative yield response. Soil test was not very helpful in predicting the response pattern, though the two lowest testing soils did give a significant yield increase when S was added, and the highest testing soil gave a significantly lower yield with S amendment.