ADVANCING MODERN WHEAT NUTRITION TO SUSTAIN BOTH YIELD AND THE ECONOMICS OF PRODUCTION

J.H. Grove, E.L. Ritchey, and J.M. Shockley
University of Kentucky, Princeton, KY
jgrove@uky.edu (859) 333-8262

ABSTRACT

This work was intended to answer certain questions that result from the implementation of a multi-element wheat nutrition program. Nitrogen (N) rate is a fundamental driver of wheat yield and quality. However, the impact/value of sulfur (S) or the micronutrients, which are likely components of a more integrated wheat nutrient management program, was not clear. The main study design included four rates of N (40, 80, 120 and 160 lb N/acre), two rates of S (0 and 10 lb S/acre), and two rates of the micronutrient [boron (B) + zinc (Zn)] ‘package’ (0 and 1 lb B + 10 lb Zn/acre); in complete factorial combination to give a total of 16 (4x2x2) treatments. There were three sites in the 2019-20 season (one was lost to a spring freeze) and four sites in the 2020-21 season. Among the six sites the main effect of micronutrients on yield was significant ($P \leq 0.10$) at two, and the main effect of S on yield was also significant at two. At one site there was a significant S by N interaction on yield and at three sites there was a significant micronutrient by N interaction. All six sites gave a significant positive response to N rate, ranging from 18.3 to 54.7 bu/acre. All sites gave yield increases to 160 lb N/acre, over 120 lb N/acre, ranging from 2.8 to 14.9 bu/acre and averaging 6.7 bu/acre. No lodging was observed at any site. Yield increases to micronutrient addition were associated with significant and large increases in flag leaf tissue B and significant but smaller increases in flag leaf tissue Zn. The micronutrient by N interaction was interesting, as the yield increase to the micronutrients diminished as the N rate increased at all three sites. Soil test information for S and B were helpful but not definitive as regards predicting whether a significant response to those nutrient elements would occur. Plant tissue composition data may 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 growing in the field.

INTRODUCTION

There have been almost no significant advances in wheat nutrition since the start of the new century. There has been continuing work to understand the potential role(s) of new fertilizer sources, especially N sources, in wheat nutrition. There have been studies to advance the use of new technologies (chlorophyll meters, proximal sensors) in nutrient deficiency detection. There has been almost no work to examine the interactions, both agronomic and economic, that may be occurring with the use of a more integrated multi-nutritional element wheat nutrient management program. We believe that such research is needed if growers are to continue to sustainably produce wheat as a component of their grain rotations.

Our objective was to conduct field research that would look for, and then examine (both agronomically and economically), possible interactions between N, S and micronutrients [especially B and Zn]. Nitrogen rate is a fundamental driver of wheat yield and quality. But the impact/value of S or the micronutrients, which are likely components of a more integrated multi-nutritional element wheat nutrient management program, is not clear. Nitrogen can drive root exploration – does that mean S and the micros are less likely to be beneficial at higher N rates? Or, are S and the micros more likely to become yield/quality limiting with intensive wheat management at high N rates)? What are the economic consequences to the integrated multi-nutritional element wheat nutrient management program if there is or is not an interaction between N, S and the micronutrients? What are the economic impacts to the program if one of the nutrient additions fails to have a positive impact on the crop, diminishing returns to the program?

MATERIAL AND METHODS

The trial design consisted of four rates of N (40, 80, 120 and 160 lb N/acre), two rates of S (0 and 10 lb S/acre), and two rates of the micronutrient (B + Zn) 'package' (0 and 1 lb B + 10 lb Zn/acre); to give a total of 16 (4x2x2) treatments – the complete factorial combination of treatments needed to find any possible interaction among the nutritional elements. These were applied in four randomized complete blocks at each of seven study sites located in the heart of Kentucky's wheat production regions (Table 1). Fertilizer sources were SuperU, gypsum, Granubor and zinc oxysulfate, respectively.

Table 1. Site information for the two seasons.

Site Number	Site County – Site Name	Wheat Variety	Planting Date
3	Simpson – Walnut Grove Farm	AgriMAXX 454	24 Oct. 2019
5	Logan – Wheat Tech RBF	AgriMAXX 454	23 Oct. 2019
9a	Caldwell – UKREC/GFCE	Pembroke 2016	15 Oct. 2019
1	Caldwell – UKREC/GFCE	Pembroke 2021	17 Oct. 2020
6	Christian – Wheat Tech (CC)	AgriMAXX 454	20 Oct. 2020
8	Logan – Wheat Tech (RBF)	AgriMAXX 454	15 Oct. 2020
9b	Logan – Wheat Tech (OFF)	AgriMAXX 454	23 Oct. 2020

All trials were planted, without prior tillage, into the residues of a recently harvested corn crop. Planting was done in October of each year (Table 1). Weed control was excellent and diseases and insects were well controlled with the appropriate pesticides. Besides grain yield, we also took flag leaf tissue at early flowering, and soil samples (0-4 inches deep) in the early spring prior to S and micronutrient application, to assess whether analytical results from these tools would assist stress diagnosis.

RESULTS AND DISCUSSION

Site 9a was adversely effected by an April frost and was dropped from this analysis. For the remaining six sites, average site yield ranged from 90 to 125 bu/acre (Table 2). All six sites gave a significant positive yield response to N rates, and all six exhibited ‘diminishing returns’ with greater N rates (Table 2). The yield increase to 160 lb N/acre, relative to 40 lb N/acre, ranged from 18.3 to 54.7 bu/acre. Two sites gave a significant positive yield response (average of 2.5 bu/acre) to the B+Zn package and two sites gave a significant positive yield response (average of 3.5 bu/acre) to S addition (Table 2).

Table 2. Wheat Grain Yield Responses – By Site.

Treatment	Site 3	Site 5	Site 1	Site 6	Site 8	Site 9b
	-----------------------------bu/acre-----------------------------					
- B&Zn	106.0†	124.7†	92.1	101.2	103.2	128.4
+ B&Zn	108.5	127.2	89.9	103.2	101.1	126.1
- S	105.1†	125.5	89.7†	102.7	103.0	127.1
+ S	109.4	126.5	92.3	101.8	101.2	127.4
40 lb N/A	83.7†	115.3†	79.0†	72.3†	89.2†	107.4†
80 lb N/A	103.9	124.2	89.0	97.4	98.0	121.2
120 lb N/A	117.3	130.8	94.9	112.1	108.0	138.1
160 lb N/A	124.1	133.6	101.2	127.0	113.2	142.4
B&Zn by S	NS	NS	NS	NS	NS	NS
B&Zn by N	†	†	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.	107.2	126.0	91.0	102.2	101.7	127.3

†Main or interaction effect, at a given site, is significant ($P \leq 0.10$). NS indicates not significant ($P > 0.10$).

A significant micronutrient by N rate interaction on yield was found at three sites (Table 2) and is detailed in Table 3. All three sites exhibited the same pattern to the yield response interaction, with micronutrient addition causing the greatest yield increase at the lowest N rate (40 lb N/acre) and little to no yield improvement at the highest N rate (160 lb N/acre). That greater N nutrition resulted in: a) greater root recovery of soil B or; b) improved internal efficiency in plant B efficiency could be speculated but is not known.

Table 3. Wheat Yield Response: The B&Zn by N Interaction.

Treatment	Site 3	Site 5	Site 6	All Sites Average
	---------------bu/acre---------------			
- B&Zn, 40 lb N	81.0	111.7	66.8	86.5
- B&Zn, 80 lb N	102.2	124.7	97.9	108.3
- B&Zn, 120 lb N	115.2	127.8	112.6	118.5
- B&Zn, 160 lb N	125.7	134.8	127.6	129.4
+ B&Zn, 40 lb N	86.4	118.9	77.8	94.4
+ B&Zn, 80 lb N	105.7	123.7	96.8	108.7
+ B&Zn, 120 lb N	119.4	133.9	111.7	121.7
+ B&Zn, 160 lb N	122.4	132.4	126.5	127.1

One other objective of our work was to gain additional clarity regarding soil test criterion for S, B and Zn applications with an expectation of a significant yield response. Site responses to S and micronutrient additions, and the associated initial soil test results, are compiled in Table 4.

Positive yield responses to S were associated with lower (10 to 17 lb S/acre) soil test S values, but only 40% (2 of 5 sites) of the time. Using soil test B, things were somewhat better, where sites with lower soil test B (0.33 to 0.53 lb B/acre) exhibiting a 60% (3 of 5 sites) positive response rate. Soil test Zn was entirely unhelpful, possibly because the range in observed values (3.7 to 6.6 lb Zn/acre) was narrow. Also, current University of Kentucky recommendations regarding Zn for corn would not have been triggered by the soil test Zn, soil test P and pH values observed at any of these sites.

Table 4. Site Responses to S, B&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
2019-2020 Season					
3	10	yes, positive	0.53	4.7	yes, positive*
5	14	no	0.37	5.4	yes, positive*
2020-2021 Season					
1	17	yes, positive	0.44	3.7	no
6	16	no	0.51	6.6	trend, positive*
8	43	no	0.53	5.9	no
9b	14	no	0.77	6.2	no

†Soil test S and B from a 0-12 inch soil sample. Soil test Zn from a 0-4 inch sample.
*Exhibited a micronutrient by N rate interaction.

Table 5 is similar to Table 4, except that the flag leaf composition data for S, B and Zn are presented in lieu of soil test S, B and Zn. With S, the situation is quite similar to that with soil test S, and positive yield responses were associated with lower (0.25 to 0.28% S) flag leaf S values, but only 40% (2 of 5 sites) of the time. Leaf B and leaf Zn were similar to soil test Zn, entirely unhelpful. Perhaps for the same reason – that the range in values was narrow. Plant tissue composition data may offer a better opportunity as regards nutrient stress monitoring if an earlier sampling time (Feekes 3-4?) is used.

Table 5. Site Responses to S, B&Zn – by Leaf Analysis Result.†

Site	Leaf S %	Response to S	Leaf B ppm	Leaf Zn ppm	Response to B&Zn
2019-2020 Season					
3	0.28	yes, positive	2.8	18.2	yes, positive*
5	0.30	no	3.5	18.2	yes, positive*
2020-2021 Season					
1	0.27	yes, positive	3.1	13.4	no
6	0.25	no	2.3	13.6	trend, positive*
8	0.31	no	2.1	15.5	no
9b	0.28	no	2.8	12.8	no