SULFUR AND MICRONUTRIENT RESPONSES ON CORN AND SOYBEANS

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Introduction

The importance of sulfur and micronutrients for corn and soybean production in the North Central region of the United States has been recognized for many years. When needed, these essential nutrients can have a substantial positive impact on production. However, neither the need for, nor the importance of, sulfur and the micronutrients is universal across the region. Importance (need) is greatly affected by crop, soil properties, and production environment.

When considering the use of phosphate and potash in a fertilizer program, rates used are based on the results of soil tests. Soil tests for zinc (Zn) and manganese (Mn) have been related to crop response. Soil tests for iron (Fe), copper (Cu) and boron (B) are shaky at best. With sulfur (S), a reliable soil test to predict the need for this nutrient has not been developed. Other soil properties and conditions are a better guide. Some old principles as well as new ideas for management of these nutrients will be discussed in the sections that follow.

Zinc

When the results of soil tests project a need for this micronutrient, small amounts can have a substantial impact on yield. Nutrients required in small amounts for optimum yield are thus called micronutrients. This response is illustrated by results of research conducted in Nebraska (Table 1). In this study, four sources of Zn (EDTA, Nulex, zinc oxide, zinc sulfate) were applied in a band as part of a suspension fertilizer (8-20-0) 2 inches to the side of and 2 inches below the seed at planting.

The application of 0.1 lb Zn per acre in this way nearly doubled corn yield. Optimum yield was achieved with the rate of 1.0 lb. Zn per acre. Small amounts do make a large difference. The uptake of Zn by young corn plants was also measured. Uptake increased as the rate of applied Zn increased. The yields and uptake values in Table 1 are the averages for the four Zn sources used.

The response to Zn fertilization shown in Table 1 should be viewed as an extreme case. When a need for Zn is indicated by a soil test, the application of Zn will probably produce an increase in yield. The increase, however, should not be expected to be as large as shown in Table 1.

Table 1. Corn yield and uptake of Zn by young corn plants as affected by rate of Zn applied in a band in a suspension fertilizer.

Zinc Applied	Yield	Zinc Uptake
lbs./A	bu./A	micrograms/plant
0	62.1	120
0.1	130.7	180
0.3	136.6	223
1.0	139.6	258
3.0	142.0	392

Zn soil test = 0.30 ppm (very low)

There has always been a discussion about the impact of Zn source on corn yield. Using results from the Nebraska study, all four sources of Zn had an equal effect on yield (Table 2). Uptake of Zn by young corn plants was greater when Zn was applied as the chelate (EDTA). An increase in uptake, however, did not translate to an increase in corn yield.

Table 2. Corn yield and zinc uptake as affected by source when applied to supply 0.3 lb. Zn per acre.

Source	Yield	Uptake
	bu./A	micrograms/plant
EDTA	138.9	388
Nulex	137.2	220
zinc oxide	129.7	218
zinc sulfate	140.7	225

Considering the small amounts required for optimum yield, it seems logical that placement in a band near the seed at planting would be an effective management option. Various fluid sources of Zn can be mixed with fluid fertilizers and applied in this way. There are, however, questions about the impact on emergence and subsequent yield.

Studies conducted in Minnesota showed that three sources mixed with 10-34-0 to apply two rates of Zn had no negative effect on either emergence (Table 3) or yield (Table 4). In this study, the 10-34-0 was applied at a rate of 5 gallons per acre. This research was conducted at a site with a silty clay loam texture. Placement of fertilizer close to the seed is not suggested for soils with a loamy sand or sandy loam texture.

The "with seed" placement describes a placement where the fluid fertilizer is placed in contact with the seed. When the fertilizer was placed on "top of the seed," there was about 0.5 to 0.75 inches of soil between seed and fertilizer.

The Zn soil test at this site was 1.2 ppm (high).

Table 3. Emergence of corn grown on a silty clay loam soil as affected by rate and placement of these sources of zinc. 2005.

	Zn Rate (lbs./A) and Placement			
	0.1		.05	
Source	With Seed	Top of Seed	With Seed	Top of Seed
	- - - - - - - % of control - - - - - - -			
Nulex	89.1	100.6	95.5	96.8
Tra-Fix	93.0	98.7	94.2	88.5
Origin	98.7	97.4	93.0	94.2

emerged population of control (no zinc) = 33,977 plants/acre

Table 4. Corn yield from a silty clay loam soil as affected by rate and placement of three sources of zinc. 2005.

	Zn Rate (lbs./A) and Placement			
	0.1		.05	
Source	With Seed	Top of Seed	With Seed	Top of Seed
	- - - - - - - - bu./A - - - - - - - -			
Nulex	218	211	213	204
Tra-Fix	201	207	213	200
Origin	210	205	201	217

yield of control (no zinc) = 209 bu./acre

While a banded application near the seed at planting has been an effective method for application of Zn, many growers do not have planters equipped for banded placement. Are there other options? Using techniques for coating soybean seed with various products, it seemed reasonable that it might be possible to coat corn seed with Zn.

Trials were initiated in Minnesota in 2005 to evaluate this method of application. The yields from that initial year are summarized in Table 5. The coating rate of 8 ounces of product per 100 lbs. seed converts to a rate of approximately 0.05 lb. Zn per acre at a planted population of 32,000 seeds per acre.

Results from the first year of the trial indicate that the seed coating alone is not adequate for optimum yield. Highest yields were achieved when the seed coating was combined with Zn in a band either as a fluid (Origin) or dry material (zinc sulfate). When used in the band, the rate was 0.5 lb. Zn per acre.

As stated previously, application of Zn will not be required for all soils. The soil test for zinc (DTPA) is an excellent predictor of zinc needs. Guidelines for application of zinc in a fertilizer program in Minnesota are provided in Table 6. These guidelines are for corn only.

Table 5. Corn grain yield as affected by zinc coated on the seed with and without zinc applied in a band.

Seed Coating Rate	Banded Zinc Source	Yield
oz./100 lbs. seed		bu./A
0	none	143
0	Origin-Zn	149
0	zinc sulfate	150
8	none	146
8	Origin-Zn	165
8	zinc sulfate	157

Table 6. Relative levels for zinc soil tests and corresponding guidelines for zinc application for corn in Minnesota.

Relative Level *	Zinc to Apply for Corn: Band	or	Broadcast
ppm	lbs. Zn/A		
0.0 to 0.25 (very low)	2		10
0.26 to 0.50 (low)	2		10
0.51 to 0.75 (medium)	1		5
0.76 to 1.00 (high)	0		0
1.01 + (very high)	0		0

*zinc extracted by the DTPA procedure

Manganese

In the North Central region, response to Mn fertilization is most frequently associated with soybean production. When needed in a fertilizer program, row applied or banded use can produce substantial increases in yield (Table 7). These results from trials conducted in Wisconsin suggest that a rate of 10 lbs. Mn per acre is adequate for optimum yield when the soil test for Mn is low.

Table 7. Effect of rate of Mn applied in a band at planting on soybean yield.

Mn Applied *	Yield
lbs./A	bu./A
0	45
10	61
20	62
40	63

Source: manganese sulfate

More recently, there has been an interest in the interaction between Mn fertilization and the glyphosate-tolerant soybean varieties. Researchers in Kansas reported that the application of Mn increased the yield of a glyphosate tolerant variety compared to an isoline that did not have the glyphosate-tolerant gene (Table 8). This identified interaction with Mn raises several questions about potential or possible interactions with other micronutrients.

Table 8. Interaction between soybean variety and Mn application as indicated by yield and Mn concentration in the trifoliate tissue.

	Variety			
	KS4202		KS4202 RR	
Mn Applied	Yield	Concentration	Yield	Concentration
lbs./A	bu./A	ppm	bu./A	ppm
0	76.9	75	64.9	32
2.5	76.1	80	72.8	72
5.0	74.9	92	77.6	87
7.5	72.6	105	77.6	95

The lower concentration of Mn in the KS4202RR variety suggests that the glyphosate tolerant trait is in some way interfering with uptake of Mn by the soybean plant.

Dr. Huber, Purdue University, has studied the Mn/glyphosate interaction extensively and has reached the following conclusions.

- The glyphosate resistance gene selectively reduced Mn uptake.
- Glyphosate-resistant soybean yields were lower on low Mn soils, but not on Mn sufficient soils.
- Application of glyphosate reduced Mn translocation in tissues.
- Glyphosate formulation and nutrient source influence uptake.
- Cultivars differ in micronutrient efficiency.
- There is a glyphosate x nutrient x cultivar interaction.
- Nutrient x glyphosate interactions can affect herbicidal efficacy.
- Seed treatment benefits are limited by rate and potential toxicity.

Two major recommendations have evolved from this research. These are:

- If a foliar application of Mn is used, apply eight days after the application of glyphosate.
- Tank mix Mn with glyphosate only if demonstrated not to interfere with Mn utilization.

Sulfur

In contrast to the research activity with micronutrients, there has been renewed interest in the effect of sulfur fertilization on corn and soybean production. This interest has been stimulated by a documented reduction in the sulfur dioxide (SO_2) concentration in the atmosphere combined with higher yields of both corn and soybeans. The higher yields are frequently associated with more removal of sulfur from the soil.

Past research with sulfur use for corn had lead to the conclusion that sulfur was required for optimum production on sandy soils with low organic matter content. Earlier research conducted in Nebraska illustrates this point (Table 9). The sites with the loamy fine sand texture also had low organic matter content (less than 1.0%) and there was a substantial increase in yield with applied sulfur. The soils with the sandy loam texture also had a higher organic matter content and there was no response to applied sulfur.

Table 9. Corn yield as affected by sulfur fertilization of sandy soils differing in organic matter content.

Site I.D.	Texture	O.M.	SO_4-S	NoS	S Applied
		%	ppm	bu./A	
P(74)	loamy fine sand	0.89	4.7	161	180
P(75)	loamy fine sand	0.97	4.6	141	163
P(76)	loamy fine sand	0.85	2.7	109	129
H(74)	sandy loam	1.40	5.6	161	152
H(76)	sandy loam	2.15	7.9	183	184

Results of several trials conducted in the past have produced the conclusion that soil texture is an important consideration when predicting the need for S in a fertilizer program. The corn yields listed in Table 10 are typical of results of many trials where S fertilizer was applied to fine textured soils. Potassium sulfate was applied at a rate to supply 25 and 50 lbs. S per acre. The K was equalized across all treatments with the use of 0-0-60.

Table 10. Effect of sulfur fertilizer on yield of corn grown on a silt loam soil.

S Applied	Yield
lbs./A	bu./A
0	142
25	144
50	146

While application of other essential nutrients for corn production has been guided by reliable soil test procedures for the specific nutrient, there has been no general acceptance of a soil test for sulfur. Extraction with calcium phosphate has been the most widely used analytical procedure.

Evaluating the effect of S fertilization in Illinois, Hoeft and co-workers measured a response at five of 81 sites. The calcium phosphate method accurately predicted a response at four of these five sites. However, the results of this test predicted a response at 14 sites where there was no response. In this extensive study, the use of the calcium phosphate procedure for S would have produced a recommendation for fertilizer S that was not needed.

The weakness of the calcium phosphate test is illustrated by results from trials in Minnesota (Table 11). Sulfur fertilization increased yield at the site where the texture was a sandy loam. Yet, the soil test for S (calcium phosphate procedure) produced nearly the same value at all sites. Therefore, there is not a large amount of confidence in the soil test for S.

Table 11. Corn yield as affected by rate of sulfur applied.

	Site I.D.		
S Applied	S84	JS86	K86
lbs./A	- - - -	bu./A	- - - -
0	122	161	168
10	132	159	169
20	137	167	173
40	128	164	172
texture:	sandy loam	silt loam	silt loam
Soil Test S, ppm:	4	3	6

When considering the amount of S supplied by soils for crop production, it's important to realize that 90% to 95% of the total S is found in soil organic matter. As this organic matter is mineralized, sulfate-sulfur (SO_4-S) becomes available for crop use. There is less soil disturbance in conservation tillage production systems, which should lead to less mineralization. With less mineralization, there should be an increased need for addition of S to a fertilizer program.

This logic was evaluated in recent studies conducted in Minnesota (Table 12). Sulfur was supplied as 21-0-0-24 (ammonium sulfate) at rates to supply 0, 6, 12, 18 lbs. per acre in a band 2 inches to the side of and 2 inches below the seed at planting. These sulfur rates were compared in a ridge-till planting system with one interrow cultivation.

Response to the application of S was affected by soil texture. The organic matter content also varied with soil texture. The silty clay loam soil had the highest organic matter content and the lowest soil organic matter was found at the site with the silt loam texture.

There was no yield increase when the banded S was applied to the silty clay loam. However, the use of S did increase corn yield when the texture was a silt loam, loam, or sandy loam. With conventional tillage systems and the increase in soil disturbance, there would have been more SO_4-S produced as the result of mineralization. These responses were not measured in soils with a silt loam or loam texture when conventional tillage systems were used. Therefore, the switch to conservation tillage production systems might change our thinking about sulfur fertilization.

Table 12. Corn yield as affected by rate of sulfur applied in a band at 4 sites with different soil textures.

	Soil Texture			
Sulfur Applied	silty clay loam	silt loam	loam	sandy loam
lbs./A	- - - - - - - -	bu./A	- - - - - - - -	
0	184	162	145	142
6	184	159	162	152
12	188	172	161	160
18	184	178	159	171

Until recently, the response to S fertilization in the North Central region was primarily limited to sandy soils. In recent years, however, the number of reports of positive yield increases is increasing in the region. Results of an evaluation of the effect of gypsum in studies in Ohio are one example (Table 13). Comparing the two sites, a positive response was measured at the site with a silt loam texture and an organic matter content of 2.5%. Even though yields were higher, there was no response when the texture was a silty clay loam with an organic matter content of 3.2%.

These results and others from soils with a silt loam texture and a relatively low soil organic matter provide a preliminary indication that S fertilization might be important in these production situations. This is especially true if conservation tillage systems are used.

Table 13. Soybean yield from a silt loam soil as affected by rate of applied S using gypsum as a source of S.

S Applied	OARDC	Clark Co.
lbs./A	- - - - - - bu./A	- - - - - -
0	39.6	49.7
15	41.4	50.0
60	44.1	49.4

Summary

For various reasons, interest in the importance of S and micronutrients in a fertilizer program has not been as keen as it was in the past. This diminished interest may be due, in part, to lack of research activity and new ideas for management practices.

As is typical of all of agriculture, management practices for these essential nutrients will change. There will be new concepts for application of the micronutrients. Placement close to the seed at planting may produce positive economical outcomes. The interaction with crop production inputs, an unexplored area of research, may change how micronutrients are applied.

The need for S in fertilizer programs for corn and soybean production in the North Central region will probably expand to soils other than those that are not sandy. Sulfur usage may not be linked to a soil test for S. Instead, it may be strongly affected by other soil properties such as organic matter and texture combined with the tillage system that is used.