Sulfur Fertilization Response in Iowa Corn Production

By John Sawyer, Brian Lang, and Daniel Barker

With the positive results from S fertilization in alfalfa (see related article, page 6), trials were started in 2006 corn fields where early plant growth was exhibiting S deficiency symptoms or where there was expectation of S deficiency. Calcium sulfate ($CaSO_4 \cdot H_2O$, gypsum) was surface broadcast applied after early corn growth at 40 lb S/A, with a control treatment for comparison. The 40 lb S/A rate was chosen as a non-limiting S rate to maximize any potential yield increase.

Corn yield was increased with the S application at five of six sites (**Table 1**). The yield increases were quite large, especially considering the surface sidedress application. However, the sites were chosen based on expected S deficiency, with many sites showing severe plant yellowing. With rainfall after application, plant response (increase in greenness) was observed in a short time period. Across all sites, the yield increase from S application was 38 bu/A. These results indicate that a substantial corn yield increase to S application is possible when soil conditions are conducive to low S supply and severe S deficiency exists. In this study, those conditions were coarse textured soils and a soil/landscape position similar to that with documented S deficiency in alfalfa.

Response to Sulfur Fertilization Rate

An expanded set of trials was conducted in 2007 and 2008 at 45 sites in north-central to northeast Iowa to determine corn response to S rate. The sites were selected to represent major soils, cropping systems, and a range in potential S response. Sites had no recent or known manure application history. Gypsum was surface broadcast applied with no incorporation shortly after planting at 0, 10, 20, and 40 lb S/A. Individual site S response was determined by grain yield comparison of the no S control vs. applied S. Corn yields were averaged across responsive sites by fine and coarse soil textural grouping, with response models fit to the yield response. Economic optimum S rate was determined with S fertilizer at USD 0.50/lb S and corn grain at USD 4.00/bu.

Corn grain yield was increased with S fertilizer application at 17 of 20 sites in 2007 and 11 of 25 sites in 2008, and ear leaf S concentration was increased at 16 sites each year. Across all sites, the average yield increase was 13 bu/A. When grouped by soil texture just for responsive sites (**Figure 1**), the yield increase was 15 bu/A for the fine-textured soils (loam, silt loam, silty clay loam, and clay loam) and 28 bu/A for the coarse-textured soils (fine sandy loam, loamy fine sand, and sandy loam). Grain yields increased with S application at 21 of 34 (62%) fine-textured soil sites and 7 of 11 (64%) coarse-textured soil sites. These are frequent and large yield increases to S fertilization. However, sites located more toward the north-central and central geographic areas of Iowa had a lower frequency of yield response to S application, indicating soil or other factors affecting potential need for S fertilization that are different from the northeast area of Iowa.

When analyzed by the responsive sites, the maximum S response rate for the 21 fine-textured soil sites was 17 lb S/A, with an economic optimum rate at 16 lb S/A (**Figure 1**). For the seven coarse-textured soil sites, the maximum response rate was 25 lb S/A, with an economic optimum rate at 23 lb S/A.

Abbreviations: S = sulfur; P = phosphorus; ppm = parts per million; SO_4^{2-} = sulfate; USD = U.S. dollar.

Table 1. Effect of S fertilizer application on corn grain yield, 2006.

County	Previous crop	Soil type†	Soil SO_4-S‡ ppm	Grain yield - S (bu/A)	Grain yield + S§ (bu/A)
Buchanan	soybean	Sparta lfs	6	123	151*
Buchanan	soybean	Sparta lfs	7	154	198*
Delaware	soybean	Chelsa lfs	9	88	108*
Delaware	soybean	Kenyon l	13	196	204NS
Allamakee	alfalfa	Fayette sil	3	96	172*
Allamakee	alfalfa	Fayette sil	–	118	171*
Across sites				129	167*

† lfs, loamy fine sand; l, loam; sil, silt loam.
‡ Extractable sulfate-S in the 0 to 6 in. soil depth.
§ Sulfur applied at 40 lb S/A. Symbol indicates statistically significant (*) or non-significant (NS) yield increase with S application, $p \leq 0.10$.

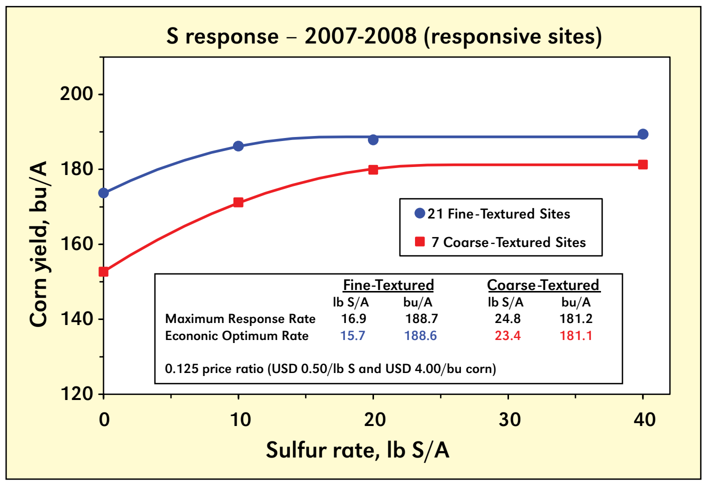

Figure 1. Corn grain yield response to S application rate at responsive sites.

One test for evaluating potential S deficiency is plant analysis for ear leaf S concentration. There is a wide range in published minimum sufficiency concentrations for corn ear leaves at the silking stage, from 0.10 to 0.21% S. The current study does not confirm or refute these minimum levels. Across measured leaf S concentrations there was no clear relationship between ear leaf S and yield response (**Figure 2**). Therefore, it is not possible to define a critical level from this study. Sulfur application increased leaf S concentration, but it was not a large increase. Across sites, an increase of 0.02% S occurred with the 40 lb S/A rate and the leaf S concentration was below 0.21% S at all except one site.

Another test for evaluating potential S deficiency is soil testing for extractable SO_4-S. This study used calcium phosphate extraction. Concentrations (0 to 6 in. depth) were not related to yield response (**Figure 3**). Also, several sites had

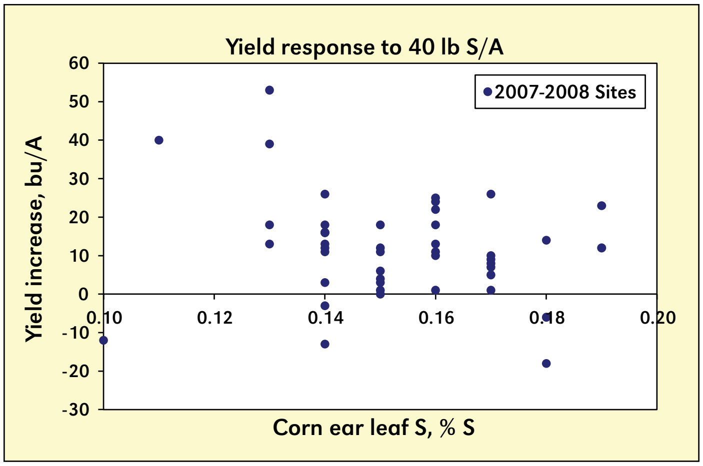

Figure 2. Corn grain yield response to S application as related to ear leaf S concentration in the no-S control.

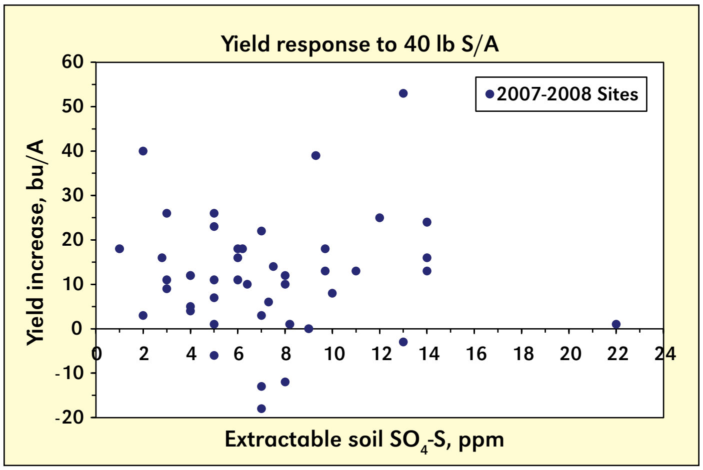

Figure 3. Corn grain yield response to S application as related to extractable soil SO_4-S concentration, 0 to 6-in. soil depth in the no-S control.

concentrations above the 10 ppm S level considered sufficient, but responded to S application. This has been found in other studies where the SO_4-S soil test has not been reliable for predicting crop response to S application on soils in the Midwest USA. Supply of crop-available S is related to more than the SO_4-S concentration in the top 6-in. of soil, thus the poor relationship between yield response and soil test. Soil organic matter has a somewhat better relationship to yield response, but for similar reasons does not clearly differentiate between responsive and non-responsive sites (**Figure 4**). These results highlight the complex combination of environment, soil, and crop factors that result in deficient or adequate season-long supply of available S. Visual observation of deficiency symptoms can lead to correct determination of S response (**Figure 5**). However, hidden hunger can exist where the corn plant does not exhibit deficiency symptoms, but yield increase may or may not occur (**Figure 5**).

Sulfur Fertilizer Product Evaluation

Field trials were conducted in 2006 (northeast Iowa, two sites), 2008 (northern Iowa, one site), and 2009 (central to northern Iowa, two sites) on producer fields to evaluate P-S fertilizer co-products: Simplot and Mosaic 13-33-0-15S (Simplot SEF in 2006 and Mosaic MES15 in 2008) and Mosaic

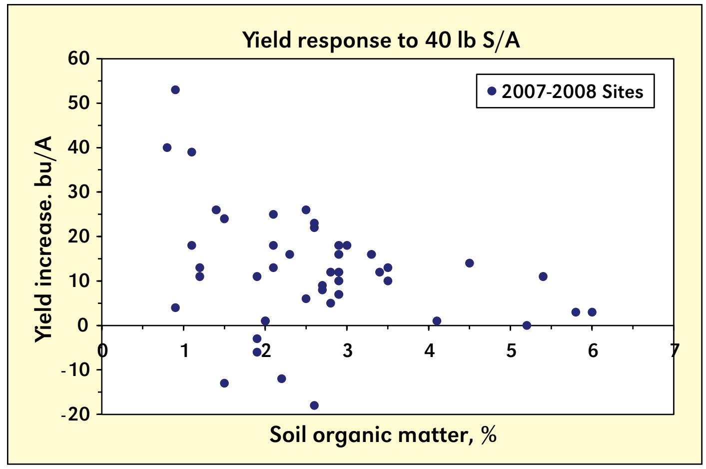

Figure 4. Corn grain yield response to S application as related to soil organic matter, 0 to 6-in. soil depth in the no-S control.

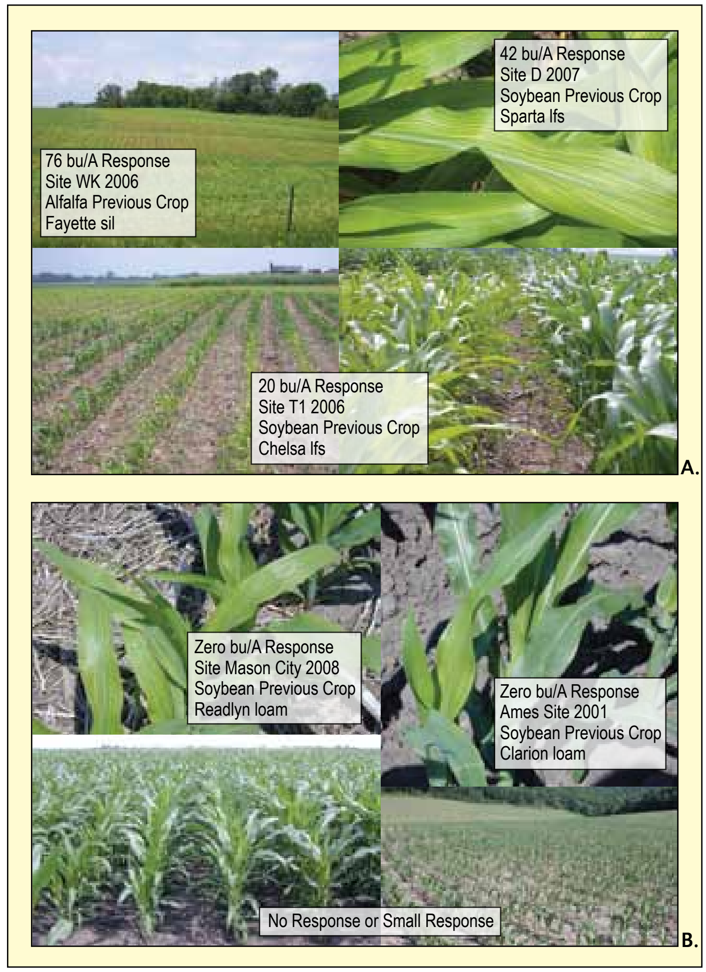

Figure 5. Corn expressing dramatic S deficiency symptoms and having large yield increase from S application (photo grouping A, top), and corn not showing deficiency symptoms and either having a yield increase or no increase from S application (photo grouping B).

12-40-0-10S (MES10 in 2009). The SEF and MES products contained half of the S as SO_4^{2-} and half as elemental. These products were compared to ammonium sulfate (AmS). The fertilizers were broadcast by hand prior to spring tillage or corn planting. For this article, only treatments related to S response are discussed: S control, AmS at 10 and 30 lb S/A, and SEF and MES at 10 and 30 lb S/A. Rates of N and P were

Table 2. Sulfur strip trials conducted in central and northeast Iowa, 2009.

Site	County	Previous crop	Special remarks†	S rate, lb/A	Corn yield, bu/A - S	+ S
3	Greene	corn	a	40	225	229
4	Greene	corn	a	40	210	215*
5	Greene	corn	b	40	217	228*
6	Dallas	soybean	–	40	201	200
9	Dallas	corn	c	40	147	152*
10	Dallas	corn	a, d	40	135	134
1	Fayette	soybean	–	15	224	236*
2	Howard	soybean	–	20	186	192*
7	Dubuque	soybean	–	30	216	229*
8	Floyd	—	e	20	199	203
11	Winneshiek	soybean	–	30	215	212

† Special remarks:
a) Planter split with two hybrids.
b) 16 of 24 rows cultivated.
c) Visual S deficiency symptoms on June 17, corn at V6-V7 growth stage.
d) Field has manure history.
e) Only two replications and considerable yield data missing from two strips.
* Significantly different yield than with no S applied, $p < 0.10$.
If no symbol, then yields are not statistically different.

equalized. The extractable soil SO_4-S concentrations were 4 to 8 ppm in the top 6 in. across sites.

In 2006, the corn grain yield response across sites between the control and 10 lb S/A as AmS or SEF was 15 bu/A (196 vs. 211 bu/A). There was no yield increase to additional S application with the 30 lb S/A rate for either S fertilizer. The ear leaf S concentration was increased from 0.15% S in the control to 0.18% and 0.21%, respectively, for the 10 and 30 lb S/A rates. The leaf S concentration and corn grain yield were the same for both AmS and SEF, indicating similar plant-available S supply from both fertilizer products. In 2008, despite early season plant S deficiency symptoms where no S was applied (a no-till site), there was a visual plant response, but no yield response to S application with either S fertilizer (MES or AmS). Yields were 172 bu/A for the control and 168 bu/A for the S application average. In 2009, despite an increase in ear leaf S concentration (same for both MES and AmS), there was no corn yield response to applied S. These results indicate that the P-S co-products supplied crop available S to corn and were similar to an all-SO_4^{2-} form.

Strip-Trials for Field-Scale Evaluation

In 2009 replicated field-length strip trials were conducted in 11 fields in central and northeast Iowa with spring preplant broadcast gypsum compared to no S application. One rate of S was used in each field, but the rate varied among sites (**Table 2**). These strip trials are considered a survey of potential field-scale S response in corn.

Six of the eleven fields had a corn yield increase from S application, with the other five fields having no S response (**Table 2**). This is a 55% response rate to S application, which is similar to the recent small plot research conducted in north central to northeast Iowa. For the six responding sites, the average yield increase was 9 bu/A, with a range of 5 to 13 bu/A.

Suggestions for Managing S Applications in Corn

- The extractable SO_4-S concentration in the 0 to 6-in. soil depth is not reliable for indicating potential S deficiency or need for S application.
- The S concentration in ear leaves collected at silking can indicate low S supply, but a specific critical concentration with modern hybrids could not be established in this research.
- For confirmed S deficiencies, on fine-textured soils apply approximately 15 lb S/A and on coarse-textured soils 25 lb S/A.
- Sulfur deficiencies have been documented and large crop yield response measured in some fields. However, at this time we are uncertain about the geographic extent of S deficient soils across Iowa. Some common soil conditions where S deficiency has been found include low organic matter soils, side-slope landscape position, eroded soils, and coarse-textured soils. With reduced- and no-till systems, lack of soil mixing and cooler soils reduce mineralization which slows release of S from organic materials — a main source of available S.
- Research to date has not fully documented the variability of deficiency within corn fields. Site-specific response is possible, but inexpensive and reliable methods are needed to "map" S deficiency. This is especially problematic in corn as symptoms are not always present or obvious, especially with minor S deficiency and small but economic yield response (**Figure 5**). Research and development is needed to provide tools for reliable S deficiency detection.

These yield increases are large enough to more than pay for a field-wide S application. This strip trial work confirms that field-scale S deficiency is occurring across a wide geographic area from central to northeast Iowa.

Summary

Corn grain yield increase to S fertilization has occurred with high frequency. Also, the magnitude of yield increase has been large. Across the small plot rate studies, 62% of the sites had a statistically significant yield increase to applied S fertilizer: 72% of sites with loam, silt loam, fine sandy loam, loamy fine sand, and sandy loam textural classes; and 14% of sites with silty clay loam or clay loam textural classes. The across-site yield increase averaged 19 bu/A for the responsive sites. Analyzed across S rate, the economic optimum S rate was 16 lb S/A for fine-textured soils and 23 lb S/A for coarse-textured soils.

This research indicates a change in need for S fertilization, especially in northeast Iowa and the associated soils, and that S application is an economically viable fertilization practice on soils in areas neighboring northeast Iowa. However, the research also shows that corn does not respond to S application in all fields.

Dr. Sawyer is Professor/Extension Soil Fertility Specialist, Department of Agronomy, Iowa State University, Ames, Iowa; e-mail: jsawyer@iastate.edu. Mr. Lang is Field Agronomist, Iowa State University Extension, Decorah, Iowa. Mr. Barker is Assistant Scientist, Department of Agronomy, Iowa State University, Ames, Iowa.

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