Evaluation of Corn Response to Sulfur Fertilization in Northeast Iowa

Project Report for 2006 and 2007 Research

John Sawyer, Associate Professor and Soil Fertility Extension Specialist
Brian Lang, Extension Field Agronomist
Daniel Barker, Assistant Scientist
Iowa State University

Introduction

Over forty years of prior research in Iowa had rarely noted improved corn yield with sulfur (S) fertilization. Statewide and regional studies conducted in Iowa from 2000-2005 had not found corn yield increase from S fertilizer application. Recently, S deficiency was document through forage yield and plant S increase from applied S fertilizers in northeast Iowa alfalfa fields (Lang et al., 2006), especially in field areas with low soil organic matter and side-slope landscape position. On similar soils and on coarse textured soils, early corn growth has been exhibiting strong visual S deficiency symptoms. The objectives of this research were to determine corn response to S fertilization and evaluate specific soils and extent of northeast Iowa affected by S deficiency.

Materials and Methods

Three studies were conducted in northeast Iowa in 2006 and 2007 to evaluate S fertilization response in corn. The first study was designed to evaluate a new phosphorus (P) and S containing fertilizer product. Only treatments related to evaluation of S response are presented here. The second study was targeted to determine if S deficiency was responsible for visual plant yellowing (chlorosis) in early corn growth, and if so, the response to early sidedress applied S fertilizer. The third study was designed to evaluate corn response to S fertilization rate and the extent of S deficiency in northeast Iowa. All of these studies provide insight into the potential for corn yield response to S application and the magnitude of S deficiency in northeast Iowa.

Study 1 – Sulfur Fertilizer Product Evaluation

Two sites were chosen on producer fields in Allamakee and Winneshiek counties in 2006, a Seaton silt loam and a Renova loam soil. The previous year crops were soybean and long-term grazed grass pasture, respectively. Other than grazing, neither site had a history of manure application. Tillage following soybean was shallow disking in the spring and no-till corn planted into the grass pasture.

Treatments were arranged in a randomized complete block design with four replications at each site. Fertilizer treatments were applied broadcast by hand prior to spring tillage or corn planting for the no-till site. For this report, only the following selected treatments are presented: S control (S-CON), ammonium sulfate (AMS) at 10 (AMS-10) and 30 (AMS-30) lb S/acre, and a Simplot 13-33-0-15S product (SEF) at 10 (SEF-10) and 30 (SEF-30) lb S/acre. The SEF product contained half of the S as sulfate and half as elemental. Nitrogen (N) and P application was equalized on all plots.

Soil samples (0-6 inch depth) were collected in spring prior to any tillage and treatment application. Extractable sulfate-S was 8 ppm at both sites. Corn ear leaf samples were collected at the silking (R1) corn growth stage and analyzed for total S. Grain yields were determined for each plot and adjusted to 15.5 % moisture content. Means and statistical analyses were combined across sites, with site as a random effect.

Study 2 – Corn Response to Sulfur Application with Visual Deficiency Symptoms

In 2006, six sites were selected based on expectation of S deficiency, either through visual observation of early plant S deficiency symptoms being present or previous experience indicating that soil conditions and previous crop would be conducive to S deficiency. Therefore, sites were considered specifically "chosen", and therefore not a set of sites with random potential of response to S application. Sites did not have recent or known manure application history.

Calcium sulfate was surface broadcast applied sidedress after early corn growth at 40 lb S/acre, with a control treatment for comparison. A non-limiting S rate was chosen to allow measurement of S response, with expectation the 40 lb S/acre rate would maximize any potential yield increase. Treatments were arranged in a randomized complete block design with four replications at each site. Soil samples (0-6 inch depth) were collected before S application. Grain yields were determined for each plot and adjusted to 15.5 % moisture content. Means and statistical analyses were computed across sites, with site as a fixed effect.

Study 3 – Corn Response to Sulfur Fertilization Rate

An expanded study was conducted in 2007 at twenty sites to determine corn response to S rate of application. The sites were selected to represent major soils and cropping systems (Table 3), and were chosen to represent a range in potential S response. Sites did not have a recent or known manure application history. Calcium sulfate was surface broadcast applied with no incorporation shortly after planting at 0, 10, 20, and 40 lb S/acre. Each rate was replicated four times at each site in a randomized complete block design. Soil samples (0-6 inch depth) were collected before S application. At the silking (R1) growth stage corn ear leaf samples were collected and analyzed for total S. Grain yields were determined for each plot and adjusted to 15.5 % moisture content. Means and statistical analyses were computed across sites, with site as a random effect. Quadratic-plateau regression models were fit to the grain yield response for the fine and coarse textured soil sites. Economic optimum S rate was determined with S fertilizer at $0.50/lb S and corn grain at $4.00/bu.

Results

Study 1 – Sulfur Fertilizer Product Evaluation

The yield difference between the control (S-CON) and 10 lb S/acre (AMS-10 and SEF-10) was 15 bu/acre, which was statistically significant (Table 1). There was no yield increase to additional S application with the 30 lb S/acre rate. Corn ear leaf S concentration was significantly increased with application of AMS and SEF fertilizers (Table 1). Grain yields and leaf S concentrations with AMS and SEF were the same, indicating similar plant-available S supply from both S sources. Leaf S concentration with no S applied was low, and below the 0.21% S level considered sufficient (Neubert, et al., 1969). Application of 30 lb S/acre increased leaf S concentration compared to the 10 lb S/acre rate, and raised the concentration just to the sufficient level. Despite this increase in leaf S, yield was not increased with the higher S rate.

Study 2 – Corn Response to Sulfur Application with Visual Deficiency Symptoms

Corn yield was increased with the sidedress calcium sulfate application at five of six sites. The yield increases were quite large, especially considering the surface fertilizer application after plant early growth. However, the sites were chosen based on expected S deficiency, with many sites showing severe plant yellowing. Therefore, substantial yield increase might be expected. With rainfall after application, plant response (increase in greenness) was observed in a short time period. This would also indicate an expected plant growth and yield increase. The site with no statistically significant response to S application (and high yield with no S) also had the highest extractable soil sulfate-S concentration.

Across all sites, the yield increase from S application was 38 bu/acre. This yield increase would easily cover the required S fertilization cost. Since only one non-limiting S rate was applied, it is not possible to determine an economic application rate. 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 soil/landscape position similar to that with documented S deficiency in alfalfa.

Study 3 – Corn Response to Sulfur Fertilization Rate

Corn grain yield was increased (statistically significant) with S application at seventeen of the twenty sites in 2007 (Figure 1) and leaf S concentration was increased at sixteen sites (Figure 2). Across all sites, the average yield increase was 18 bu/acre. When grouped by soil texture, the yield increase was 15 bu/acre for the fine textured soils (loam and silt loam) and 25 bu/acre for the coarse textured soils (loamy sand and sandy loam). These are large yield increases to S fertilization. The yield levels were quite high in 2007, with an average yield (with S application) of 201 bu/acre at the fine textured soil sites and 190 bu/acre for the coarse textured soil sites.

When analyzed across S rate, the maximum response rate for the fourteen fine-textured soil sites was 15 lb S/acre, with an economic optimum rate at 14 lb S/acre (Figure 3). For the six coarse-textured soil sites, the maximum response rate was 26 lb S/acre, with an economic optimum rate at 24 lb S/acre (Figure 3).

Corn ear leaf S concentrations were below the 0.21% S critical level (Neubert, et al., 1969) at all sites. The application of S increased leaf S concentration, but was not a large increase (across sites, an increase of 0.03% S with the 40 lb S/acre rate). Even with the 40 lb S/acre rate, the leaf S concentration was below 0.21% S at all but one site. Two of the non-responding sites did not have a statistically significant increase in leaf S concentration with S application. The three non-significant yield responsive sites (Figure 1) all had leaf S concentrations well below 0.21% S without S application (Figure 2).

Ear leaf S concentration in the control (zero applied S) can be used as a guide for potential corn response to S application. Figure 4 shows this relationship for relative yield of the control (relative to yield with the 40 lb S/acre rate). All sites had leaf S concentrations below the 0.21% S critical level established by Neubert et al. (1969). That critical level was established years ago and may not be valid with today's hybrids. The current work, however, does not refute that level. No site had a leaf S concentration greater than 0.19% S (without S application), and sites with that leaf S concentration did respond to S (yield increase). Therefore, it is not possible to define a critical level in this study or determine if the 0.21% S level is still valid. The data does indicate that the critical level is greater than 0.19% S.

The extractable soil sulfate-S concentrations in the control (Table 3 and Figure 5) were not well related to yield response to applied S. Also, several sites had concentrations above the 10 ppm S level considered sufficient (Hoeft et al., 1973), but still responded to S. This has been found in other studies where the sulfate-S soil test has not been reliable for predicting crop responses to S application on soils in the Midwest USA (Hoeft et al., 1985; Sawyer and Barker, 2002). Supply of crop-available S is related to more than the sulfate-S concentration in the top six inches of soil, thus the poor relationship between relative yield and soil test.

Summary

Corn grain yield increase to S fertilization has occurred with high frequency in these studies. Also, the magnitude of yield increase has been large. Across the two years and three studies, 82% of the sites had a statistically significant yield increase to applied S fertilizer. By study, statistically significant across-site yield increases averaged 15, 18, and 38 bu/acre. Analyzed across S rate, the economic optimum S rate was 14 lb S/acre for fine-textured soils and 24 lb S/acre for coarse-textured soils. This research indicates a dramatic change in need for S fertilization in northeast Iowa, and that S application is an economically viable fertilization practice on many soils.

In addition, this work indicates that more research is critically needed, not only to continue study on soils in northeast Iowa, but also for a larger geographic area extending into central and southeast Iowa. If the responses found in these studies are indicative of potential S fertilization need in other geographic areas, then yields of corn and other crops could be suffering due to S deficiency. The only way to know is to expand research efforts. In addition, additional information is needed regarding plant and soil S tests, plant S stress sensing, site characteristics, and S deposition in order to develop better predictive indices of S deficiency and need for S fertilization. These tools will provide better decision making and enhance positive economic return to S fertilization for producers.

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Table 1. Effect of S fertilizer product application on corn ear leaf S concentration and grain yield combined across sites, 2006.

Treatment[†]	Ear Leaf S Concentration	Grain Yield
	%	bu/acre
S-CON	0.15	196
SEF-10	0.18	211
AMS-10	0.18	211
SEF-30	0.21	204
AMS-30	0.20	207
Contrast	Statistics ($p>F$)	
SEF-10 & SEF-30 vs. AMS-10 & AMS-30	0.6620	0.7433
S-CON vs. AMS-10	0.0001*	0.0467*
AMS-10 vs. AMS-30	0.0166*	0.5796

[†] S-CON, S control; SEF, 13-33-0-15S product; AMS, ammonium sulfate product; 10 or 30 indicates the rate of S applied.

* Indicates statistical significance of the contrast, $p \leq 0.10$.

Table 2. Effect of S fertilizer application on corn grain yield, 2006.

Site	County	Previous Crop[†]	Map Unit	Soil	Soil S[‡]	Grain Yield	
						- S	+ S[§]
					ppm	- - - bu/acre - - -	
L1	Buchanan	S	41B	Sparta lfs	6	123	151*
L2	Buchanan	S	41B	Sparta lfs	7	154	198*
T1	Delaware	S	63C	Chelsa lfs	9	88	108*
T2	Delaware	S	83B	Kenyon l	13	196	204NS
WK	Allamakee	A	163C	Fayette sil	3	96	172*
WT	Allamakee	A	163C	Fayette sil	--	118	171*
Across Sites						129	167*

[†] S, soybean; A, first-cut alfalfa harvested.

[‡] Extractable sulfate-S in the 0-6 inch soil depth.

[§] Sulfur applied at 40 lb S/acre. Symbol indicates statistically significant (*) or non-significant (NS) yield increase with S application ($p \leq 0.10$).

Table 3. Site information for the S rate study, 2007.

Site	County	Previous Crop[†]	Soil OM[‡]	Soil S[‡]	Map Unit	Soil
			%	ppm		
B	Black Hawk	S	1.9	5	408B	Olin fsl
C	Buchanan	S	2.7	3	399	Readlyn l
D	Buchanan	S	0.8	2	41B	Sparta lfs
E	Buchanan	S	1.4	3	284	Flagler sl
F	Buchanan	S	0.9	13	41B	Sparta lfs
G	Delaware	S	2.0	5	241B	Burkhardt-Saude sl
H	Delaware	S	2.5	5	391B	Clyde-Floyd l
I	Delaware	S	2.6	7	177	Saude l
J	Delaware	S	1.1	6	175B	Dickinson fsl
K	Delaware	S	0.9	4	408B	Olin fsl
L	Delaware	S	3.4	4	83B	Kenyon l
M	Fayette	S	2.6	5	163D2	Kenyon l
O	Clayton	C	1.5	14	158	Dorchester sil
Q	Clayton	S	2.9	5	162C	Downs sil
R	Clayton	S	2.7	10	163C2	Fayette sil
U	Clayton	A	2.1	1	163B	Fayette sil
W	Winneshiek	S	2.8	4	162D	Downs sil
X	Allamakee	C	2.1	12	163C2	Fayette sil
Y	Allamakee	C	2.3	6	162C2	Downs sil
Z	Allamakee	C	2.1	11	162C2	Downs sil

[†] S, soybean; C, corn; A, alfalfa.

[‡] Soil organic matter (OM) and extractable sulfate-S in the 0-6 inch soil depth.

Figure 1. Corn grain yield response to S application (no S vs. plus S), 2007. The average across all sites is designated by [a], * indicates statistically significant response to S, and NS indicates non-significant response to S ($p \leq 0.10$).

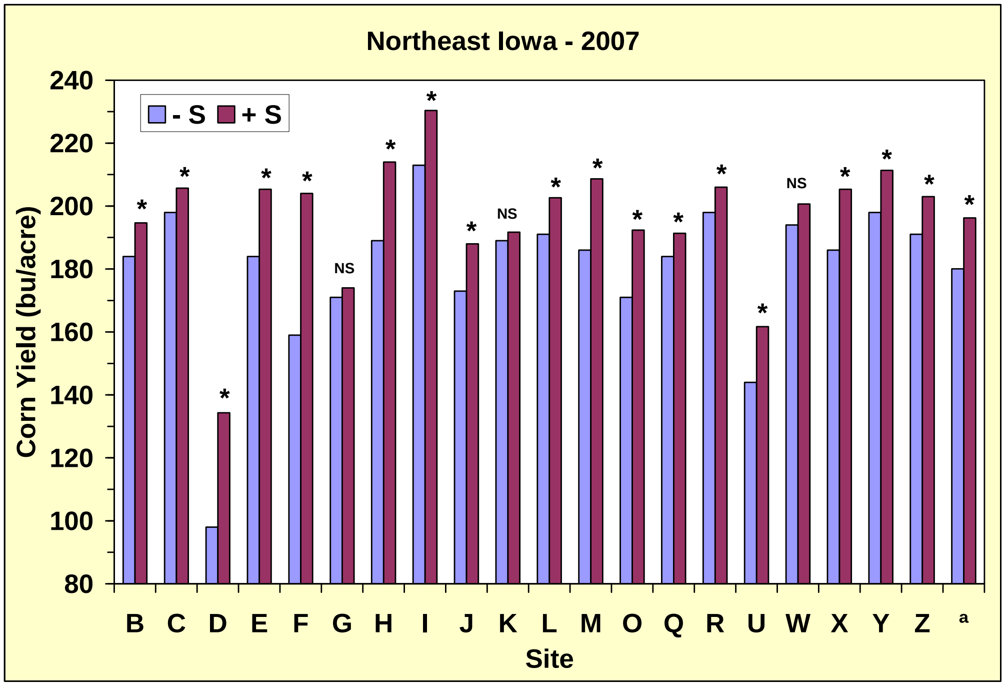

Figure 2. Corn ear leaf S concentration response to S application (no S vs. plus S), 2007. The average across all sites is designated by [a], * indicates statistically significant response to S, and NS indicates non-significant response to S ($p \leq 0.10$).

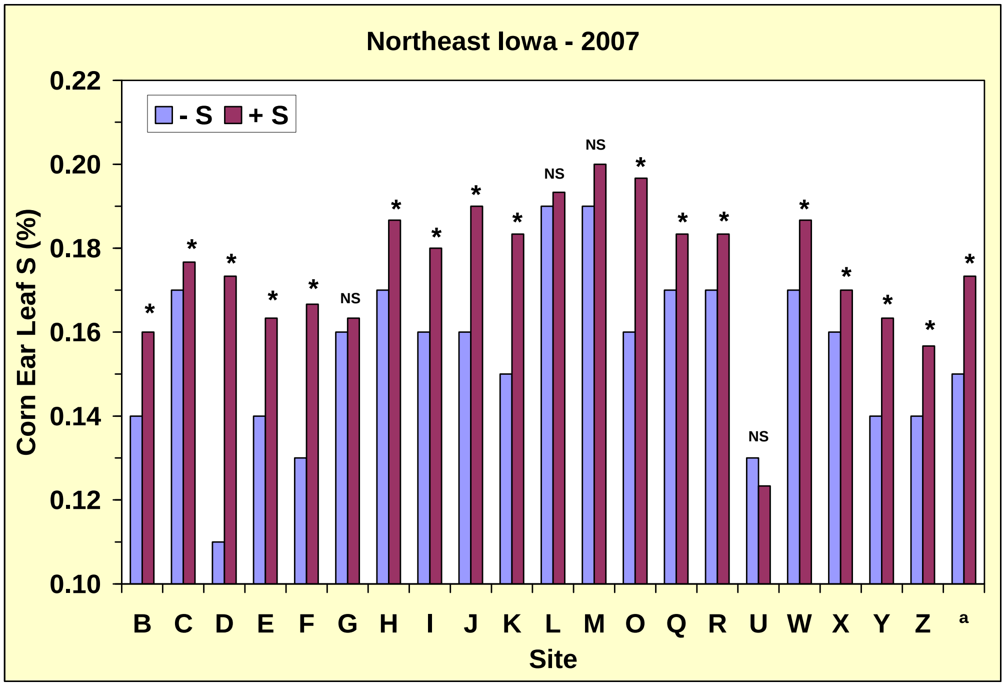

Figure 3. Corn grain yield response to S rate of application, 2007.

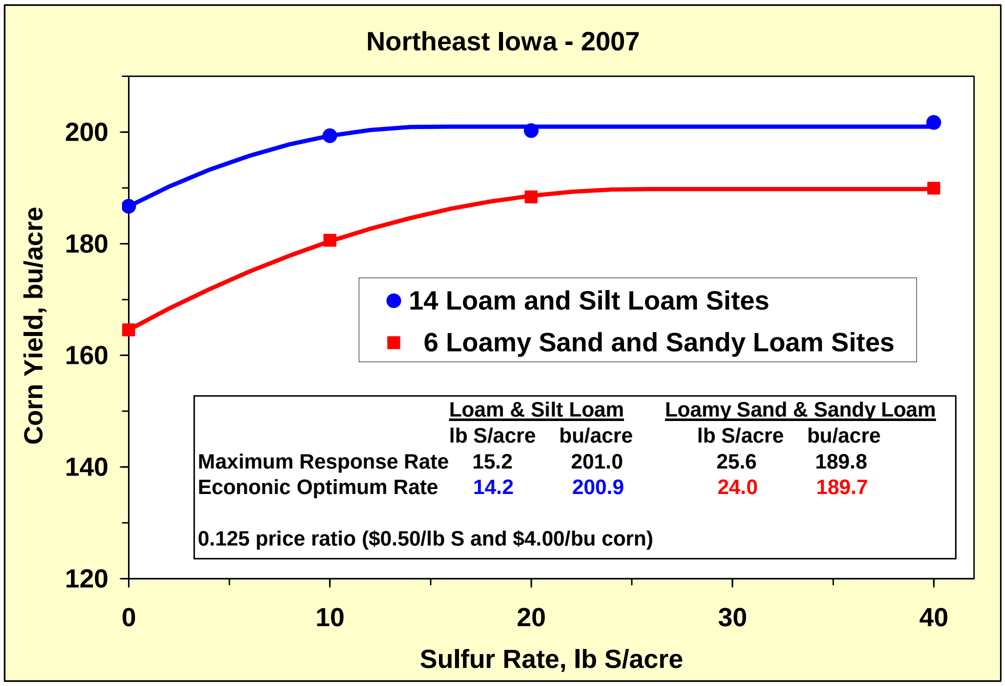

Figure 4. Corn grain relative yield as related to ear leaf S concentration, 2007.

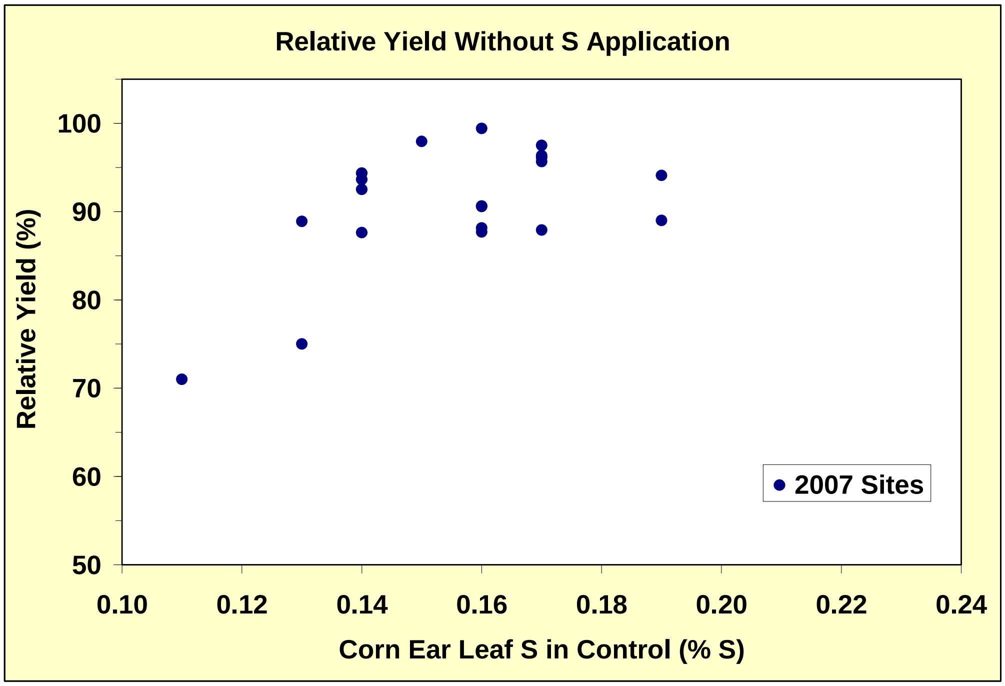

Figure 5. Corn grain relative yield as related to extractable soil sulfate-S concentration (0-6 inch soil depth), 2007.