Evaluation of Corn Response to Sulfur Fertilization in Central to Northeast Iowa

Project Report for 2007-2008 Research

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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 S deficiency in the central, north-central to northeast Iowa geographic area.

Materials and Methods

Two studies were conducted to evaluate S fertilization response in corn. The first study was conducted in 2008 and 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 conducted in 2007 and 2008 and designed to evaluate corn response to S fertilization rate. All of these studies provide insight into the potential for corn yield response to S application and the magnitude of S deficiency in the central, north-central to northeast area of Iowa.

Study 1 – Sulfur Fertilizer Product Evaluation

Two sites were chosen that had potential for S deficiency. One site was no-till corn following soybean (several years of no-till) in northern Iowa at the North Iowa Area Community College (NIACC), Mason City on a Readlyn loam soil. The other site was at an Iowa State University (ISU) Agronomy Research Farm near Ames on a Spillville loam soil with corn following soybean. Treatments were applied in the spring prior to planting at both sites, but unfortunately the site near Ames was lost due to flooding of the Skunk River floodplain in the late spring.

Treatments were arranged in a randomized complete block design with four replications. 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 Mosaic 13-33-0-15S product (MES15) at 10 (MES-10) and 30 (MES-30) lb S/acre. The MES product contained half of the S as sulfate and half as elemental. Nitrogen (N) and P application was equalized on all plots, and potassium (K) was applied at 60 lb K_2O/acre as potassium chloride to all plots.

Soil samples (0-6 inch depth) were collected in spring prior to any tillage and treatment application. Extractable sulfate-S was 4 ppm, and the Mehlich-3 soil test P 16 ppm and K 140 ppm at the Mason City site. 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.

Study 2 – Corn Response to Sulfur Fertilization Rate

Studies were conducted in 2007 and 2008 at forty-five sites to determine corn response to S rate of application. The sites were selected to represent major soils and cropping systems, and were chosen to represent a range in potential S response. Most sites were on producer fields. 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. Individual site S responsiveness was determined by contrast comparison of the no S control application vs. applied S. Means and statistical analyses were computed across all sites and by fine and coarse soil textural grouping, with site as a random effect. Quadratic-plateau regression models were fit to the grain yield response for the fine- and coarse-textured responsive site groupings. 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

Corn plants at the Mason City no-till site exhibited S deficiency symptoms early in the growing season where no S was applied. Plants did not exhibit the deficiency symptoms where S was applied. However, despite these visual symptoms and plant response to applied S, there was no increase in grain yield with S application for either the MES or AMS products (Table 1). Ear leaf S concentrations were increased only slightly with S application (Table 1). Grain yield was lower with 30 lb S/acre than with 10 lb S/acre from MES and AMS application. That grain yield decrease with the higher S rate would not be expected based on other research with S rate of application to corn.

Study 2 – Corn Response to Sulfur Fertilization Rate

The location, previous crop, and soil characteristics of each site in 2007 and 2008 are listed in Tables 2 and 3. Corn grain yield was increased (statistically significant) with S fertilizer application at 17 of the 20 sites in 2007 and 11 of the 25 sites in 2008 (Figs. 1 and 2) and leaf S concentration was increased at 16 sites each year (data not shown). Across all sites, the average yield increase was 13 bu/acre. When grouped by soil texture for responsive sites, the yield increase was 15 bu/acre for the fine-textured soils (loam, silt loam, silty clay loam, and clay loam) and 28 bu/acre 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.

Efficiency of fertilizer use is important to gain best advantage from nutrient inputs. Table 4 gives two measures of S use efficiency (SUE). The first is the partial factor productivity (PFP), which is the grain yield produced per unit of fertilizer applied (yield divided by the applied S fertilizer rate), and the agronomic efficiency (AE) which is the increase in yield from the S fertilizer applied (yield at the fertilized rate minus the yield with no fertilizer applied divided by the fertilizer rate). Usually these efficiency measures are associated with N fertilization, but can be applied to other nutrient applications like S fertilizer. High SUE indicates a high return to S input. As found with other nutrients, as S application rate increased the efficiency decreased. This occurred because it takes more nutrient to increase each unit of yield as the yield approached maximum response. The PFP was similar for all sites and the responsive sites, and the AE was generally greatest for the coarse-textured responsive sites, indicating the larger yield increase from S application on those soils.

While nutrient use efficiency is important and interesting, for producers the important question is what is the economic optimum application rate? When analyzed for the responsive sites, the maximum response rate for the 21 fine-textured soil sites was 17 lb S/acre, with an economic optimum rate at 16 lb S/acre (Fig. 3). For the 7 coarse-textured soil sites, the maximum response rate was 25 lb S/acre, with an economic optimum rate at 23 lb S/acre (Fig. 3). The economic optimum S rate is near the maximum response because the fertilizer cost (rate times price) is low compared to the yield return (yield increase times corn price).

Corn ear leaf S concentrations were below the 0.21% S critical level (Neubert, et al., 1969) at all sites (Fig. 4). The application of S increased leaf S concentration, but was not a large increase (across sites an increase of 0.02% 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 (data not shown).

Ear leaf S concentration in the control (zero applied S) can be used as a guide for potential corn yield response to S application. Fig. 4 shows this relationship for yield response to S application (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 study, 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). Also, some sites had low leaf S concentrations (≤ 0.17% S) but there was no yield increase with S application. Therefore, it is not possible to define a critical level from data in this study or determine if the 0.21% S level is valid. The data does indicate that the critical level may be greater than 0.19% S.

The extractable soil sulfate-S concentrations in the control (no applied S) (Tables 2 and 3, and Fig. 5) were not 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 application. 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, 62% of the sites had a statistically significant yield increase to applied S fertilizer, with similar frequency for fine- and coarse-textured soils. The across-site yield increase averaged 13 bu/acre for all sites and 19 bu/acre for the responsive sites. Analyzed across S rate, the economic optimum S rate was 16 lb S/acre for fine-textured soils and 23 lb S/acre 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 many soils. However, the research also shows that corn does not respond to S application in all fields or field areas and that chance of S response decreases outside of the northeast Iowa geographic area.

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, north-central and east-central Iowa, and the associated soils in those regions. If the frequency of response found in these studies is indicative of potential S fertilization need in other Iowa 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 critically needed regarding plant and soil S tests, plant canopy 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 would provide better decision making and enhance positive economic return to S fertilization for producers.

Acknowledgements

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Table 1. Effect of S fertilizer product application on corn ear leaf S concentration and grain yield at the Mason City, IA site, 2008.

Treatment†	Ear Leaf S Concentration	Grain Yield
	%	bu/acre
S-CON	0.16	172
MES-10	0.17	173
AMS-10	0.16	175
MES-30	0.19	162
AMS-30	0.17	160
Contrast	Statistics ($p>F$)	
MES-10 & MES-30 vs. AMS-10 & AMS-30	0.003*	0.305
S-CON vs. AMS-10	0.659	0.696
AMS-10 vs. AMS-30	0.037*	0.075*

† S-CON, S control; MES, 13-33-0-15S product; AMS, ammonium sulfate product; 10 or 30 indicates the rate of S applied.
* Indicates statistical significance of the contrast, $p \le 0.10$.

Table 2. 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 cl
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.

Table 3. Site information for the S rate study, 2008.

Site	County	Previous Crop†	Soil OM‡	Soil S‡	Map Unit	Soil
			%	ppm		
1	Black Hawk	S	2.9	4	399	Readlyn l
2	Black Hawk	S	1.1	9	41B	Sparta lfs
3	Black Hawk	S	1.2	10	408B	Olin fsl
4	Buchanan	S	2.8	8	83B	Kenyon l
5	Howard	S	3.5	6	198B	Floyd l
6	Winneshiek	S	4.5	8	482B	Racine l
7	Winneshiek	S	2.0	8	171C	Bassett l
8	Howard	S	2.9	3	214B	Rockton l
9	Chickasaw	S	3.0	10	482B	Racine l
10	Chickasaw	S	2.5	7	84	Clyde cl
11	Howard	S	2.9	6	171B	Bassett l
12	Butler	A	1.2	6	173B	Hoopeston fsl
13	Butler	A	4.1	22	152	Marshan cl
14	Floyd	S	3.5	14	83	Kenyon l
15	Floyd	S	1.9	13	399	Readlyn l
16	Floyd	S	3.3	14	394B	Ostrander l
17	Worth	C	5.2	9	107	Webster sicl
18	Worth	C	1.5	7	236C2	Lester l
19	Worth	S	2.2	8	214	Rockton l
20	Worth	S	2.9	8	188	Kensett sil
21	Winneshiek	S	2.6	7	491	Renova l
22	Hancock	S	5.8	7	507	Canisteo cl
23	Butler	S	1.9	5	408B	Olin fsl
24	Story	S	6.0	2	507	Canisteo sicl
25	Butler	S	5.4	3	84	Clyde sicl

† S, soybean; C, corn; A, alfalfa.

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

Table 4. Average S fertilizer use efficiency measures, 2007-2008.

	Partial Factor Productivity (PFP)†			Agronomic Efficiency (AE)‡		
	S fertilizer rate (lb S/acre)			S fertilizer rate (lb S/acre)		
	10	20	40	10	20	40
	- - - - bu/lb S applied - - - -			- - - - Δ bu/lb S applied - - - -		
Across all sites	18.9	9.5	4.8	1.20	0.65	0.35
Fine texture responsive sites	18.6	9.4	4.7	1.26	0.72	0.39
Coarse texture responsive sites	17.1	9.0	4.5	1.86	1.36	0.71

† Partial Factor Productivity (PFP): Yield produced per unit of fertilizer applied (yield divided by the fertilizer rate).

‡ Agronomic Efficiency (AE): Increase in yield from fertilizer applied (yield at the fertilized rate minus the yield with no fertilizer applied divided by the fertilizer rate).

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 ($p \leq 0.10$).

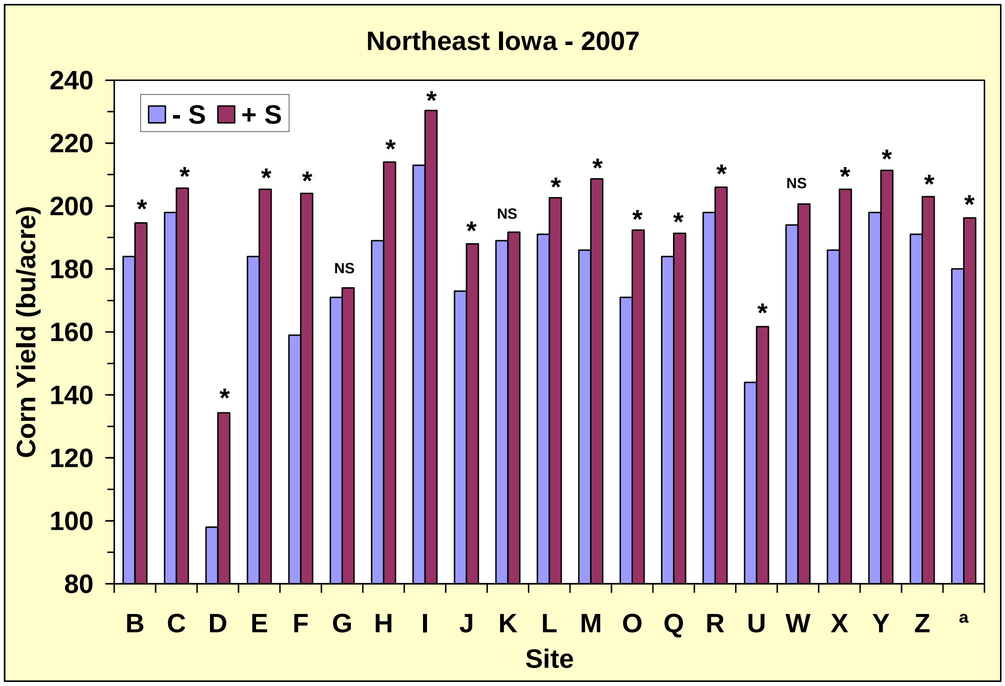

Figure 2. Corn grain yield response to S application (no S vs. plus S), 2008. The average across all sites is designated by [a], * indicates statistically significant response to S, and NS indicates non-significant response to S ($p \leq 0.10$).

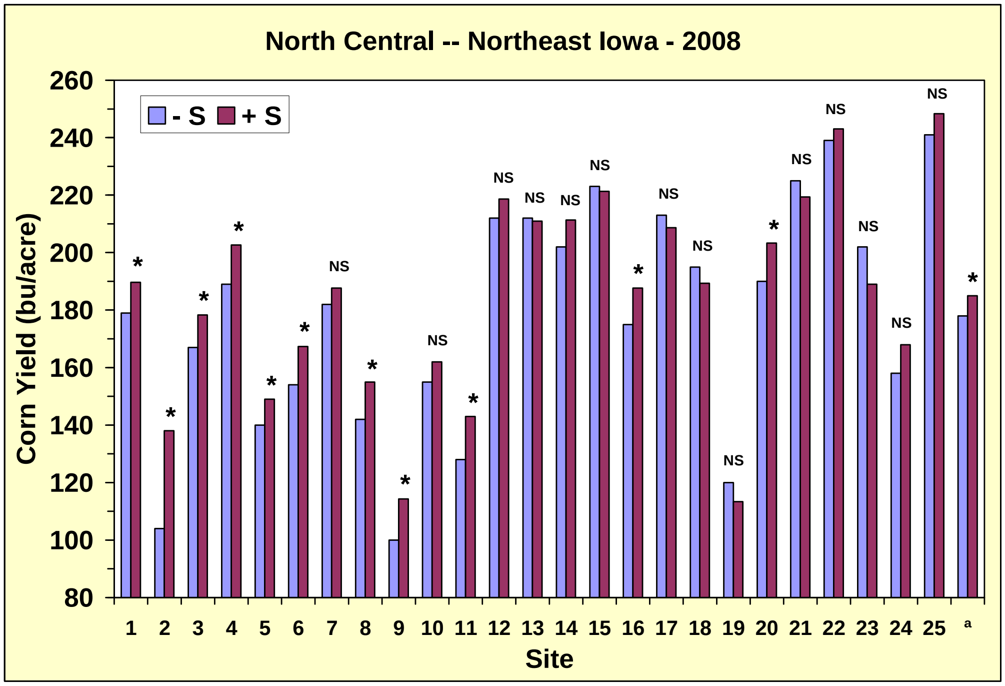

Figure 3. Corn grain yield response to S application rate at responsive sites, 2007-2008.

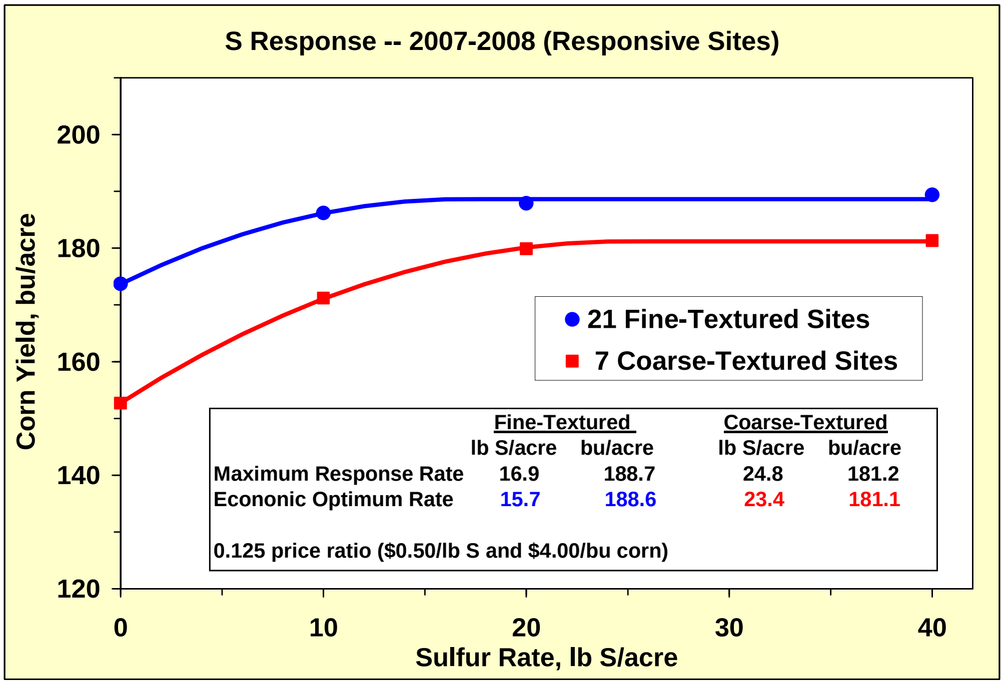

Figure 4. Corn grain yield response to S application as related to ear leaf S concentration, 2007-2008.

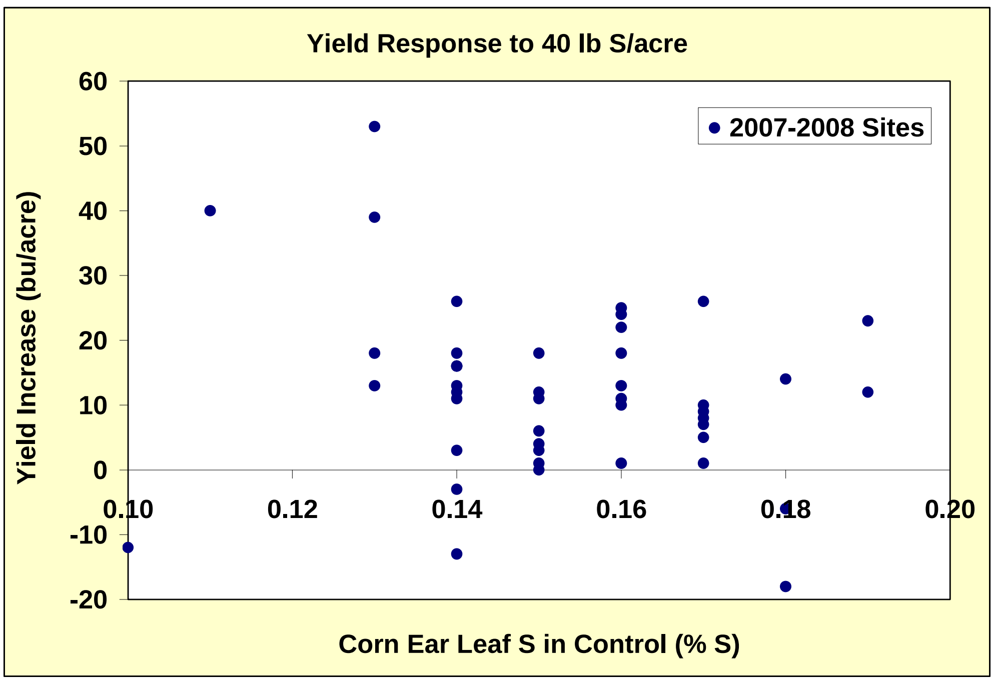

Figure 5. Corn grain yield response to S application as related to extractable soil sulfate-S concentration (0-6 inch soil depth), 2007-2008.