Corn Yield as Affected by Sulfur Fertilization in Southern Minnesota

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Abstract

Historically, sulfur (S) fertilizer has not been recommended on medium- and fine-textured soils in Minnesota, because corn (Zea mays L.) yield responses to S fertilization were found only on coarse textured soils. Mineralization of S from organic matter in fine-textured soils was generally sufficient to optimize corn yields in past trials. The increasing frequency of greater than 12.5 Mg ha^{-1} corn yields along with decreased S additions from various sources (atmospheric deposition and manure application) have reduced the amount of available S in many soils of the Midwest. The primary objective of this paper is to document corn yield responses to S fertilization on medium- and fine-textured soils in Minnesota in the last decade. Initial studies were conducted from 1999 through 2006 on tile drained Nicollet-Webster clay loam soils (Aquic Hapludolls and Typic Endoaquolls, respectively). In one 6-yr study average corn grain yields were increased 0.4 Mg ha^{-1} by an annual broadcast application of 76 kg S ha^{-1} as gypsum. In a 3-yr trial average corn yield responses of 0.5 to 0.7 Mg ha^{-1} were obtained with planter band rates of 5 and 11 kg S ha^{-1}. In a recent study yields were increased at 3 of 9 sites and for the 9 site averaged when 6.4 kg S ha^{-1} as ammonium thiosulfate was added to ammonium polyphosphate starter fertilizer. In a 2010 study continuous corn yield response to S ranged from 1.7 to 2.9 Mg ha^{-1} on a Webster clay loam. These data suggest fertilizer recommendations for S on medium- and fine-textured soils should be revisited.

Introduction

Since the 1960's in Minnesota and much of the Northern Corn Belt, sulfur fertilization of corn was recommended only on coarse-textured, low organic matter soils. Sulfur from mineralization of organic matter, atmospheric deposition, manure applications, and to a lesser extent from other fertilizer sources which contained S was more than adequate to meet crop needs on most medium and fine-textured soils.

Objectives

To document and summarize corn grain yield responses to sulfur fertilization observed on medium and fine textured soils across Southern Minnesota in the last decade.

To compare the effects of various sulfur sources, rates, and application methods on corn yield, grain moisture, and sulfur concentrations in plant tissue.

Study A

Methods

- Study period: 1999 – 2005 except 2003 when corn was not grown.
- Previous crop: Soybean (4 yr) or alfalfa (2 yr)
- Soil characteristics: Nicollet clay loam (glacial till), pH=5.3 and organic matter=4.8%
- Sulfur source, rate, and application timing: Gypsum ($CaSO_4$), 76 kg S ha^{-1} (448 kg gypsum ha^{-1}), annual fall broadcast and incorporated.

Results

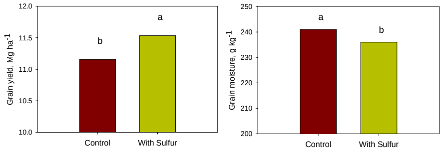

Figure 1. Six-year average corn grain yield and moisture as affected by sulfur.

- Averaged across six-years, 76 kg S ha^{-1} as gypsum increased corn grain yield 0.4 Mg ha^{-1} and decreased corn grain moisture 5 g kg^{-1} on a clay loam soil with 4.8% organic matter.

Study B

Methods

- Study period: 2004 – 2006.
- Soil characteristics: Nicollet and Webster clay loams, pH=5.2, 6.0, 7.1 and organic matter=4.9, 4.5, 6.8% for 2004, 2005, and 2006, respectively.
- Sulfur source, rate, and placement: Potassium thiosulfate, and ammonium thiosulfate (ATS), 4.5 and 11 kg S ha^{-1} applied at planting. The data in Table 1 are an average of two placements – dribbled on the soil surface near the row and 5 × 5 cm injected band. No differences were found between placements.

Results

Table 1. Three-year average corn grain yield and moisture as affected by rate of sulfur and potassium in combination with nitrogen and phosphorus starter fertilizers.

Starter fertilizer treatment	Corn Grain Yield	Corn Grain Moisture
kg ha^{-1} of N+P+K+S	Mg ha^{-1}	g kg^{-1}
22 + 10 + 6 + 0	11.9	229
22 + 10 + 6 + 5	12.4	216
22 + 10 + 0 + 5	12.4	222
22 + 10 + 9 + 11	12.6	217
LSD (0.05):	0.4	9

- Averaged across three-years, the addition of 5 and 11 kg S ha^{-1} to liquid starter fertilizers increased yields from 0.5 to 0.7 Mg ha^{-1} and decreased grain moisture.

Study C

Methods

- Study period: 2008 – 2010 (multiple sites/locations each year)
- Sulfur source, rate, placement, and timing: ATS at 6.4 kg S ha^{-1} (7.6 L of ATS ha^{-1}), applied as a surface dribble band near the row at planting.

Results

Table 2. Experiment location, previous crop, soil type, organic matter content and pH for each site.

Site/location	Previous Crop	Soil Type	Organic Matter	pH
			%	
1-Waseca	Soybean	Webser cl	6.8	5.5
2-Rochester	Corn	Port Byron sil	5.4	5.8
4-Waseca	Soybean	Nicollet cl	5.3	5.4
5-Mower Co.	Soybean	Oran sil	4.8	7.2
6-Rice Co.	Soybean	Hayden l	3.0	6.2
7-Lamberton	Soybean	Ves l	4.0	5.5
8-Mower Co.	Soybean	Kasson sil	3.7	7.3
9-Goodhue Co.	Soybean	Kasson sil	4.7	6.3
10-Lamberton	Soybean	Ves l	4.6	5.4

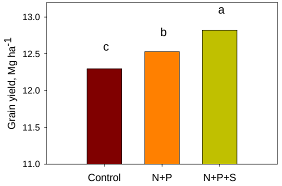

Figure 2. Nine-site average corn yield as affected by the addition of 6.4 kg S ha^{-1} (7.6 L ha^{-1}) as ammonium thiosulfate to fluid starter fertilizer (19 L ha^{-1} of ammonium poly phosphate).

- Averaged across nine sites, adding 6.4 kg S ha^{-1} (7.6 L ha^{-1} of ATS) to a fluid starter fertilizer (19 L ha^{-1} of APP) increased corn grain yield 0.3 Mg ha^{-1} compared with APP alone.
- A significant site × treatment interaction (data not shown) showed sulfur addition to starter fertilizer increased yields significantly at 3 of 9 sites (sites 1, 7, and 10).
- Averaged across nine sites, sulfur addition decreased grain moisture 4 g kg^{-1} and increased economic return \$7 ha^{-1} compared with a APP alone (data not shown).
- Sulfur concentration in whole plants harvested at V6-7 was increased from 2.04 g kg^{-1} for APP alone to 2.28 g kg^{-1} for the APP + ATS starter, averaged across sites (data not shown).

Study D

Methods

- Study period: 2010 (single year data)
- Crop rotation and tillage: continuous corn with conservation tillage.
- Soil characteristics: Webster-Nicollet clay loam, pH=6.2 and organic matter=5.8%.
- Sulfur sources: ATS, ammonium sulfate (AMS), and gypsum
- Sulfur rates: 0, 3.2, 6.4, 11, and 22 kg ha^{-1}
- Sulfur placement and timing: broadcast preplant and incorporated, dribbled on the soil surface near-the-row and in-furrow (3.2 kg rate only) at planting, broadcast at V5 not incorporated and injected midrow at V5.

Results

Table 3. Corn grain moisture, grain yield, and earleaf concentration of N and S at R1 as affected by sulfur source, rate, time of application and placement at Waseca.

S Source	S timing	S rate	Placement	APP rate	Grain Yield	Grain Moist.	R1 Leaf N Conc.	R1 Leaf S Conc.
		kg ha^{-1}		L ha^{-1}	Mg ha^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
Control	none	0	none	0	11.4	212	24.2	1.18
Control	none	0	none	0	11.3	208	22.0	1.12
APP Control	planting	0	In-furrow	15	11.5	199	23.1	1.16
ATS	planting	3.2	In-furrow	15	11.8	182	22.2	1.22
ATS	planting	6.4	Dual†	15	13.2	169	23.4	1.34
AMS	preplant	11	Broadcast	0	13.4	166	28.3	1.59
AMS	preplant	22	Broadcast	0	14.1	158	26.8	1.63
Gypsum	preplant	11	Broadcast	0	13.0	162	27.0	1.50
Gypsum	preplant	22	Broadcast	0	14.3	163	27.2	1.58
Gypsum	V5	11	Broadcast	0	14.0	181	27.4	1.53
Gypsum	V5	22	Broadcast	0	14.1	172	29.6	1.66
ATS	V5	11	Injected	0	13.1	173	27.7	1.50
			Average LSD (alpha=0.10):		1.2	15	2.0	0.11

† Dual placement was in-furrow placement of APP and a dribble surface band of ATS.

- Sulfur fertilization at rates of 6.4 kg ha^{-1} or greater increased grain yields from 1.7 to 2.9 Mg ha^{-1} compared with the control plots.
- Grain yields were increased by the 22 kg ha^{-1} rate of preplant broadcast S compared with the 11 kg rate when averaged across sources (contrast statistics not shown, *p* value=0.057).
- Generally, sidedress applications of S at V5 produced similar yields as preplant applications.
- Sulfur fertilization decreased corn grain moisture at harvest up to 50 g kg^{-1}.
- Applying sulfur at V5 decreased grain moisture compared with the control but not to the same extent as preplant applications.
- Earleaf N concentrations were increased by S rates of 11 kg ha^{-1} or greater, however planter applied rates (3.2 and 6.4 kg S ha^{-1}) were not different from the control plots.
- Earleaf S concentrations increased markedly with S rates of 11 kg ha^{-1} or greater compared with the control plots.
- The 6.4 kg ha^{-1} planter applied rate of ATS was marginal on this very responsive site and the 3.2 kg rate was inadequate.

Summary

- In one study on a clay loam soil with 4.8% organic matter (1999 – 2005), corn grain yields were increased 0.4 Mg ha^{-1} with an annual application of gypsum at 76 kg S ha^{-1}, while corn grain moisture decreased 5 g kg^{-1}.
- In a three-year study (2004 – 2006) on similar soils , the addition of 5 and 11 kg S ha^{-1} to liquid starter fertilizers increased corn yields from 0.5 to 0.7 Mg ha^{-1} and decreased grain moisture.
- A three-year (2008 – 2010) multi-site study found a corn yield response to S on 3 of 9 sites and for the 9-site average (0.3 Mg ha^{-1}), when 6.4 kg S ha^{-1} as ATS was added to a fluid starter fertilizer (19 L ha^{-1} of APP).
- In a one year study (2010) in reduced tillage continuous corn on a Webster-Nicollet clay loam with 5.8% organic matter:
  - Sulfur fertilization at rates of 6.4, 11, and 22 kg ha^{-1} increased grain yields from 1.7 to 2.9 Mg ha^{-1} compared with the control plots.
  - Sulfur fertilization decreased corn grain moisture up to 50 g kg^{-1}.

Conclusions

- Corn grain yield responses to S are common on medium and fine textured soils in Southern Minnesota.
- When averaged across sites-years the response may appear small, but in some instances they are large and result in a sizable return on investment to the farmer.
- Some of these responses occur on soils with organic matter contents greater than 5%.

Recommendations

- Although corn responses to S on medium and fine textured soils are not completely understood at this time, fertilizer recommendations need to be revised to better advise farmers and fertilizer dealers about the probability of a response and the magnitude of response.
- High residue continuous corn fields have the greatest response potential followed by high yielding fields that have not received S fertilizer or manure in the last few years.

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