# INVESTIGATING SULFUR MANAGEMENT FOR IOWA CORN AND SOYBEANS: S RATE, CARRYOVER, AND INTERACTIONS WITH NITROGEN AND COVER CROPS

R. Roth, L. Dorissant, A. Sassman, M. Licht, A. Rieck-Hinz, and G. Sorenson
Iowa State University, Ames, IA
rtroth@iastate.edu (515) 294-0506

## ABSTRACT

Sulfur (S) deficiency has become more common in Midwest corn and soybean as atmospheric S deposition has declined and crop S removal has increased. It remains unclear where S responses occur, how much S is needed, whether S applied to one crop benefits the next, and how S interacts with nitrogen (N) and cover crop management. We addressed these questions through a network of field trials across Iowa State University Research and Demonstration Farms from 2024 to 2026. A corn–soybean rotation study at three sites (Kanawha, Boone, and Crawfordsville) compared 0 and 25 lb S/ac, applied as gypsum or ammonium thiosulfate (ATS), in year one, year two, both years, or neither, to quantify immediate and residual S effects. A split-plot S rate × N rate study in corn (0–40 lb S/ac; 0–300 lb N/ac) evaluated whether S fertilization alters the corn N response and economic optimum N rate (EONR). A cereal rye × S rate study (0–50 lb S/ac) examined whether a cover crop changes corn and soybean response to S. Through 2025, neither corn nor soybean yield responded to S at any carryover site. At the three N × S sites analyzed to date, S rate did not interact with N rate, suggesting S fertilization had little effect on the corn N response on these soils. In 2026, cereal rye reduced V4 corn biomass by about one-third regardless of S rate, while early soybean growth was unaffected by either factor. However, at Kanawha and Boone, neither cereal rye nor S rate affected 2026 corn or soybean grain yield, and yield did not respond to S with or without rye. The consistent lack of response raises a practical question: under what soil, weather, and management conditions does S fertilizer actually increase yield in Iowa? Expanding the network to coarse-textured, eroded, and lower organic matter soils through on-farm trials beginning in 2027 will help answer it.

## INTRODUCTION

For decades, Iowa research rarely found corn or soybean yield increases from S fertilization. That changed in the mid-2000s, when S deficiency was documented first in northeast Iowa alfalfa and then in corn, most often on coarse-textured, eroded, side-slope, and low organic matter soils (Sawyer et al., 2011; Sawyer et al., 2015). Several trends have made deficiency more likely. Clean Air Act regulations have reduced sulfur dioxide emissions more than threefold since the 1970s, sharply lowering atmospheric S deposition to cropland (Hinckley et al., 2020). At the same time, higher yields remove more S, widespread reduced tillage keeps soils cooler and slows early-season mineralization of organic S, and high-analysis fertilizers supply less incidental S than they once did.

Current Iowa State University guidance suggests 15 lb S/ac on fine-textured soils and 25 lb S/ac on coarse-textured soils where a response is expected, and states that application at these rates should be adequate for corn and the next corn or soybean crop (Sawyer et al., 2015). However, the frequency of response varies widely across soils and regions. In 2007–2008 trials, corn yield increased with S at 62% of sites in north-central to northeast Iowa, but responses were less frequent toward north-central and central Iowa (Sawyer et al., 2011), and only 14% of sites with silty clay loam or clay loam soils responded (Sawyer et al., 2015). In Illinois, corn responded to S in only 2 of 40 trials across a range of soils and environments (Preza Fontes et al., 2025). Soil sulfate tests also do not reliably predict response (Sawyer et al., 2015).

Three management questions are especially relevant for Iowa. First, the every-other-year recommendation assumes that S applied to one crop carries over to the next, but this has rarely been tested directly in rotation. Second, N and S are tightly linked in protein synthesis, and high N rates can induce S deficiency, so S supply could alter the corn N response and the EONR. Third, cereal rye cover crops are expanding in Iowa. In Iowa trials, corn following rye showed more N stress, reduced stands, and slower growth (Pantoja et al., 2015), and microbial immobilization of soil N during rye decomposition can reduce corn N uptake and yield (Preza-Fontes et al., 2022). Because most soil S is also held in organic forms and cycled by the same microbial processes, rye residue could likewise immobilize S and increase the need for S fertilizer in the following crop. The objectives of this work were to (1) quantify the immediate and residual (carryover) yield responses of corn and soybean to S fertilization; (2) determine whether S fertilization changes the corn grain yield response to N; and (3) evaluate whether a cereal rye cover crop changes corn and soybean response to S.

## MATERIALS AND METHODS

Since 2024, we have established a network of S fertility trials, which we refer to as the Iowa Sulfur Utilization Research Network (Iowa SulfURNet), on six Iowa State University Research and Demonstration Farms: Northwest (Sutherland), Northern (Kanawha), Northeast (Nashua), Agricultural Engineering and Agronomy (Boone), Armstrong Memorial (Lewis), and Southeast (Crawfordsville). The network grew from 3 site-years in 2024 to 12 in 2025 and 22 in 2026, for a total of 37 site-years (23 corn and 14 soybean) across three trial types. This paper reports the results that were available in fall 2026.

### Sulfur Rate and Carryover Study

The carryover study was established at Crawfordsville in 2024 and at Kanawha and Boone in 2025, with both corn and soybean phases of the rotation present each year. In year one, plots received 0 or 25 lb S/ac broadcast preplant as gypsum (Crawfordsville and Kanawha) or ATS (Boone). In year two, each year-one plot was split to receive 0 or 25 lb S/ac, creating four S histories: no S, S in year one only, S in year two only, and S in both years. Plots were arranged in a randomized complete block design with four replications at Crawfordsville and Kanawha and three at Boone; plot size varied by site. Soils in the carryover fields were silty clay loam or clay loam with 4.0 to 4.1% organic matter and pH 6.3 to 7.3. Grain yield was measured with a plot combine and adjusted to 15.5% moisture for corn and 13% for soybean.

**Nitrogen Rate × Sulfur Rate Study**

The N × S study is being conducted in corn at six locations in 2025 and 2026; results from three 2025 sites (Crawfordsville, Nashua, and Sutherland) have been analyzed to date. The design was a split-plot randomized complete block with three replications. Main plots were five S rates (0, 10, 20, 30, and 40 lb S/ac) applied preplant as gypsum (Crawfordsville and Nashua) or ATS (Sutherland). Subplots were eight N rates (0, 75, 150, 175, 200, 225, 250, and 300 lb N/ac) applied as urea ammonium nitrate (UAN), with 50 lb N/ac at planting and the remainder sidedressed at V3–V5. The previous crop was soybean at all sites. Soils in the N × S fields were loam to silty clay loam with 3.8 to 4.8% organic matter and pH 6.3 to 6.4. Ear leaf and upper leaf samples were collected at VT–R1 for S concentration and N:S ratio (analyses in progress). For each S rate, the yield response to N was described with a quadratic-plateau model.

**Cereal Rye × Sulfur Rate Study**

In 2026, this study was established in both corn and soybean at five locations as a split-plot randomized complete block design with four replications. Main plots were cover crop (cereal rye or no cover crop), and subplots were six S rates (0, 10, 20, 30, 40, and 50 lb S/ac) applied as gypsum. Cereal rye was terminated at least 10 days before planting. Plant stand and V4 aboveground biomass were measured, the corn ear leaf and the most recently matured soybean trifoliate were sampled at R1, and grain yield was harvested. V4 biomass is reported for Boone, and grain yield for the two sites analyzed to date (Kanawha and Boone). Biomass and yield were converted from metric units to lb/ac and bu/ac for reporting. The effect of S rate on yield was tested with linear regression.

**Exploratory Soybean Trial**

In 2024, a soybean trial at the Armstrong Memorial Farm (Lewis) compared an unfertilized check, ammonium sulfate (25 lb N + 25 lb S/ac), gypsum (25 lb S/ac), and urea (25 lb N/ac) in four replications.

**Statistical Analysis**

Data were analyzed by site with analysis of variance, treating blocks as random effects. Means were separated with Fisher's LSD at $\alpha = 0.05$. All analyses were conducted in R.

## RESULTS AND DISCUSSION

**Sulfur Rate and Carryover**

Neither corn nor soybean yield responded to S in year one at any of the three carryover sites (Figure 1). Corn yields were about 220 bu/ac at Crawfordsville in 2024, 195 bu/ac at Boone, and 215 bu/ac at Kanawha in 2025, with or without S. Soybean yields were similarly unaffected, ranging from about 58 bu/ac at Boone to 78 bu/ac at Crawfordsville and Kanawha. In the second year at Crawfordsville, corn yields were about 220 bu/ac and soybean yields 79 to 81 bu/ac regardless of S history (no S, S in year one only, S in year two only, or both years). Likewise, the 2024 exploratory soybean trial at Lewis showed no effect of N, S, or N + S fertilizer on yield (69.6 to 72.4 bu/ac; $P = 0.50$).

These results do not show that S carryover is absent, only that it could not be measured. Carryover can only express itself as a yield benefit in a crop that needs S,

and none of these sites responded to direct S application. Testing the every-other-year recommendation will require sites where the crop responds in the year of application.

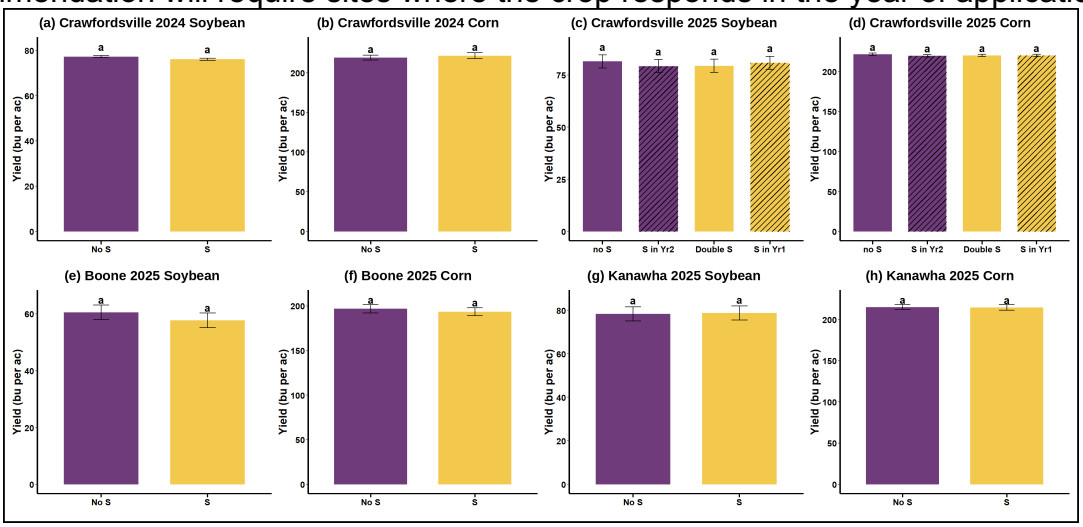



**Figure 1.** Corn and soybean grain yield in the S rate and carryover study. Year-one panels (a, b, e–h) compare 0 (No S) and 25 lb S/ac. Year-two panels at Crawfordsville (c, d) compare no S, S in year two only (S in Yr2), S in both years (Double S), and S in year one only (S in Yr1). Bars are means ± standard error; bars with the same letter are not significantly different (α = 0.05).

## Nitrogen × Sulfur Interaction in Corn

Corn yield responded strongly to N at all three N × S sites, but S rate did not interact with N rate at any of them (Figure 2). At Crawfordsville, the response curves for all five S rates reached nearly the same plateau of about 230 bu/ac at a similar N rate. Plateau yields were also similar at Nashua (about 225 to 230 bu/ac). The curves differed somewhat in shape, but the differences were not ordered by S rate: the 10 lb S/ac curve reached its plateau at the lowest N rate and the 40 lb S/ac curve at the highest. At Sutherland, plateau yields ranged from about 213 to 227 bu/ac and were reached at similar N rates, and the differences were again not ordered by S rate: the highest plateau was at 20 lb S/ac and the lowest at 30 lb S/ac, with 0 lb S/ac in between.

On these soils, S did not change how much N corn needed, so there is no evidence yet to adjust N rates when S is applied; the more important test will come from sites where S limits yield. The ear leaf S concentrations and N:S ratios collected at VT–R1 will help determine whether S supply was adequate even in the 0 lb S/ac plots.

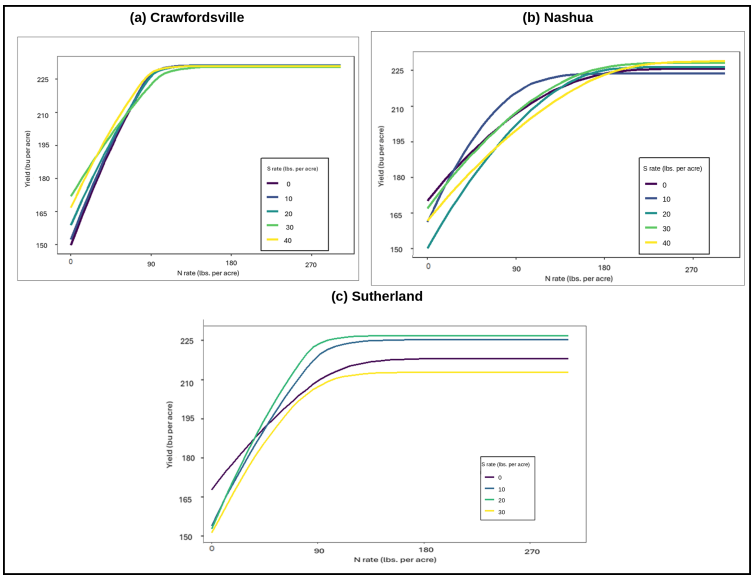



**Figure 2.** Corn grain yield response to N rate at five S rates (0–40 lb S/ac) at (a) Crawfordsville, (b) Nashua, and (c) Sutherland, 2025. Lines are fitted response curves; curves for 0–30 lb S/ac are shown for Sutherland. The S rate × N rate interaction was not significant at any site.

## Cereal Rye × Sulfur Rate

In 2026, cereal rye reduced corn V4 biomass by 32%, from about 264 to 179 lb/ac (P = 0.004), with no effect of S rate (P = 0.73) and no cover crop × S rate interaction (P = 0.72; Figure 3). Soybean V4 biomass was about 214 lb/ac and was not affected by cover crop (P = 0.92), S rate (P = 0.94), or their interaction (P = 0.98). Adding up to 50 lb S/ac did not offset the early growth penalty, which suggests that S immobilization was not the main cause at this site. However, the early biomass reduction did not carry through to grain yield (see below).

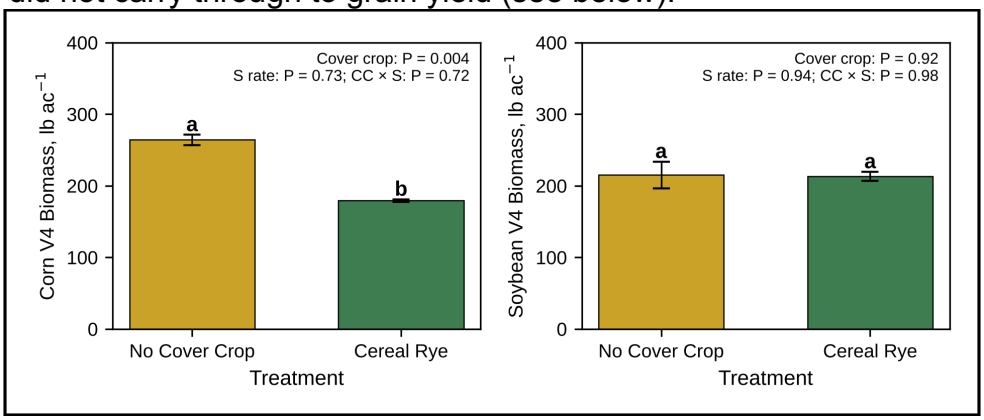



**Figure 3.** Effect of cereal rye cover crop on V4 aboveground biomass of (a) corn and (b) soybean, averaged across S rates (0–50 lb S/ac), Boone, 2026. Bars are means ± standard error; bars with the same letter are not significantly different (α = 0.05).

## Cereal Rye × Sulfur Rate: Grain Yield

At the two sites harvested to date, neither cover crop nor S rate affected 2026 corn or soybean grain yield (Table 1). Corn yielded 219 to 230 bu/ac and soybean 53 to 63 bu/ac across all treatments. Cereal rye did not reduce corn yield at Kanawha (P = 0.14) or Boone (P = 0.40), even though it reduced V4 corn biomass by about one-third

at Boone. Yield did not increase linearly with S rate at either site (P = 0.15 to 0.98), and the lack of response to S held both with and without cereal rye. These soils supplied enough S in 2026, even following cereal rye; fall-seeded rye at all five locations will provide a second year of data in 2027.

**Table 1.** Corn and soybean grain yield (bu/ac) by cover crop and S rate in the cereal rye × S rate study, 2026. Cover crop means are averaged across S rates, and S rate means are averaged across cover crop. Yields were converted from Mg/ha (corn, 56 lb/bu at 15.5% moisture; soybean, 60 lb/bu at 13% moisture).

| | | Cover crop | | | S rate, lb S/ac | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Site** | **Crop** | **None** | **Rye** | **P** | **0** | **10** | **20** | **30** | **40** | **50** | **P (linear)** |
| Kanawha | Corn | 227 | 223 | 0.14 | 222 | 223 | 224 | 226 | 224 | 230 | 0.15 |
| | Soybean | 60 | 62 | 0.07 | 60 | 63 | 62 | 61 | 61 | 59 | 0.42 |
| Boone | Corn | 221 | 224 | 0.40 | 223 | 225 | 221 | 219 | 224 | 224 | 0.98 |
| | Soybean | 55 | 55 | 0.77 | 55 | 57 | 55 | 55 | 55 | 53 | 0.18 |

## Where Does Sulfur Pay in Iowa?

The trial fields in this paper were loam, silty clay loam, or clay loam soils with 3.8 to 4.8% organic matter on research farms. These differ from the coarse-textured, low organic matter, eroded, and side-slope soils where Iowa S deficiency has been most common, and resemble the silty clay loam and clay loam soils where only 14% of earlier Iowa corn sites responded (Sawyer et al., 2015). Soils like these may mineralize enough sulfate to meet crop demand in most years, so the lack of response is consistent with earlier research but leaves the practical question open. The network expanded to 22 site-years in 2026, and on-farm trials planned for 2027 will target coarse-textured, eroded, and low organic matter soils, reduced-tillage systems, and fields following cereal rye, where responses are more likely. Combining yield, tissue S, soil, and weather data across sites should help identify where S fertilizer increases yield in Iowa.

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