1985

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R. G. Hoeft, *University of Illinois at Urbana-Champaign*
J. E. Sawyer, *University of Illinois at Urbana-Champaign*
R. M. Vanden Heuvel, *University of Illinois at Urbana-Champaign*
M. A. Schmitt, *University of Illinois at Urbana-Champaign*
G. S. Brinkman, *University of Illinois at Urbana-Champaign*

JOURNAL OF FERTILIZER ISSUES Volume 2, Number 3, July - September, 1985, Pages 95-104

# Corn Response to Sulfur on Illinois Soils[1]

R. G. Hoeft, J. E. Sawyer, R. M. Vanden Heuvel,
M. A. Schmitt and G. S. Brinkman[2]

## ABSTRACT

**Field studies were conducted over a three-year period at a total of 82 site-years to evaluate the sulfur (S) status of representative Illinois soils. In addition, greenhouse studies were conducted using soils from two of the three years of field experiments. The sites selected were either low in organic matter, sandy in texture and/or in areas where apparent S deficiency had been reported. At each location, gypsum was applied at a rate to supply 50 lb S/ac prior to the final tillage operation before planting. Whole plant samples were collected at the sixth-leaf stage of growth and ear leaf samples were collected at silking for S analysis. Soil was collected from each location in the second and third year of the study for use in the greenhouse study. Corn yield was measured in both the field and greenhouse studies.**

**Significant yield response to applied S was observed at five of the 81 locations studied — with an average increase of 11.2 bu/ac. For the 76 nonresponding sites, where there were no significant responses, yields on the S treated plots were an average of 0.5 bu/ac greater than the control treatments indicating that S had little influence on grain yield at these sites. In the greenhouse, plants responded to the application of S during the second cropping period on 60% of the soils evaluated.**

**Under field conditions, plants grown on the untreated plots had adequate S concentration in the plant tissue at all but two locations. However, in the greenhouse, the concentration of S in plants grown on the untreated soil was below the critical level on 41% and 91% of the soils at first and second harvest, respectively.**

**Sulfur in precipitation collected during the growing season ranged from 3.6 to 18.9 lb S/ac. The S soil test reliably predicted S deficiency at four of the five responding locations. However, it did not reliably predict those sites which did not respond to S as 14 of the nonresponding sites had levels below those normally considered to be deficient.**

**The differential response to S observed between the field and greenhouse studies implies that the soils have low ability to supply S and/or that the atmospheric contribution of S in the field is a major contributor to the S nutrition of field grown plants. If the latter is correct, then continued reduction in atmospheric S supply combined with higher crop yields will likely result in more frequent occurrences of S deficiency in field crops grown on Illinois soils.**

***Additional index words:*** **S soil test, precipitation S, S concentration.**

SULFUR deficiency has been recognized with increasing frequency over the last several years. This has been particularly true throughout the midwestern US where Minnesota researchers first identified the problem in the 1920's (1). This was followed by recognition of the problem in Nebraska in the early 1950's (9). In the late 1960's and early 1970's several other states including Missouri, Wisconsin and Iowa reported S deficiencies (4, 5, 10).

This increase in S deficiencies was likely the result of a combination of factors, some of which decreased the incidental supply of S while others increased the demand of the crop for the nutrient. These included a reduction in both atmospheric S contribution and in the amount of S added as an impurity in fertilizers and pesticides. At the same time, crop yields were increasing rapidly, creating an increased demand on the soil to supply S. In many areas, farming systems were changing from a crop-livestock operation to purely cash grain or cash grain with confinement livestock operations. This change in farming systems resulted in less S being returned to the land in the form of manure and in the case of the confinement operations, more concentration of the manure on small areas with a corresponding increase in the amount of land which received no manure.

A study was initiated in 1977 and continued through 1979 to evaluate the effect of applied S on crop yield on several Illinois soils under both field and greenhouse conditions. In addition, the study was designed to evaluate the reliability of various methods to accurately identify S deficiency.

## MATERIALS AND METHODS

Field experiments with corn were conducted in farmers' fields in Illinois at 27 locations in 1977, 26 in 1978 and 29 in 1979 (Table 1). Several criteria were used in selecting experimental sites. Approximately 40%

[1] Contribution from the Dept. of Agronomy, Univ. of Illinois, Urbana, IL. Research supported by Agric. Exp. Sta., Univ. of Illinois, Brandt Chemical Co., International Mineral & Chemical Corporation, United States Gypsum Co., Dow Chemical, U.S. Borax, The Sulphur Institute and Eagle Picher Industries, Inc.

[2] Professor of Soil Fertility, Research Assistants and former Assistant Agronomist, respectively, Dept. of Agronomy, Univ. of Illinois, Urbana, IL.

of the sites selected were either low in organic matter (less than 2.0%) or sandy (sandy loam or coarser) in texture or both. These two criteria were used in the selection process because they influence both the inherent ability of the soil to supply S as well as the ability of the soil to retain plant available S within the rooting zone. Additional sites were selected in areas where County Extension Service personnel or fertilizer dealers had observed apparent S deficiencies. At all locations, farmer cooperators were selected who had records of high production for the area. Soil P and K levels were at or above the desired level for optimum yield at 89 and 79%, respectively, of the fields studied. In those cases where the levels were below optimum, the producers applied adequate amounts of the nutrients. The pH level was below the desired level (pH 6.0) on 46% of the fields studied.

Treatments were a control and 50 lb S/ac as gypsum at all locations except 8, 9, 10, 11 and 12 where 25 lb S/ac was applied. The treatments were applied in a randomized complete block design with three replications. Corn was used as the test crop.

Treatments were applied in late April or early May prior to the final tillage operation before planting. The cooperators performed the tillage and planting operations and applied their normal fertilizer treatment except for the application of sulfur.

Whole plants were collected at the sixth-leaf stage of growth and ear leaves were collected at silking and analyzed for S concentration (2). Soil samples were collected from each plot to a depth of nine inches in late May and analyzed for pH, organic matter, P, K, Ca, Mg and S (Table 1). Phosphorus was extracted using the Bray $P_1$ procedure (3); K, Ca and Mg were extracted using 1 *N* $NH_4OAc$; and S was determined using $Ca(H_2PO_4)_2 \bullet HOAc$ (6).

**Table 1. Soil type and chemical characteristics of the soils evaluated.**

| Location number | Soil* type | Soil pH | Organic matter | P | K | Ca | Mg | S |
|---|---|---|---|---|---|---|---|---|
| | | | % | | lb/ac | | | ppm |
| | | | | 1977 | | | | |
| 1 | Ipava sil | 5.0 | 3.2 | 134 | 1044 | 3302 | 355 | 13.7 |
| 2 | Sawmill sicl | 6.9 | 5.1 | 96 | 344 | 10333 | 1635 | 26.1 |
| 3 | Sable sicl | 5.8 | 3.4 | 51 | 540 | 4828 | 671 | 10.6 |
| 4 | Tama sil | 5.7 | 4.1 | 75 | 384 | 6318 | 997 | 12.4 |
| 5 | Hartsburg sicl | 5.9 | 2.9 | 80 | 288 | 7937 | 1853 | 8.9 |
| 6 | Plainfield s | 5.1 | 0.6 | 136 | 116 | 362 | 58 | 6.6 |
| 7 | Seaton sl | 6.1 | 2.8 | 193 | 1958 | 5535 | 841 | 13.3 |
| 8 | Wier si | 5.7 | 1.5 | 49 | 304 | 5488 | 1025 | 12.9 |
| 9 | Harco sil | 5.4 | 2.3 | 89 | 281 | 4937 | 845 | 6.8 |
| 10 | Patton sicl | 6.3 | 2.1 | 80 | 350 | 4827 | 636 | 7.8 |
| 11 | McGary sil | 5.8 | 2.2 | 191 | 1107 | 2200 | 383 | 45.0 |
| 12 | Cisne sil | 6.8 | 1.8 | 59 | 418 | 3105 | 269 | 10.7 |
| 13 | Drummer sicl | 5.6 | 3.3 | 113 | 368 | 6710 | 1393 | 5.4 |
| 14 | Drummer sicl | 5.7 | 4.5 | 181 | 814 | 7416 | 1209 | 6.7 |
| 15 | Fayette sil | 5.6 | 1.3 | 91 | 393 | 3835 | 1153 | 7.0 |
| 16 | Fayette sil | 5.6 | 2.2 | 40 | 280 | 2628 | 719 | 7.3 |
| 17 | Warsaw sil | 6.0 | 3.5 | 100 | 499 | 4313 | 1375 | 11.1 |
| 18 | Greenriver s | 6.6 | 2.2 | 102 | 597 | 2343 | 664 | 5.5 |
| 19 | Fayette sil | 5.8 | 4.5 | 82 | 360 | 5148 | 1211 | 51.9 |
| 20 | Greenriver s | 5.6 | 2.2 | 179 | 564 | 4827 | 912 | 148.5 |
| 21 | Greenriver s | 6.2 | 3.0 | 121 | 607 | 2338 | 789 | 10.9 |
| 22 | Tama sil | 5.2 | 1.9 | 114 | 391 | 3995 | 1186 | 34.0 |
| 23 | Ogle sil | 6.5 | 2.1 | 172 | 600 | 4172 | 1602 | 10.8 |
| 24 | Warsaw sil | 4.9 | 2.9 | 186 | 818 | 3000 | 806 | 77.9 |
| 25 | Dickinson sl | 5.2 | 2.3 | 124 | 350 | 2165 | 572 | 33.9 |
| 26 | Drummer sicl | 5.2 | 5.1 | 177 | 346 | 7995 | 1697 | 146.3 |
| 27 | Elliot sil | 5.2 | 1.9 | 76 | 307 | 4083 | 831 | 61.5 |

**Table 1. Continued.**

| Location number | Soil* type | Soil pH | Organic matter | P | K | Ca | Mg | S |
|---|---|---|---|---|---|---|---|---|
| | | | % | | lb/ac | | | ppm |
| | | | **1978** | | | | | |
| 28 | Hoyleton sil | 5.4 | 1.8 | 77 | 374 | 1438 | 338 | 19.5 |
| 29 | Hoyleton sil | 5.6 | 2.1 | 34 | 233 | 3033 | 213 | 28.0 |
| 30 | Seaton sl | 4.8 | 1.3 | 125 | 351 | 404 | 68 | 4.5 |
| 31 | Seaton sl | 6.3 | 1.4 | 129 | 444 | 1985 | 113 | 5.1 |
| 32 | Seaton sl | 6.1 | 2.4 | 43 | 445 | 6925 | 1088 | 4.8 |
| 33 | Seaton sl | 5.7 | 2.4 | 142 | 530 | 4777 | 447 | 4.7 |
| 34 | Cisne sil | 4.9 | 2.4 | 55 | 285 | 1438 | 124 | 20.5 |
| 35 | Patton sicl | 6.3 | 2.6 | 59 | 282 | 5290 | 1020 | 5.2 |
| 36 | Sable sicl | 6.4 | 4.5 | 36 | 300 | 6353 | 1638 | 10.1 |
| 37 | Sable sicl | 7.0 | 3.1 | 60 | 253 | 6763 | 1160 | 7.2 |
| 38 | Harpster sicl | 6.4 | 6.0 | 138 | 526 | 8582 | 1538 | 7.2 |
| 39 | Ipava sil | 6.6 | 3.8 | 15 | 236 | 6355 | 880 | 9.0 |
| 40 | Plainfield s | 6.3 | 2.3 | 32 | 277 | 2127 | 462 | 7.3 |
| 41 | Plainfield s | 5.5 | 0.9 | 106 | 138 | 208 | 53 | 2.8 |
| 42 | Muscatine sil | 6.7 | 4.8 | 143 | 693 | 7047 | 1022 | 10.8 |
| 43 | Tama sil | 6.4 | 3.1 | 98 | 464 | 4030 | 518 | 9.0 |
| 44 | Hagener ls | 6.8 | 1.9 | 79 | 209 | 2772 | 206 | 8.4 |
| 45 | Hagener ls | 6.9 | 1.9 | 82 | 240 | 1947 | 131 | 7.6 |
| 46 | Fayette sil | 6.5 | 2.5 | 128 | 467 | 2928 | 976 | 11.3 |
| 47 | Greenriver s | 6.6 | 5.7 | 171 | 408 | 3728 | 806 | 9.1 |
| 48 | Fayette sil | 6.5 | 2.2 | 19 | 165 | 3392 | 880 | 7.2 |
| 49 | Tama sil | 7.4 | 3.2 | 36 | 319 | 4420 | 1595 | 4.7 |
| 50 | Harpster sicl | 7.1 | 5.4 | 31 | 238 | 9342 | 1810 | 6.6 |
| 51 | Blount sil | 7.6 | 3.7 | 80 | 349 | 4381 | 1294 | 12.2 |
| 52 | Ade lfs | 6.1 | 1.7 | 144 | 496 | 1749 | 365 | 4.6 |
| 53 | Bonfield l | 7.9 | 4.6 | 11 | 259 | 9253 | 830 | 17.3 |
| | | | **1979** | | | | | |
| 54 | Dickinson sl | 6.6 | 3.2 | 238 | 933 | 3693 | 962 | 8.4 |
| 55 | Dickinson sl | 5.2 | 2.3 | 132 | 245 | 1103 | 235 | 7.7 |
| 56 | Greenriver s | 5.2 | 3.1 | 238 | 929 | 1455 | 326 | 7.9 |
| 57 | Drummer sicl | 6.8 | 3.2 | 158 | 863 | 4260 | 1177 | 15.5 |
| 58 | Flanagan sil | 6.2 | 4.7 | 69 | 304 | 4925 | 1368 | 8.8 |
| 59 | Breton sil | 7.5 | 6.3 | 20 | 207 | 10018 | 1698 | 10.5 |
| 60 | Andres sil | 5.2 | 3.1 | 250 | 399 | 1207 | 227 | 9.6 |
| 61 | Seaton sl | 5.9 | 3.6 | 200 | 848 | 3587 | 291 | 8.8 |
| 62 | Hoyleton sil | 5.7 | 2.5 | 142 | 954 | 1783 | 511 | 14.0 |
| 63 | Hoyleton sil | 6.9 | 2.4 | 31 | 186 | 4048 | 234 | 13.8 |
| 64 | Seaton sl | 5.7 | 2.5 | 73 | 902 | 2450 | 185 | 8.2 |
| 65 | Cisne sil | 6.2 | 2.2 | 57 | 203 | 4440 | 490 | 14.6 |
| 66 | Cisne sil | 6.5 | 2.9 | 113 | 332 | 3333 | 164 | 19.0 |
| 67 | Plainfield sl | 5.5 | 3.0 | 154 | 923 | 2478 | 543 | 8.1 |
| 68 | Plainfield s | 5.2 | 1.9 | 78 | 203 | 773 | 48 | 15.8 |
| 69 | Oquawka s | 5.6 | 1.7 | 112 | 171 | 1140 | 780 | 4.9 |
| 70 | Plainfield s | 6.4 | 2.1 | 63 | 286 | 1306 | 85 | 4.7 |
| 71 | Ipava sil | 6.8 | 4.9 | 180 | 247 | 8653 | 1415 | 10.2 |
| 72 | Ipava sil | 6.2 | 5.1 | 238 | 1046 | 5823 | 1036 | 10.2 |
| 73 | Alvin sl | 6.1 | 2.5 | 227 | 1018 | 3300 | 533 | 8.0 |
| 74 | Worthen sil | 6.3 | 2.3 | 149 | 395 | 4120 | 625 | 12.8 |
| 75 | Stoy sil | 6.7 | 2.3 | 78 | 247 | 3570 | 298 | 8.1 |

Table 1. Continued.

| Location number | Soil* type | Soil pH | Organic matter | P | K | Ca | Mg | S |
|---|---|---|---|---|---|---|---|---|
| | | | % | | | lb/ac | | ppm |
| | | | | 1979 | | | | |
| 76 | Stoy sil | 5.3 | 2.8 | 92 | 343 | 2613 | 219 | 10.4 |
| 77 | Hartsburg sicl | 6.2 | 3.9 | 117 | 267 | 7830 | 1760 | 5.7 |
| 78 | Harpster sil | 7.7 | 4.1 | 44 | 239 | 10283 | 1863 | 6.1 |
| 79 | Ipava sil | 5.6 | 4.1 | 60 | 328 | 4900 | 853 | 10.0 |
| 80 | Hartsburg sicl | 5.8 | 5.4 | 67 | 356 | 8127 | 1690 | 7.3 |
| 81 | Cisne sil | 5.1 | 3.0 | 73 | 304 | 1833 | 170 | 16.3 |
| 82 | Saybrook sil | 6.5 | 3.9 | 53 | 315 | 3808 | 1325 | 5.6 |

* l = loam, lfs = loamy fine sand, ls = loamy sand, s = sand, sicl = silty clay loam, sil = silt loam, sl = sandy loam.

In late May, two 30 ft rows in each plot were staked and thinned to a uniform population and were hand harvested at maturity. Samples were collected to determine moisture content and shelling percentage.

Rainfall was collected at each site during 1978 and 1979, commencing when the plots were established and continuing until the plots were harvested. Samples of the precipitation were taken in early June, mid July and at harvest. The samples were analyzed for $SO_4$-S and the amount of S deposited in precipitation at each site was calculated.

In late May of 1978 and late July of 1979, bulk soil samples were collected from the 0 to 9 inch layer of the check plots at each location. The soil was air-dried and stored until potted in early winter for the greenhouse study.

Each pot contained a layer of 2.2 lb of oven dry soil between two layers of 1.1 lb of acid washed silica sand. The sand was added to provide additional rooting and water holding capacity. Prior to potting, the treatments of 0 or 25 ppm S as $K_2SO_4$ were mixed with the soil. Uniform amounts of N, P and K were added to all pots at the initiation of the study, and as needed during the growing period. Two crops of three corn plants (variety B73 x Mo17) were grown in each pot. In 1978 the first crop was grown for 40 days and the second crop for 44 days. In 1979 the first crop was grown for 30 days and the second crop for 42 days. Yield and S concentration were determined on a dry weight basis.

Analysis of variance was determined for each parameter measured at each location. The calculated F value for treatment was tested at the 0.10 level of probability to determine significance of either positive or negative response to S.

## RESULTS AND DISCUSSION

### Field Study

The concentration of S in small plant samples collected from plots which had not received S were equal to or above the level (0.20% S) considered to be sufficient by Lockman (7) at all but one of the 82 locations (Table 2). Similarly, the S concentration in ear leaf samples collected at silking from the plots which had not received S were equal to or above the level (0.21% S) considered sufficient by Neubert *et al.* (8) at all but one location (Table 2). In both cases the plants which were low in S were grown on sandy soils which were low in organic matter. At location 80 where the S concentration in the small plants was low, visual growth differences between the S treated and untreated plants were observed early in the growing season and persisted until near the time of tasseling.

The application of S significantly increased the S concentration in the small plant samples at 13 and in the ear leaf samples at 20 of the locations. At seven of the locations, S concentrations were increased at both sampling times. The soils were sandy loam or coarser at 13 of the 26 locations where S concentrations were increased by the application of S fertilizer.

A statistically significant yield response to the application of S was observed at five of the 82 locations evaluated (Table 2). Two of the five responding sites were found in northwestern Illinois, one on an eroded silt loam and the other on an irrigated sand; one responding site was in central Illinois on a silty clay loam; and the other two were in southern Illinois, one on a silt loam and the other on a sandy loam soil. At two of the five locations where yield response was observed, there was an increase in the S concentration due to the application of S. At location 80, where a visual response was observed early in the growing season, there was no associated increase in grain yield. The reason that this apparent growth response was not followed by an associated yield response was not known. However, it is possible that there were other factors which limited yield potential more than S or that the irrigation water contained enough S to meet the needs of the plants grown on the untreated plots. At this location, irrigation was not applied until approximately three weeks prior to tasseling.

**Table 2. Effect of S application on corn grain yield, and S concentration of whole plant samples at the sixth-leaf stage and of ear leaf samples at silking at each experimental location.**

| Location number | S lb/ac 0 | S lb/ac 50 | S lb/ac 0 | S lb/ac 50 | S lb/ac 0 | S lb/ac 50 |
|---|---|---|---|---|---|---|
| | yield (bu/ac) | | % S, small plants | | % S, ear leaf | |
| **1977** | | | | | | |
| 1 | 156 | 159 | 0.35 | 0.35 | 0.35 | 0.36* |
| 2 | 176 | 179 | 0.36 | 0.34 | 0.28 | 0.31 |
| 3 | 159 | 155 | 0.39 | 0.34 | 0.27 | 0.30* |
| 4 | 97 | 112 | 0.40 | 0.43 | 0.31 | 0.35 |
| 5 | 172 | 183* | 0.33 | 0.40 | 0.23 | 0.31* |
| 6 | 109 | 93 | 0.32 | 0.42* | 0.25 | 0.52* |
| 7 | 138 | 163 | 0.32 | 0.28 | 0.33 | 0.33 |
| 8 | 117 | 122 | 0.29 | 0.27 | 0.26 | 0.28 |
| 9 | 147 | 168 | 0.25 | 0.26 | 0.27 | 0.27 |
| 10 | 162 | 160 | 0.27 | 0.25 | 0.23 | 0.23 |
| 11 | 104 | 99 | 0.41 | 0.40 | 0.24 | 0.23 |
| 12 | 96 | 92 | 0.57 | 0.50 | 0.32 | 0.32 |
| 13 | 151 | 145 | 0.36 | 0.37 | 0.28 | 0.28 |
| 14 | 134 | 128 | 0.36 | 0.36 | 0.25 | 0.26 |
| 15 | 151 | 155 | 0.43 | 0.46 | 0.28 | 0.31 |
| 16 | 145 | 162* | 0.46 | 0.49 | 0.24 | 0.32* |
| 17 | 145 | 156 | 0.42 | 0.40 | 0.26 | 0.28 |
| 18 | 104 | 96 | 0.43 | 0.47 | 0.29 | 0.34 |
| 19 | 167 | 167 | 0.48 | 0.50 | 0.33 | 0.37* |
| 20 | 155 | 159 | 0.52 | 0.51 | 0.25 | 0.28 |
| 21 | 166 | 167 | 0.47 | 0.58* | 0.28 | 0.33 |
| 22 | 157 | 156 | 0.47 | 0.56 | 0.27 | 0.33* |
| 23 | 124 | 132 | 0.31 | 0.37* | 0.29 | 0.31* |
| 24 | 126 | 113 | 0.33 | 0.36 | 0.24 | 0.23 |
| 25 | 114 | 108 | 0.34 | 0.36 | 0.24 | 0.26 |
| 26 | 199 | 201 | 0.40 | 0.40 | 0.31 | 0.33* |
| 27 | 83 | 90 | 0.33 | 0.31 | 0.35 | 0.37 |
| **1978** | | | | | | |
| 28 | 148 | 156* | 0.26 | 0.28 | 0.31 | 0.32 |
| 29 | 92 | 101 | 0.34 | 0.33 | 0.32 | 0.33 |
| 30 | 152 | 145 | 0.32 | 0.37 | 0.29 | 0.36 |
| 31 | 126 | 140* | 0.28 | 0.30 | 0.29 | 0.28 |
| 32 | 154 | 151 | 0.25 | 0.28* | 0.26 | 0.28 |
| 33 | 193 | 191 | 0.30 | 0.29 | 0.25 | 0.25 |
| 34 | 182 | 181 | 0.30 | 0.31 | 0.36 | 0.36 |
| 35 | 123 | 126 | 0.32 | 0.32 | 0.28 | 0.29 |
| 36 | 166 | 184 | 0.30 | 0.33* | 0.24 | 0.30* |
| 37 | 152 | 153 | 0.32 | 0.32 | 0.27 | 0.26 |
| 38 | 160 | 163 | 0.27 | 0.29 | 0.25 | 0.26 |
| 39 | 153 | 146 | 0.27 | 0.30 | 0.24 | 0.28 |
| 40 | 188 | 168 | 0.28 | 0.33* | 0.29 | 0.30 |

Table 2. Continued.

| Location number | S lb/ac | | S lb/ac | | S lb/ac | |
|---|---|---|---|---|---|---|
| | 0 | 50 | 0 | 50 | 0 | 50 |
| | yield (bu/ac) | | % S, small plants | | % S, ear leaf | |
| 41 | 85 | 81 | 0.22 | 0.37* | 0.19 | 0.32* |
| 42 | 164 | 160 | 0.27 | 0.29 | 0.25 | 0.30 |
| 43 | 141 | 140 | 0.24 | 0.26 | 0.30 | 0.31 |
| 44 | 148 | 144 | 0.21 | 0.24* | 0.27 | 0.34* |
| 45 | 156 | 153 | 0.21 | 0.25* | 0.30 | 0.38* |
| 46 | 190 | 186 | 0.29 | 0.27 | 0.30 | 0.31 |
| 47 | 108 | 115* | 0.27 | 0.28 | 0.34 | 0.33 |
| 48 | 129 | 141 | 0.28 | 0.29 | 0.39 | 0.40 |
| 49 | 172 | 178 | 0.24 | 0.33* | 0.30 | 0.43* |
| 50 | 183 | 172 | 0.34 | 0.38* | 0.47 | 0.55* |
| 51 | 162 | 153 | 0.34 | 0.35 | 0.50 | 0.46 |
| 52 | 163 | 160 | 0.27 | 0.29 | 0.32 | 0.40* |
| 53 | 148 | 153 | 0.23 | 0.24 | 0.34 | 0.37 |
| | | | 1979 | | | |
| 54 | 158 | 176 | 0.35 | 0.43 | 0.48 | 0.60* |
| 55 | 180 | 173 | 0.39 | 0.39 | 0.48 | 0.57* |
| 56 | 165 | 151 | 0.22 | 0.25 | 0.42 | 0.42 |
| 57 | 158 | 165 | 0.49 | 0.47 | 0.37 | 0.39 |
| 58 | 160 | 158 | — | — | — | — |
| 59 | 158 | 153 | 0.35 | 0.40 | 0.30 | 0.36 |
| 60 | 152 | 152 | 0.34 | 0.35 | 0.40 | 0.47* |
| 61 | 143 | 148 | 0.35 | 0.42 | 0.35 | 0.29 |
| 62 | 132 | 126 | 0.40 | 0.39 | 0.42 | 0.39 |
| 63 | 113 | 110 | 0.52 | 0.47 | 0.37 | 0.44 |
| 64 | 132 | 121 | 0.53 | 0.60 | 0.47 | 0.52 |
| 65 | 145 | 148 | 0.45 | 0.50 | 0.28 | 0.38 |
| 66 | 102 | 100 | 0.48 | 0.48 | 0.37 | 0.39 |
| 67 | 173 | 186 | 0.37 | 0.37 | 0.38 | 0.41* |
| 68 | 124 | 142 | — | — | — | — |
| 69 | 137 | 138 | 0.18 | 0.32 | 0.44 | 0.47 |
| 70 | 177 | 167 | 0.21 | 0.36* | 0.40 | 0.45 |
| 71 | 158 | 169 | 0.48 | 0.52 | 0.48 | 0.50 |
| 72 | 146 | 136 | 0.43 | 0.42 | 0.55 | 0.50 |
| 73 | 140 | 149 | 0.41 | 0.46 | 0.45 | 0.42 |
| 74 | 166 | 173 | 0.53 | 0.44 | 0.47 | 0.50 |
| 75 | 170 | 168 | 0.28 | 0.28 | 0.50 | 0.44 |
| 76 | 140 | 140 | 0.51 | 0.52 | 0.43 | 0.45 |
| 77 | 186 | 182 | 0.48 | 0.46 | 0.35 | 0.42 |
| 78 | 163 | 163 | 0.42 | 0.41 | 0.38 | 0.41 |
| 79 | 161 | 160 | 0.39 | 0.33 | 0.41 | 0.45 |
| 80 | 143 | 143 | 0.36 | 0.40 | 0.47 | 0.46 |
| 81 | 194 | 202 | 0.37 | 0.42 | 0.54 | 0.55 |
| 82 | 124 | 133 | 0.47 | 0.48 | 0.34 | 0.38 |

* Significantly different at the 10% level of probability.

At the five locations where significant response was observed, the S treatment resulted in an average increase of 11.2 bu/ac over the check plots. For the 76 sites where there was no statistically significant response, yields from the S treated plots were only 0.5 bu/ac higher than those of the check plots.

Considering only the five locations where yield response was observed, the S soil test predicted with good reliability which sites would respond. Of the five responding sites, one was deficient (having only 5 ppm S) and three were in the marginal range of 6 to 10 ppm S for normal plant growth. The other site (site 28) had a test level of 19.5 ppm S which is above the level at which response would normally be expected. Since the S concentration in the plants was above the critical level and since there was no response to S for site 28 in the greenhouse, it is possible that the response in the field may have been due to chance rather than treatment. For the nonresponding sites, 14 had S soil test levels below 6 ppm S and 29 had levels in the marginal range of 6 to 10 ppm S. Therefore, the S soil test did not provide a reliable prediction of S availability.

In addition to extractable S levels, both soil organic matter and soil pH have been shown to have an influence on plant available S. Therefore, the effect these variables might have on the dependent variables of grain yield, S concentration in the plants grown on the control plots, and the increase in S concentration in the plant tissue from applied S were determined using regression analysis techniques. None of the regression equations obtained from these calculations were significant. Even though the regression coefficients were very low, the best equations obtained for the dependent variables demonstrated the consistency of the presence of both organic matter and soil pH and the lack of soil S test levels in the equations.

The amount of S collected in rainfall in 1978 ranged from 5.2 to 18.9 lb S/ac (Table 3). In 1979 the values ranged from 3.6 to 16.3 lb S/ac. The average amount of S deposited during the growing season in the two years was 10.1 lb S/ac. Since these values represent only the amount contributed by the precipitation during the five-month growing season, it is likely that the total amount deposited during a year would be 1.5 to 2 times greater than that measured. Therefore, in some cases the amount of S deposited in the precipitation would be nearly as large as the amount taken up by a 150 bu corn crop, *i.e.*, about 35 lb S/ac.

The grain moisture content varied considerably from location to location, but the application of S did not have a consistent effect on moisture levels (Table 4). The average content over all locations was 31.5% for the S treated plots and 31.6% for the control plots. Grain moisture content in the S treated plots at the responding locations was 0.2% lower than the untreated plots.

**Table 3. Total S collected in rainwater during the growing season at experimental sites.**

| Location number | S in rainwater | Location number | S in rainwater |
|---|---|---|---|
| | lb/ac | | lb/ac |
| 28 | 5.2 | 56 | 3.6 |
| 29 | 10.4 | 57 | 9.1 |
| 30 | 18.9 | 58 | 9.1 |
| | | 59 | 4.1 |
| 31 | 18.9 | 60 | 24.5 |
| 32 | 11.0 | | |
| 33 | 10.1 | 61 | 11.1 |
| 34 | 10.7 | 62 | 6.4 |
| 35 | 8.5 | 63 | 14.1 |
| | | 64 | 7.8 |
| 36 | 11.9 | 65 | 6.0 |
| 37 | 14.1 | | |
| 38 | 8.7 | 66 | 6.0 |
| 39 | 8.9 | 67 | 5.6 |
| 40 | 6.3 | 68 | 10.5 |
| | | 69 | 16.3 |
| 41 | 10.6 | 70 | 21.3 |
| 42 | 9.6 | | |
| 43 | — | 71 | 5.1 |
| 44 | 10.7 | 72 | 9.5 |
| 45 | 10.7 | 73 | 11.4 |
| | | 74 | 11.4 |
| 46 | 6.9 | 75 | 3.8 |
| 47 | 15.0 | | |
| 48 | — | 76 | 4.8 |
| 49 | 12.0 | 77 | 10.9 |
| 50 | 12.8 | 78 | 7.5 |
| | | 79 | — |
| 51 | 10.2 | 80 | — |
| 52 | 9.2 | | |
| 53 | 9.2 | 81 | 6.7 |
| 54 | 10.6 | 82 | 8.3 |
| 55 | 12.3 | | |

## Greenhouse Study

The S concentration of the plants grown on nontreated soil in the greenhouse was below the sufficient level (0.20% S) for 41% of the soils for the first crop and 91% for the second crop (Table 5). At first harvest, addition of S resulted in a significant increase in S concentration of 50% of the samples which had been deficient and 20% of those which had not been deficient. At second harvest, the S concentration of 82% of those which had been deficient and 33% of those which had not been deficient was significantly increased by the application of S. However, nearly 50% of the S treated plants were still below 0.20% S at second harvest.

There was a significant yield response to applied S on only one soil at first harvest (Table 5). This occurred even though the S concentration of the plants

**Table 4. Effect of S application on corn grain moisture at harvest.**

| Location number | S lb/ac 0 | S lb/ac 50 | Location number | S lb/ac 0 | S lb/ac 50 |
|---|---|---|---|---|---|
| | Grain moisture % | | | Grain moisture % | |
| 1 | 23.6 | 22.8 | 47 | 20.5 | 22.0 |
| 2 | 27.4 | 28.9 | 48 | 27.9 | 24.9 |
| 3 | 33.8 | 33.4 | 49 | 29.8 | 29.5 |
| 4 | 24.3 | 26.7 | 50 | 30.2 | 30.6 |
| 5 | 27.3 | 26.9 | 51 | 37.1 | 38.8 |
| 6 | 27.6 | 27.2 | 52 | 17.4 | 16.5 |
| 7 | 26.1 | 26.7 | 53 | 30.3 | 30.1 |
| 8 | 29.7 | 29.9 | 54 | 35.0 | 36.7 |
| 9 | 16.4 | 17.3 | 55 | 29.9 | 30.5 |
| 10 | 21.2 | 21.2 | 56 | 34.6 | 33.8 |
| 11 | 24.7 | 24.3 | 57 | 34.2 | 34.7 |
| 12 | 19.7 | 20.4 | 59 | 30.3 | 30.3 |
| 13 | 20.2 | 16.0 | 60 | 35.6 | 36.8 |
| 14 | 26.2 | 24.1 | 61 | 28.6 | 29.2 |
| 15 | 31.4 | 32.3 | 62 | 33.7 | 34.2 |
| 16 | 33.8 | 33.2 | 63 | 26.6 | 26.5 |
| 17 | 27.9 | 26.5 | 64 | 35.6 | 32.2 |
| 18 | 28.5 | 27.5 | 65 | 36.3 | 36.4 |
| 19 | 29.3 | 29.9 | 66 | 34.6 | 35.8 |
| 20 | 29.7 | 29.8 | 67 | 30.6 | 28.7 |
| 21 | 24.6 | 25.3 | 68 | 41.3 | 34.7 |
| 22 | 32.4 | 30.5 | 69 | 32.7 | 34.0 |
| 23 | 31.7 | 31.0 | 70 | 11.5 | 12.7 |
| 24 | 33.8 | 34.3 | 71 | 30.5 | 30.3 |
| 25 | 30.4 | 31.6 | 72 | 28.5 | 27.2 |
| 26 | 30.2 | 31.5 | 73 | 25.0 | 28.0 |
| 27 | 37.3 | — | 74 | 37.6 | 39.1 |
| | | | 75 | 35.8 | 33.7 |
| 28 | 33.0 | 31.5 | 76 | 34.7 | 36.1 |
| 29 | 29.1 | 28.0 | 77 | 31.6 | 31.3 |
| 34 | 35.9 | 33.7 | | | |
| 36 | 27.5 | 28.1 | 78 | 20.6 | 23.9 |
| 37 | 29.0 | 28.5 | 79 | 29.3 | 31.0 |
| | | | 80 | 31.1 | 30.9 |
| 42 | 32.6 | 32.5 | 81 | 34.2 | 32.7 |
| 43 | 27.7 | 27.1 | 82 | 44.0 | 42.5 |
| 44 | 25.1 | 24.7 | | | |
| 45 | 26.3 | 24.7 | | | |
| 46 | 22.6 | 26.0 | | | |

grown on several of the soils was below the level for optimum growth. By second harvest, there was a significant yield increase associated with the application of S on 60% of the soils studied. This differential response to S between crops implies that the ability of many of the soils to supply available S was low.

Regression equations for both crops grown in the greenhouse were calculated for the dependent variables of S concentration of the plants grown on the untreated soils, S concentration increase in plants from the application of S, and plant dry matter increase of the plants from the application of S. Similar to the field results, the regression coefficients were low. However, as in the field study, the most important factors affecting the dependent variables were organic matter and soil pH. Extractable soil S was significant only for percent yield increase to applied S.

**Table 5. Effect of S application on dry matter production and S concentration of corn grown in the greenhouse.**

| Location number | Applied S ppm: 0 (1st harvest) | 25 (1st harvest) | 0 (2nd harvest) | 25 (2nd harvest) | 0 (1st harvest) | 25 (1st harvest) | 0 (2nd harvest) | 25 (2nd harvest) |
|---|---|---|---|---|---|---|---|---|
| | yield gms/pot | | | | % S | | | |
| **1978** | | | | | | | | |
| 28 | 4.05 | 3.98 | 5.83 | 6.45 | 0.26 | 0.27 | 0.15 | 0.18 |
| 29 | 4.34 | 3.33 | 6.06 | 6.77 | 0.23 | 0.25 | 0.13 | 0.17 |
| 30 | 3.20 | 3.06 | 3.09 | 3.46 | 0.24 | 0.29* | 0.11 | 0.18* |
| 31 | 3.41 | 3.22 | 2.10 | 6.32* | 0.18 | 0.27* | 0.08 | 0.14 |
| 32 | 3.26 | 3.18 | 2.08 | 6.20* | 0.19 | 0.24 | 0.08 | 0.16* |
| 33 | 5.59 | 5.49 | 3.82 | 9.29* | 0.20 | 0.29* | 0.09 | 0.14* |
| 34 | 3.81 | 3.90 | 5.59 | 5.22 | 0.27 | 0.26 | 0.18 | 0.18 |
| 35 | 3.28 | 3.64 | 3.57 | 6.41* | 0.23 | 0.25 | 0.08 | 0.16* |
| 36 | 3.04 | 3.33 | 3.64 | 6.02* | 0.20 | 0.23 | 0.07 | 0.16* |
| 37 | 3.15 | 2.90 | 3.96 | 6.02 | 0.22 | 0.23 | 0.10 | 0.16* |
| 38 | 3.48 | 2.94 | 4.77 | 5.44 | 0.22 | 0.25* | 0.12 | 0.16 |
| 39 | 3.98 | 3.77 | 4.30 | 4.89 | 0.19 | 0.23* | 0.11 | 0.17* |
| 40 | 3.20 | 3.22 | 3.40 | 6.73* | 0.18 | 0.22 | 0.09 | 0.16* |
| 41 | 3.58 | 4.07 | 1.20 | 4.83* | 0.15 | 0.23* | 0.09 | 0.16* |
| 42 | 4.27 | 3.81 | 5.41 | 8.97* | 0.18 | 0.21 | 0.09 | 0.16* |
| 43 | 5.10 | 5.07 | 5.58 | 9.17* | 0.17 | 0.20 | 0.10 | 0.17* |
| 44 | 4.30 | 4.70 | 2.00 | 7.20* | 0.17 | 0.22* | 0.08 | 0.15* |
| 45 | 3.77 | 4.10 | 2.36 | 6.17* | 0.17 | 0.23* | 0.08 | 0.16* |
| 46 | 6.55 | 5.93 | 7.50 | 12.09* | 0.19 | 0.23 | 0.07 | 0.16* |
| 47 | 4.14 | 5.20 | 9.43 | 10.67 | 0.20 | 0.21 | 0.08 | 0.14* |
| 48 | 5.68 | 5.29 | 2.55 | 7.01* | 0.13 | 0.21* | 0.08 | 0.14* |
| 49 | 2.98 | 3.47 | 2.28 | 5.72* | 0.15 | 0.18 | 0.08 | 0.16* |
| 50 | 4.54 | 3.24 | 2.40 | 7.43* | 0.14 | 0.18 | 0.05 | 0.13* |
| 51 | 4.26 | 4.72 | 5.58 | 10.88* | 0.19 | 0.23 | 0.07 | 0.13* |
| 52 | 5.68 | 6.42 | 1.25 | 10.16* | 0.09 | 0.20* | 0.07 | 0.09* |
| 53 | 1.56 | 1.85 | 3.34 | 4.64* | 0.16 | 0.19 | 0.13 | 0.16* |
| **1979** | | | | | | | | |
| 54 | 3.29 | 3.71 | 3.37 | 6.30* | 0.23 | 0.33 | 0.13 | 0.30* |
| 55 | 4.58 | 5.04 | 2.61 | 5.88* | 0.18 | 0.41* | 0.09 | 0.23* |
| 56 | 4.03 | 4.40 | 7.63 | 7.88 | 0.45 | 0.48 | 0.10 | 0.26* |
| 57 | 4.53 | 2.86 | 4.66 | 6.74* | 0.43 | 0.45 | 0.10 | 0.23* |
| 58 | 4.51 | 4.14 | 4.85 | 8.48 | 0.41 | 0.45 | 0.09 | 0.22* |
| 59 | 3.86 | 3.60 | 2.69 | 5.64* | 0.40 | 0.42 | 0.08 | 0.26* |
| 60 | 4.49 | 4.36 | 3.42 | 5.77* | 0.35 | 0.54* | 0.13 | 0.30* |
| 61 | 4.23 | 4.56 | 5.24 | 6.88 | 0.35 | 0.40 | 0.10 | 0.29* |
| 62 | 5.90 | 9.86 | 9.47 | 4.46 | 0.39 | 0.41 | 0.17 | 0.26 |
| 63 | 5.74 | 6.57 | 5.72 | 9.20 | 0.38 | 0.41 | 0.21 | 0.44* |
| 64 | 5.14 | 5.58 | 4.69 | 6.57* | 0.33 | 0.42* | 0.13 | 0.22 |
| 65 | 5.40 | 6.75* | 7.24 | 6.82 | 0.41 | 0.38 | 0.21 | 0.25 |
| 66 | 5.59 | 5.44 | 10.63 | 8.95 | 0.38 | 0.43 | 0.20 | 0.20 |
| 67 | 5.91 | 7.12 | 3.60 | 8.70* | 0.28 | 0.42* | 0.11 | 0.15 |
| 68 | 2.00 | 2.86 | 2.17 | 1.38 | 0.41 | 0.50 | 0.11 | 0.21* |
| 69 | 3.93 | 4.17 | 1.50 | 3.65* | 0.20 | 0.45* | 0.12 | 0.24* |
| 70 | 4.74 | 4.95 | 2.58 | 6.46* | 0.19 | 0.44* | 0.12 | 0.21 |
| 71 | 7.94 | 7.98 | 6.90 | 9.71* | 0.38 | 0.33 | 0.08 | 0.23* |
| 72 | 6.14 | 5.10 | 9.99 | 11.30 | 0.25 | 0.30 | 0.16 | 0.22* |
| 73 | 3.10 | 4.30 | 6.98 | 9.83 | 0.20 | 0.30 | 0.12 | 0.27* |
| 74 | 7.84 | 6.32 | 4.41 | 7.76 | 0.14 | 0.22* | 0.07 | 0.22* |
| 75 | 6.14 | 6.04 | 7.33 | 7.86 | 0.32 | 0.31 | 0.18 | 0.28 |

Table 5. Continued.

| Location number | Applied S ppm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 25 | 0 | 25 | 0 | 25 | 0 | 25 |
| | 1st harvest | | 2nd harvest | | 1st harvest | | 2nd harvest | |
| | yield gms/pot | | | | % S | | | |
| 76 | 5.18 | 3.87 | 9.43 | 9.90 | 0.24 | 0.28 | 0.25 | 0.28 |
| 77 | 5.86 | 6.13 | 2.60 | 10.57* | 0.14 | 0.35 | 0.09 | 0.19 |
| 78 | 5.21 | 4.98 | 1.62 | 8.88* | 0.15 | 0.34 | 0.10 | 0.28* |
| 79 | 6.52 | 6.71 | 5.37 | 7.55* | 0.37 | 0.24 | 0.12 | 0.32* |
| 80 | 7.15 | 6.55 | 4.82 | 8.73* | 0.32 | 0.35 | 0.09 | 0.31* |
| 81 | 5.89 | 5.53 | 8.76 | 6.17 | 0.36 | 0.36 | 0.22 | 0.38* |
| 82 | 6.42 | 6.36 | 4.89 | 8.98* | 0.16 | 0.34* | 0.09 | 0.28* |

* Significantly different at the 90% level of probability.

## CONCLUSIONS

Corn response to applied S was observed to a limited extent under field conditions in Illinois. Use of the S soil test to predict deficiency was not reliable. Under greenhouse conditions, plants grown on 60% of the soils studied responded to the application of S. This difference in response to applied S between field and greenhouse conditions suggests that factors other than surface soil S supply may have a major influence on S availability. The two most likely factors affecting this differential response on Illinois soils are atmospheric and subsoil S contributions, with the atmospheric contribution being the most likely factor. Combination of the continued reduction in atmospheric S levels, higher crop yields, and the apparently limited ability of many Illinois surface soils to supply an adequate amount of available S will likely result in increased S deficiency on field crops grown on Illinois soils.

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