7-1978

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Research Bulletin

284

July 1978

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University of Nebraska – Lincoln
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Contents

Issued July 1978 1,000

SUMMARY

Studies conducted in north-central Nebraska from 1973 through 1975 were designed to evaluate sulfur (S) fertilizers and determine optimum rates of fertilizer S for both alfalfa and corn production on sandy soils. Several sites were selected for study each year. For alfalfa, both irrigated and dryland sites were selected. All sites selected for corn were irrigated with the center pivot sprinkler systems. Conclusions of the study are:

1. Alfalfa did not respond to the application of fertilizer S at all sites. Failure of alfalfa to respond to applied S may be attributed to either a high organic matter content of the surface soil or a substantial amount of S in the irrigation water.

2. At responsive sites, all sources of fertilizer S were equally effective in increasing alfalfa production. For individual cuttings, response to rate of applied S was both linear and curvilinear. The nature of the response varied with site.

3. Rates of S applied in 1973 increased alfalfa production through 1975. For this site, the application of 55 kg S/ha in 1973 was sufficient to produce maximum yield in all three years.

4. Source of fertilizer S had a significant effect on the S content of the first cutting at some sites. When differences due to S sources were observed, the total S content was lower when the elemental S + bentonite product was used. Source of S had no effect on the total S content of alfalfa collected from second, third and fourth cuttings.

5. For the majority of the cuttings at the responsive sites, the total S content of alfalfa receiving no S was less than .200%. The S content of alfalfa tissue was curvilinearly related to rate of applied S.

6. Throughout the study, corn yields were not affected by source of fertilizer S. In some cases, corn fertilized with the elemental S + bentonite product appeared to be shorter than corn fertilized with sources containing $SO_4^{=}-S$. This visual obervation could not be confirmed by either plant weights or grain yields.

7. Small amounts of fertilizer S were needed to produce maximum yields at responsive sites. Rates of 11 to 17 kg/ha were sufficient for maximum production with the exception of one site which sustained hail damage.

8. Response to S fertilization could not be related solely to the $SO_4^{=}-S$ content of the soil as extracted by the calcium phosphate procedure. Response to applied S could be related to a consideration of the organic matter content as well as the $SO_4^{=}-S$ content of the surface soil.

9. The S content as well as S uptake by young corn plants about three weeks after emergence could not be used to adequately evaluate either source of fertilizer S or rate of S applied.

10. Based on the data collected from this study, it was not possible to establish a critical level for the S content of the corn ear leaf at silking.

Sulfur Fertilization of Alfalfa and Corn on the Sandy Soils of Nebraska

G. W. Rehm[1]

Introduction

The importance of fertilizer sulfur (S) for crop production on the sandy soils of Nebraska was first recognized in 1952 in Pierce County where responses of corn to S fertilization were reported by Fox and Hoover (1961). More detailed research with this nutrient in both field and greenhouse studies has been summarized by Fox *et al.* (1964). Based on results of the early research, the application of S was recommended for both alfalfa and corn production on all sandy soils of Nebraska.

Subsequent to the completion of this early research, several new fertilizer materials designed to supply S have been developed. The rapid disappearance of ordinary superphosphate (0-20-0) from the fertilizer market and problems associated with spreading materials such as powdered gypsum and finely ground elemental sulfur stimulated this development. Field evaluation of some of these products was needed in Nebraska. Objectives of these studies were:

1. To determine the effect of various S fertilizers and rates of S application on the yield of both alfalfa and corn grown on sandy soils.
2. To determine the residual effects of a single application of S fertilizer on the production of alfalfa.
3. To measure the influence of S fertilizers and the rate of S applied on the S content of corn and alfalfa tissue and S uptake by these two crops.
4. To develop a soil testing procedure which accurately predicts the requirement for the application of S fertilizers to alfalfa and corn on sandy soils.

EXPERIMENTAL PROCEDURE

The Soils

Research started in 1973 and continued through 1975 was conducted on sandy soils in the Sandhills border area of northeast and northcentral Nebraska. The following soil series involved are listed in Table 1.

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Table 1. Soil types at the experimental sites.

Crop	Year	County	Soil type
Alfalfa	1973, 1974, 1975	Stanton (dryland)	Thurman loamy fine sand
Alfalfa	1973 and 1974	Antelope (dryland)	Thurman loamy fine sand
Corn	1973	Pierce (irrigated)	Thurman loamy fine sand
Corn	1973	Holt (irrigated)	Meadin sandy loam
Corn	1974	Pierce (irrigated)	Thurman loamy fine sand
Corn	1974	Knox (irrigated)	Thurman loamy fine sand
Corn	1974	Holt (irrigated)	Meadin sandy loam
Alfalfa	1975	Antelope (irrigated)	Thurman loamy fine sand
Alfalfa	1975	Antelope (dryland)	Thurman loamy fine sand
Alfalfa	1975	Pierce (dryland)	Bazile loam
Corn	1975	Pierce (irrigated)	Thurman loamy fine sand
Corn	1975	Holt (irrigated)	Jansen loam
Corn	1975	Antelope (irrigated)	Thurman loamy fine sand

Bazile Loam

This soil was formed in Peoria loess or silty outwash material over wind-deposited sand or sandy outwash material. The surface layer has a relatively high organic matter content with a loam or sandy loam texture.

Jansen Loam

Formed in loamy sediments over alluvial sand and gravel, this soil is moderately deep and well drained. It is loamy to a depth of about 46 cm. Sandy clay loam is found from 46 to 64 cm and coarse sand or gravel below 64 cm.

Meadin Sandy Loam

This relatively shallow soil was formed in loamy material over gravel. The surface 20 cm of this soil is a sandy loam. This surface layer is underlain by a gravelly sandy loam which, with increasing depth, changes to a very coarse sand or gravel. The organic matter content of the surface soil is somewhat similar to the organic matter content of the surface soil of the Jansen series.

Thurman Loamy Fine Sand

Thurman soils are deep, somewhat excessively drained soils formed in wind-deposited sand. The organic matter of the surface layer (0–38 cm) is relatively low and declines with increasing depth.

Studies With Alfalfa

In 1973, established alfalfa stands were used at two sites while alfalfa was seeded in the spring of 1973 at a third site.

Two series of plots were established at each site. In one series (hereafter referred to as the residual study), four sulfur sources (powdered gypsum, granular gypsum, elemental S + bentonite, and $K_2SO_4 \cdot MgSO_4$) were applied at rates to supply 0, 56, 112, and 168 kg S/ha. The four sources listed above were applied at rates to supply 0, 22, 44, and 66 kg S/ha in the second series (referred to as the annual phase) of the study.

All plots in the residual phase received 133 kg P_2O_5/ha as concentrated superphosphate (0-52-0) while all plots in the annual phase received 44 kg P_2O_5/ha as concentrated superphosphate (0-52-0). In both sets, KCl (0-0-62) was applied at a rate equivalent to the amount of K applied with the highest rate of $K_2SO_4 \cdot MgSO_4$ used. All fertilizer materials were broadcast on the surface at sites where the alfalfa had been previously established. The fertilizer materials were broadcast and incorporated with a disk at the site where alfalfa was seeded.

The four sulfur sources listed above were applied to supply 0, 22, 44, and 66 kg S/ha at three additional sites in the region in the early spring of 1974. An established stand of alfalfa was present at all sites. As in 1973, adequate P and K were applied to all plots at each location.

In 1975, three sulfur sources (granular gypsum, elemental S + bentonite, and fortified gypsum) were applied to supply 0, 17, 33, 50, and 66 kg S/ha at three additional locations. Established alfalfa was present at all sites. One of the sites was irrigated with a center pivot sprinkler irrigation system. Adequate P and K were broadcast to all plots at all sites.

Throughout the study, alfalfa was harvested at a 5 cm height at the 1/10 bloom stage. The harvested area from each plot was about 1 m × 4 m. Whole plant samples were collected from each plot for determination of moisture and S content. These samples were dried, ground to pass a 2-mm screen, and analyzed for total S after digestion with nitric and perchloric acid (Blanchar, Rehm, and Caldwell, 1965). Sulfur uptake was computed by multiplying S content by dry matter yield.

Studies With Corn

Two of the three experimental sites selected in 1973 were irrigated with center pivot systems; a third site was not irrigated.

Four S sources (granular gypsum, elemental S + bentonite, ammonium sulfate, and $K_2SO_4 \cdot MgSO_4$) were applied to supply 0, 17, 33, and 50 kg S/ha. All plots received 112 kg P_2O_5/ha as concentrated superphosphate (0-52-0), 66 kg N/ha as either NH_4NO_3 (33-0-0) or a combination of NH_4NO_3 and $(NH_4)_2SO_4$, 69 kg K_2O/ha as either KCl (0-0-62) or the combination of KCl and $K_2SO_4 \cdot MgSO_4$, and 11 kg Zn/ha as ZnO. All fertilizer materials were broadcast and incorporated with a disk before planting.

The corn at the irrigated sites received 88 kg/ha of 8-24-0 as a starter. No starter fertilizer was used at the dryland site. A total of 255 kg N/ha was used at each of the irrigated sites. Corn at the dryland site received 133 kg N/ha.

The three experimental sites selected in 1974 were irrigated with the center pivot irrigation systems.

Three S sources (granular gypsum, elemental S + bentonite, and $K_2SO_4 \cdot MgSO_4$) were applied to supply 0, 11, 22, and 33 kg S/ha. All plots received 74 kg P_2O_5/ha as concentrated superphosphate (0-52-0), 44 kg N/ha as NH_4NO_3 (33-0-0), 11 kg Zn/ha as ZnO, and 39 kg K_2O/ha as either KCl or a combination of KCl and K_2SO_4 $MgSO_4$. All fertilizer materials were broadcast and incorporated with a disk before planting. All plots at all sites received a total of about 255 kg N/ha during the growing season.

The four experimental sites used in 1975 were irrigated with automated center pivot sprinkler systems.

Three sulfur sources (granular gypsum, elemental S + bentonite, and fortified gypsum) were applied to supply 0, 11, 22, 33, and 44 kg S/ha. Each plot at all sites received a broadcast application of 88 kg P_2O_5/ha as 0-52-0, 55 kg K_2O/ha as KCl, 55 kg N/ha as 33-0-0, and 11 kg Zn/ha as ZnO. All fertilizer materials were broadcast and incorporated with a disk before planting.

All experimental locations selected in this study were in farmers' fields. Therefore, several corn varieties and plant populations were used. In general, all corn was planted in early to mid-May. Recommended rates of chemicals were used for weed and insect control at all sites.

Each year, whole corn plants were collected from each plot when the corn was 30-40 cm tall. Ear leaves were collected at silking. All plant samples were dried, weighed, ground to pass a 2-mm screen, and analyzed for total S after digestion with nitric and perchloric acid (Blanchar, Rehm, and Caldwell, 1965). Sulfur uptake by whole plants was computed by multiplying plant weight by S content.

Yields were measured in October and November. Corn was harvested from a 6.67 m section of two center rows in each plot. Samples were collected from each plot for determination of moisture. Yields are reported as kg of dry matter per ha.

Collection of Soil Samples

Throughout the study, soil samples were collected from all sites before fertilizers were applied. In 1973 and 1974, samples were taken at 0-15, 15-30, 30-60, 60-90, 90-120, and 120-150 cm increments. In 1975, soil samples were collected at 0-20, 20-40, and 40-60 cm increments. All samples were analyzed for pH, O.M., P (Bray and Kurtz

Table 2. Nutrient content of irrigation water at irrigated corn experimental sites from 1973 through 1975.

	County and year							
Nutrient	Pierce (73)	Holt (73)	Pierce (74)	Knox (74)	Holt (75)	Pierce (75)	Antelope (75)	Holt (75)
	ppm							
N	7.2	.92	5.6	4.0	8.4	4.4	.8	1.6
P	.30	.22	.40	.19	.19	.22	.24	.02
K	4.0	7.4	3.0	3.7	3.5	9.7	9.0	4.6
S	2.9	1.4	6.0	3.0	6.0	3.5	3.5	2.0
Mg	7.2	4.2	2.3	2.5	3.2	2.8	12.1	5.7
Zn	.01	.01	.01	.01	.02	0.0	0.0	0.0
Fe	.01	.01	.02	.07	.04	0.0	0.0	0.0
Mn	.15	.02	.01	.01	.01	0.0	.05	0.0
Cu	.02	.03	.01	.01	.01	.01	.01	.01
B	.19	.22	0.0	0.0	0.0	.05	.50	.23

#1), K ($NH_4C_2H_3O_2$), and $SO_4^=$–S. The $SO_4^=$–S was extracted by the mono-calcium phosphate procedure outlined by Fox, Olson, and Rhoades (1964).

Analysis of Irrigation Water

Samples of the irrigation water were collected in mid-summer at all irrigated sites. These samples were analyzed to determine nutrient content and water quality. Results are listed in Table 2.

Statistical Analysis

Randomized complete block factorial designs with four replications were used at all experimental sites. The approach suggested by Petersen (1977) was used in analyzing the data. The data were first analyzed by analysis of variance described for a two factor factorial procedure (Steel and Torrie, 1960). A comparison of sources was completed by using these procedures. The influence of rate of applied S was determined by using regression procedures outlined by Steel and Torrie (1960) when there was no interaction between S source and rate of applied S.

RESULTS AND DISCUSSION

Residual Effects of S Applied to Alfalfa

Yield

Yields were measured at two of the three sites selected for study in 1973. Severe drought prevented satisfactory establishment of alfalfa at the site seeded in the spring of 1973.

There were no interactions between source and rate of S throughout the study. The effects of S source are listed in Table 3 while the

Table 3. The effect of source of S applied in 1973 on total yield of alfalfa in 1973, 1974, 1975.

Sulfur source	Stanton (73)	Stanton (74)	Stanton (75)	Antelope (73)	Antelope (74)
	County and year				
	kg/ha				
Powdered gypsum	6149 a*	7489 a	6441 a	1357 a	5309 a
Granular gypsum	6261 a	7458 a	6495 a	1294 a	5237 a
Elemental S + bentonite	6077 a	7314 a	6436 a	1305 a	5155 a
$K_2SO_4 \cdot MgSO_4$	6052 a	7668 a	6700 a	1494 a	5376 a

*Treatment means in any one column followed by the same letter are not significantly different at the .05 confidence level.

influence of rate of S on total yield is shown in Table 4. In both Stanton and Antelope Counties, the source of S applied had no effect on yield throughout the three-year period (Table 3). Three cuttings were harvested from the Stanton County site while dry weather prevented the harvest of more than one cutting at the Antelope County location in 1973. In 1974, three cuttings were harvested from the Stanton County site while two cuttings were made at the Antelope County site. A severe infestation of pocket gophers prevented harvest from the Antelope County site in 1975.

Response to rate of applied S was variable. Except for the 3rd cutting at the Stanton County site, the response to applied S was curvilinear in 1973 (Table 4).

With the exception of the first cutting at the Stanton County site, S applied in 1973 produced a curvilinear yield response in 1974. The

Table 4. Regression equations for the influence of rate of applied S (kg/ha) applied in 1973 on yield (Y) of alfalfa (kg/ha) in 1973, 1974, and 1975.

County	Year	Cutting	Equation	Level of significance
Stanton	1973	1st	$Y = 1887.5 + 11.82X - .0568X^2$	.01
Stanton	1973	2nd	$Y = 2090.5 + 7.08X - .0329X^2$	.01
Stanton	1973	3rd	$Y = 2130.5 + 2.09X$	.01
Stanton	1973	Total	$Y = 6088.2 + 21.82X - .0980X^2$	.01
Antelope	1973	1st	$Y = 1143.9 + 12.15X - .0604X^2$	.01
Stanton	1974	1st	$Y = 4241.4 + 3.04X$	.01
Stanton	1974	2nd	$Y = 1183.6 + 13.58X - .0660X^2$	.01
Stanton	1974	3rd	$Y = 1767.9 + 19.24X - .1049X^2$	.01
Stanton	1974	Total	$Y = 7095.0 + 41.55X - .2093X^2$	.01
Antelope	1974	1st	$Y = 3634.6 + 18.60X - .0917X^2$	.01
Antelope	1974	2nd	$Y = 1482.9 + 8.25X - .0486X^2$	.01
Antelope	1974	Total	$Y = 5118.3 + 26.91X - .1407X^2$	.01
Stanton	1975	1st	$Y = 2229.5 + 1.03X$	.05
Stanton	1975	2nd	$Y = 2667.4 + 6.60X - .0327X^2$	.01
Stanton	1975	3rd	$Y = 1853.2 + 10.36X - .0578X^2$	.01
Stanton	1975	Total	$Y = 6740.4 + 18.63X - .0951X^2$	.01

Table 5. Properties of the soils at the sites selected for evaluating S sources for alfalfa in 1973.

Soil depth	Stanton					Antelope				
	pH	O.M.	P	K	$SO_4^=-S$	pH	O.M.	P	K	$SO_4^=-S$
cm		%	ppm				%	ppm		
0-15	6.4	1.30	33	186	5.8	6.8	1.08	32	138	4.5
15-30	5.9	1.05	15	106	6.0	6.7	.83	12	124	4.6
30-60	6.2	.99	4	64	3.0	6.6	.70	3	63	2.8
60-90	6.4	.61	3	52	3.0	6.7	.53	2	43	1.5
90-120	6.5	.91	3	95	3.3	6.6	.47	2	60	2.0
120-150	6.5	.64	3	103	4.0	6.6	.50	3	86	2.0

rates of S applied in 1973 produced a curvilinear yield response in all but the first cutting at the Stanton County site in 1975.

Based on earlier work, Fox *et al.* (1964) concluded that alfalfa on sandy soils could be expected to respond to the use of S fertilizers if the organic matter content of the surface soil was less than 1%. Data collected in this study indicate that this suggested value may be too low. The organic matter content of the surface soil at the Stanton County site was 1.30% (Table 5). The surface soil at the Antelope County site had an organic matter content of 1.08%.

Data from the Stanton County site also show that large applications of S should be sufficient for three years of alfalfa production in non-irrigated fields. The curvilinear response through the 1975 growing season at the Stanton County site indicates that the initial application of 55 kg S/ha in 1973 was satisfactory for at least three years of dryland alfalfa production (Figure 1).

Higher rates of fertilizer S may be needed to produce maximum yield for a three-year period at other sites. Additional research is needed in this regard.

S Content of Alfalfa

There were no interactions between source and rate of S on the S content of the alfalfa plants. Therefore, average effects of S sources

Table 6. Effect of S source applied in 1973 on the S content of alfalfa harvested in 1973 and 1974.

Sulfur source	Stanton County 1st (73)	2nd (73)	3rd (73)	1st (74)	2nd (74)	3rd (74)	Antelope County 1st (73)	1st (74)	2nd (74)
	% S								
Powdered gypsum	.345 b*	.257 a	.261 a	.227 a	.395 a	.288 a	.314 b	.238 a	.272 ab
Granular gypsum	.328 ab	.259 a	.270 a	.265 a	.391 a	.296 a	.306 b	.279 a	.305 b
Elemental S + bentonite	.267 a	.245 a	.245 a	.244 a	.362 a	.295 a	.229 a	.244 a	.244 a
$K_2SO_4 \cdot MgSO_4$	.370 b	.259 a	.266 a	.220 a	.364 a	.268 a	.309 b	.231 a	.274 ab

*Treatment means in any one column followed by the same letter are not significantly different at the .05 confidence level.

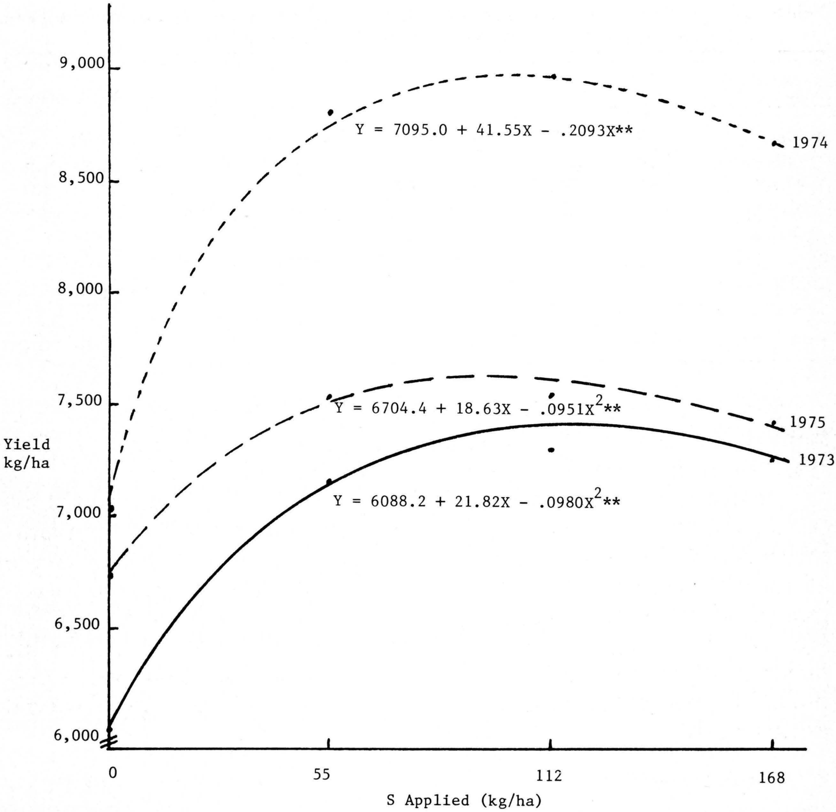

Figure 1. The effect of rate of S applied in the spring of 1973 on total yield of alfalfa at the Stanton County site in 1973, 1974, and 1975.

are listed in Table 6. Effects of rate of applied S are listed in Table 7. Considering the sources, the S content of the tissue from the first cutting in 1973 at both locations was lower when the elemental S + bentonite product was used (Table 6). This observation may be explained by the fact that the elemental S must be oxidized to $SO_4^=$ before it can be utilized by growing plants. This oxidation requires time and is delayed by low soil temperatures in early spring. Oxidation of the elemental S may not have been complete at time of harvest of the first cutting in 1973. Oxidation was probably completed shortly thereafter because S source had no influence on the S content of the alfalfa plants from subsequent cuttings at both sites.

The S content of the plants for all cuttings at both sites was affected by rate of S applied (Table 7). The response to rate of applied S was not consistent. Except for the third cutting at the Stanton County site, the response was curvilinear in 1973. In 1974, the response to S

Table 7. Regression equations for the influence of rate of S (X) applied in 1973 (kg/ha) on the S content (Y) of alfalfa in 1973 and 1974.

County	Year	Cutting	Equation	Level of Significance
Stanton	1973	1st	$Y = .201 + .0028X - .00001X^2$	.01
Stanton	1973	2nd	$Y = .180 + .0014X - .000001X^2$	.01
Stanton	1973	3rd	$Y = .179 + .0006X$	.01
Antelope	1973	1st	$Y = .175 + .0025X - .00001X^2$	.01
Stanton	1974	1st	$Y = .190 + .0005X$	.01
Stanton	1974	2nd	$Y = .260 + .0024X - .00001X^2$	.01
Stanton	1974	3rd	$Y = .224 + .0006X$	.01
Antelope	1974	1st	$Y = .176 + .0016X - .00001X^2$	.01
Antelope	1974	2nd	$Y = .211 + .0006X$	.01

applied in 1973 was curvilinear for the second cutting at the Stanton County site and the first cutting at the Antelope County site. The response to applied S was linear for all other cuttings.

Except for the relatively high values from the second and third cuttings in Stanton County in 1974, the percentages of S in the plants measured in this study are of the same order as those reported in the literature (Metson, 1973). In the majority of the cuttings, the S content of whole alfalfa plants was about .200% or less when no S was applied (Table 7). These results are in general agreement with the majority of results reported in the literature. The high values reported by Sorensen, Penas and Alexander, (1968) were not observed in this study.

S Uptake by Alfalfa

Sulfur uptake was determined by multiplying dry matter production by the S content of the tissue for each harvest. The total uptake of S at the Stanton County site was influenced by the source of S used in 1973 (Table 8). This difference in total uptake was a reflection of a difference in uptake for the first cutting (data not shown). In subsequent cuttings, S source had no effect on S uptake by alfalfa.

Table 8. Effect of S sources applied in 1973 on the total S uptake by alfalfa during the growing season in 1973 and 1974.

Sulfur source	County and year			
	Stanton (73)	Stanton (74)	Antelope (73)	Antelope (74)
	kg S/ha			
Powdered gypsum	20.3 b	17.5 a	10.3 a	15.2 a
Granular gypsum	20.8 b	19.0 a	12.2 a	17.4 a
Elemental S + bentonite	17.6 a	17.0 a	10.5 a	14.6 a
$K_2SO_4 \cdot MgSO_4$	20.9 b	16.5 a	10.3 a	15.5 a

*Treatment means in any one column followed by the same letter are not significantly different at the .05 confidence level.

Table 9. Regression equations for the effect of rate of S applied (kg/ha) in 1973 (X) on S uptake (Y) by alfalfa (kg/ha) in 1973 and 1974.

County	Year	Cutting	Equation	Level of significance
Stanton	1973	1st	$Y = 3.78 + .091X - .00044X^2$	.01
Stanton	1973	2nd	$Y = 3.77 + .046X - .00020X^2$	.01
Stanton	1973	3rd	$Y = 4.16 + .019X$	.01
Stanton	1973	Total	$Y = 11.47 + .170X - .00073X^2$	.01
Stanton	1974	1st	$Y = 8.02 + .029X$	.01
Stanton	1974	2nd	$Y = 3.09 + .077X - .00035X^2$	.01
Stanton	1974	3rd	$Y = 3.73 + .074X - .00035X^2$	.01
Stanton	1974	Total	$Y = 11.98 + .053X$	.01
Antelope	1974	1st	$Y = 6.35 + .103X - .00049X^2$	.01
Antelope	1974	2nd	$Y = 2.99 + .039X - .00019X^2$	.01
Antelope	1974	Total	$Y = 9.33 + .142X - .00069X^2$	.01

Uptake of S in both 1973 and 1974 was dependent on the rate of S applied in 1973 (Table 9). Except for the third cutting, there was a curvilinear response to rate of S at the Stanton County site in 1973. Rate of S had no effect on S uptake from the Antelope County site in the same year. With the exception of S uptake from the first cutting and total S uptake, there was a curvilinear response of S uptake to rate of applied S in 1974.

For the most part, the effect of rate of S on S uptake parallels the effect of rate of fertilizer S on yield.

Yearly Application of Sulfur to Alfalfa

Yield

In addition to the study of the residual effects of S fertilization described previously, annual applications of S to alfalfa were also studied. New sites were selected each year. Lower rates of S were selected when annual applications of S were used. Severe drought and inadequate stands eliminated harvest in 1974. Therefore, results from 1973 and 1975 are included for discussion.

Table 10. Effect of source of S applied on an annual basis on the yield of alfalfa in 1973.

Sulfur source	County and cutting				
	Stanton				Antelope
	1st	2nd	3rd	Total	1st
	kg/ha				
Powdered gypsum	1844 a*	2107 a	1952 a	5903 a	1705 a
Granular gypsum	2028 a	2087 a	1940 a	6055 a	1711 a
Elemental S + bentonite	1835 a	2014 a	1874 a	5726 a	1812 a
$K_2SO_4 \cdot MgSO_4$	1809 a	1972 a	1773 a	5554 a	1643 a

*Treatment means within any one column followed by the same letter are not significantly different at the .05 confidence level.

Table 11. Regression equations for the effect of rate of S applied in 1973 (kg/ha) on an annual basis on yield (Y) of alfalfa (kg/ha)

County	Year	Cutting	Equation	Level of significance
Stanton	1973	1st	$Y = 1590.5 + 36.65X - .4165X^2$	.01
Stanton	1973	2nd	$Y = 2156.0 + 4.49X$	.05
Stanton	1973	3rd	$Y = 1926.2 + 6.15X$	.01
Stanton	1973	Total	$Y = 5553.9 + 65.78X - .7252X^2$	.01
Antelope	1974	1st	$Y = 1539.4 + 39.79X - .5782X^2$	.01

Source of S had no influence on total yields in either 1973 (Table 10) or 1975 (Table 12). Sources were altered each year but total yields from sources supplying S as $SO_4^{=}-S$ were equal to total yields produced by sources supplying S as elemental S. Apparently, sufficient $SO_4^{=}$ was oxidized from the elemental S during the course of the growing season to provide for the production obtained.

Rate of S applied in 1973 produced a curvilinear yield response for the first cutting at both sites (Table 11). The second and third cuttings at the Stanton County site responded linearly to rate of fertilizer S applied. For total yield, however, there was a curvilinear response to rate of S.

In 1975, alfalfa yields were increased by rate of fertilizer S for the non-irrigated site in Antelope County only (Figure 2). There was a linear response to applied S for both cuttings as well as for total yield at this site. Application of S had no effect on yield of alfalfa at the irrigated sites in both Antelope and Pierce Counties.

The response of alfalfa to S in Antelope County in 1975 cannot be predicted from an examination of soil properties. The properties of

Table 12. Effect of source of S applied on an annual basis on the yield of alfalfa in 1975.

County	Cutting	Sulfur source: granular gypsum	Sulfur source: elemental S + bentonite	Sulfur source: fortified gypsum
		kg/ha		
Antelope (irrigated)	1st	3458 a*	3367 a	3494 a
Antelope (irrigated)	2nd	2318 a	2301 a	2304 a
Antelope (irrigated)	3rd	2389 a	2459 a	2389 a
Antelope (irrigated)	4th	1517 a	1583 a	1511 a
Antelope (irrigated)	Total	9682 a	9710 a	9698 a
Antelope (dryland)	1st	3398 a	3392 a	3360 a
Antelope (dryland)	2nd	2790 a	2792 a	2949 a
Antelope (dryland)	Total	6187 a	6185 a	6316 a
Pierce	1st	3106 a	3109 a	3112 a
Pierce	2nd	3316 a	3364 a	3321 a
Pierce	Total	8028 a	8091 a	6432 a

*Treatment means in any one row followed by the same letter are not significantly different at the .05 confidence level.

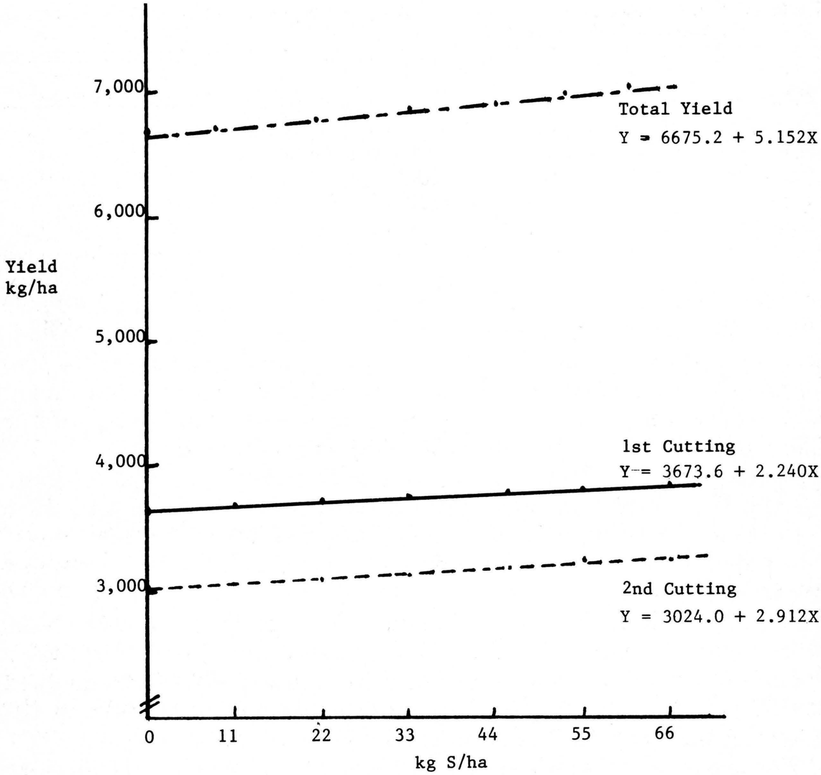

Figure 2. Effect of rate of applied S on yield of alfalfa at the dryland site in Antelope County in 1975.

the irrigated and non-irrigated sites are quite similar (Table 13). Yet the nature of the response was quite different. Soil samples taken from the 20-40 and 40-60 cm depths showed no higher values for $SO_4^{=}-S$ at the irrigated site in Antelope County. So the lack of response at this site cannot be attributed to an accumulation of $SO_4^{=}-S$ below the surface. The S content of the irrigation water was such that approximately 22 kg S/ha were applied during the growing season. Although it would seem that this is not enough S to meet the needs of an irrigated alfalfa crop, it was apparently enough to correct any slight deficiency for the alfalfa since it did not respond to the application of S. The lack of a response for the irrigated site in Pierce County may be attributed to the relatively high organic matter content of the soil. Since approximately 95% of the total S of soils is contained in the organic matter, mineralization of S from organic matter may have provided sufficient S for alfalfa at this site.

Table 13. Properties of soils at sites selected for alfalfa studies in 1975.

Property	Depth	County		
		Antelope (Irrigated)	Antelope (Dryland)	Pierce
	cm			
pH	0-20	6.0	6.4	5.9
	20-40	5.8	6.1	5.9
	40-60	6.3	5.9	6.2
Organic matter content (%)	0-20	.87	.79	1.92
	20-40	.94	1.16	1.85
	40-60	.72	.94	1.21
ppm $SO_4^{=}-S$	0-20	3.6	4.7	5.7
	20-40	3.3	3.9	4.1
	40-60	2.8	3.0	2.8
Bray P (ppm)	0-20	24	34	70
Exchangeable K (ppm)	0-20	80	117	334
CEC (meq/100 gm)	0-20	4.97	3.69	9.50

S Content

The elemental S + bentonite product produced a lower S content in the first cutting at both sites in 1973 (Table 14). As in the residual phase of the study, the lower S content of the first cutting can be attributed to the delay in oxidation of the elemental S promoted by the cool temperatures in early spring. There is no apparent explanation for the lower S content of alfalfa receiving granular gypsum for the first cutting at the Stanton County site. The S content of the second and third cuttings at the Stanton County site was not influenced by S source, indicating that oxidation of elemental S was sufficient to supply ample $SO_4^{=}-S$ at this point in the growing season.

The rate of applied S influenced the S content of the plants (Table 15). The relationship between rate of S applied and S content of the plants was linear for the three cuttings taken at the Stanton County site and curvilinear for the one cutting taken at the Antelope County site in 1973 (Table 15).

In 1975, the effects of S source on the S content of the plants were similar to effects observed in 1973 (Table 16). Rate of applied S in-

Table 14. Total S content of alfalfa in 1973 as influenced by source of S applied.

Sulfur source	County and cutting			
	Stanton			Antelope
	1st	2nd	3rd	1st
	% S			
Powdered gypsum	.364 b*	.256 a	.239 a	.317 b
Granular gypsum	.307 a	.247 a	.242 a	.314 b
Elemental S + bentonite	.289 a	.229 a	.217 a	.258 a
$K_2SO_4 \cdot MgSO_4$	.368 b	.265 a	.233 a	.337 b

*Treatment means in any one column followed by the same letter are not significantly different at the .05 confidence level.

Table 15. Regression equations for the effect of rate of S (kg/ha) on the S content (%) of alfalfa in 1973 and 1975.

Year	County	Cutting	Equation	Level of significance
1973	Stanton	1st	$Y = .214 + .0027X$	.01
1973	Stanton	2nd	$Y = .200 + .00116X$	.01
1973	Stanton	3rd	$Y = .190 + .00105X$	.01
1973	Antelope	1st	$Y = .187 + .00607X - .00007X^2$	.01
1975	Antelope (irrigated)	1st	$Y = .180 + .00041X$	.10
1975	Antelope (irrigated)	2nd	$Y = .215 + .00159X$	.01
1975	Antelope (irrigated)	3rd	$Y = .234 + .00115X$	.01
1975	Antelope (irrigated)	4th	$Y = .287 + .00247X - .00003X^2$	.10
1975	Antelope (dryland)	1st	$Y = .199 + .00075X$	.05
1975	Antelope (dryland)	2nd	$Y = .212 + .00096X$	.01

Table 16.Total S content of alfalfa as influenced by source of S applied in 1975.

	County and cutting							
Sulfur	Antelope, irrigated				Antelope, dryland		Pierce	
source	1st	2nd	3rd	4th	1st	2nd	1st	2nd
	% S							
Granular gypsum	.205 b*	.276 a	.270 a	.320 a	.229 b	.236 a	.282 a	.248 a
Elemental S + bentonite	.175 a	.242 a	.260 a	.325 a	.198 a	.246 a	.266 a	.243 a
Fortified gypsum	.197 b	.268 a	.275 a	.312 a	.237 b	.241 a	.289 a	.240 a

*Treatment means in any one column followed by the same letter are not significantly different at the .05 confidence level.

creased the S content of the plants at both Antelope County sites but had no effect on the S content of the alfalfa harvested at the Pierce County site. Except for the fourth cutting at the irrigated site in Antelope County in 1975, the S content of the plants was linearly related to rate of applied S. With the exception of the first cutting in Stanton County in 1973 and the third and fourth cuttings from the irrigated site in Antelope County, the S content of the alfalfa plants was close to or below the .200% level when no S was applied. This is in general agreement with much of the research reported in the literature.

Relationship of S Content to Yield

The relationship of the S content of the plants to alfalfa yield in kg of dry matter per ha was examined by using standard regression procedures (Steel and Torrie, 1960). The regression equations showing significant relationshps are listed in Table 17.

Significant relationships between these two variables were limited to the Stanton County site and the non-irrigated site in Antelope County. In addition, significant relationships were limited to the first two cuttings. There was no consistency in the nature of the regression

Table 17. Regression equations for the relationship of S content of alfalfa (%) to yield (metric ton per ha).

Year	Cutting	Site	Equation	Level of significance
1973	1st	Stanton	$Y = 1.27 + 21.488X - .318X^2$	.05
1973	1st	Antelope	$Y = 3.84 + 43.340X - 77.222X^2$	.05
1973	1st	Stanton (residual)	$Y = 1.47 + 24.343X - 37.397X^2$	.05
1973	2nd	Stanton (residual)	$Y = 2.25 + 38.116X - 77.371X^2$	.05
1973	1st	Antelope (residual)	$Y = .82 + 2.803X$	.05
1974	2nd	Stanton (residual)	$Y = -4.23 + 31.866X - 42.017X^2$	.01
1975	1st	Antelope (dryland)	$Y = 3.39 + 1.807X$	.10
1975	2nd	Antelope (dryland)	$Y = 2.18 + 4.241X$	.10

equations. The S content was related to yield in both a linear and curvilinear manner and the nature of this relationship was not associated with either site or cutting.

S Uptake

As in the residual phase of the study with alfalfa, S uptake was computed by multiplying yield of dry matter by the S content of the plants. In 1973, total S uptake by alfalfa was lower when the elemental S + bentonite product was used at the Stanton County site (Table 18). Sulfur source had no significant effect on S uptake for the individual cuttings. The source of S used had no significant effect on the amount of S taken up by the alfalfa in 1975 (Table 19). In addition, there was no interaction between S source and rate of applied S.

In both 1973 and 1975, total S uptake increased with rate of applied S (Table 20). With the exception of the first cutting in 1973 and total S uptake for the same year, S uptake increased linearly with rate of fertilizer S applied. Sulfur uptake was not affected by rate of S at the site where S application had no effect on either yield or the S content of the tissue (Pierce Co., 1975).

Table 18. Effect of source of sulfur applied on an annual basis on the uptake of sulfur by alfalfa in 1973.

County	Cutting	S Source: powdered gypsum	granular gypsum	elemental S + bentonite	$K_2SO_4 \cdot MgSO_4$
		kg/ha			
Stanton	1st	8.15 a*	7.61 a	6.41 a	7.88 a
Stanton	2nd	6.31 a	5.94 a	5.29 a	5.93 a
Stanton	3rd	5.67 a	5.51 a	4.74 a	4.75 a
Stanton	Total	20.13 b	19.06 b	16.44 a	18.56 b
Antelope	1st	5.52 a	4.96 a	4.18 a	6.30 a

*Treatment means within any one row followed by the same letter are not significantly different at the .05 confidence level.

Table 19. Effect of source of sulfur applied on an annual basis on the uptake of sulfur by alfalfa in 1975.

County	Cutting	S Source: granular gypsum	S Source: elemental S + bentonite	S Source: fortified gypsum
		kg/ha		
Antelope (irrigated)	1st	7.99 a*	6.52 a	7.97 a
Antelope (irrigated)	2nd	7.69 a	6.56 a	7.09 a
Antelope (irrigated)	3rd	7.55 a	7.45 a	7.60 a
Antelope (irrigated)	4th	5.53 a	5.95 a	5.52 a
Antelope (irrigated)	Total	28.76 a	26.48 a	28.18 a
Antelope (dryland)	1st	9.18 a	7.67 a	9.63 a
Antelope (dryland)	2nd	7.68 a	7.71 a	8.20 a
Antelope (dryland)	Total	16.86 a	15.38 a	17.83 a
Pierce	1st	10.10 a	9.15 a	10.28 a
Pierce	2nd	9.56 a	8.94 a	8.84 a
Pierce	Total	19.66 a	18.09 a	19.12 a

*Treatment means in any one row followed by the same letter are not significantly different at the .05 confidence level.

Table 20. Regression equations for the effect of rate of S (kg/ha) on the uptake (kg/ha) of S by alfalfa (Y) in 1973 and 1975.

County	Year	Cutting	Equation	Level of significance
Stanton	1973	1st	$Y = 2.90+.2230X-.0023X^2$	.01
Stanton	1973	2nd	$Y = 4.33+.0360X$	.01
Stanton	1973	3rd	$Y = 3.70+.0350X$	.01
Stanton	1973	Total	$Y = 10.48+.3810X-.0038X^2$	.01
Antelope (irrigated)	1975	2nd	$Y = 5.49+.0378X$	.01
Antelope (irrigated)	1975	3rd	$Y = 6.28+.0293X$	.01
Antelope (irrigated)	1975	4th	$Y = 5.04+.0133X$	.05
Antelope (irrigated)	1975	Total	$Y = 21.54+.0691X$	.05
Antelope (dryland)	1975	1st	$Y = 7.28+.0338X$	.05
Antelope (dryland)	1975	2nd	$Y = 6.32+.0392X$	.01
Antelope (dryland)	1975	Total	$Y = 13.59+.0731X$	.01

Yearly Applications of Sulfur to Corn

Yield

In the past, documented reports of the response of alfalfa to S have been more numerous than reports of the response of corn to fertilizer S (Beaton, Tisdale and Platou, 1971). In this study, the S sources and rates of applied S were changed each year. Throughout the three years, however, the comparision of a source containing $SO_4^=-S$ to a source containing elemental S was maintained.

As with alfalfa, the S source had no significant effect on the yield of corn (Table 21). Throughout the study, there was a tendency for growth of corn fertilized with the elemental S + bentonite product to

Table 21. Effect of source of sulfur on the yield of corn in 1973, 1974, and 1975.

County	Year	S Source granular gypsum	elemental S + bentonite	ammonium sulfate	$K_2SO_4 \cdot MgSO_4$	fortified gypsum
		kg/ha				
Pierce	1973	9,865 a*	9.348 a	9,655 a	9,849 a	—
Holt	1973	8,575 a	8,104 a	8,035 a	8,217 a	—
Pierce	1974	8,999 a	8,379 a	—	8,915 a	—
Knox	1974	5,309 a	4,784 a	—	5,357 a	—
Holt	1974	5,482 a	5,664 a	—	5,862 a	—
Pierce	1975	6,860 a	7,008 a	—	—	7,101 a
Holt	1975	10,017 a	9,859 a	—	—	9,928 a
Antelope	1975	5,105 a	4,977 a	—	—	4,534 a

*Treatment means in any one row followed by the same letter are not significantly different at the .05 confidence level.

lag behind the growth of corn fertilized with the other S sources. Except for the Pierce County site in 1973, this visual observation could not be measured in plant weights (Table 24). This difference in early growth was not evident in grain yields recorded at the end of the growing season. The oxidation of elemental S in the elemental S + bentonite product during the course of the growing season was apparently sufficient to meet the S requirements of the corn crop.

Yields were increased by the use of S at the Pierce County site in 1973, the Pierce and Knox County sites in 1974, and the Pierce County site in 1975 (Table 22).

Relatively low rates of S were needed to produce maximum yields. Since yields in 1973 were not improved by S rates in excess of 17

Table 22. The effect of rate of S applied on yield of irrigated corn on sandy soils.

County	Year	Rate of S	Yield
		kg/ha	kg/ha
Pierce	1973	0	8648.3
		17	9755.6
		33	9648.7
		51	9629.4
Pierce	1974	0	7594.9
		11	8633.1
		22	8994.7
		33	8838.6
Knox	1974	0	3831.9
		11	4549.2
		22	5173.7
		33	5720.5
Pierce	1975	0	6126.8
		11	6900.6
		22	6969.5
		33	7054.3
		44	7027.8

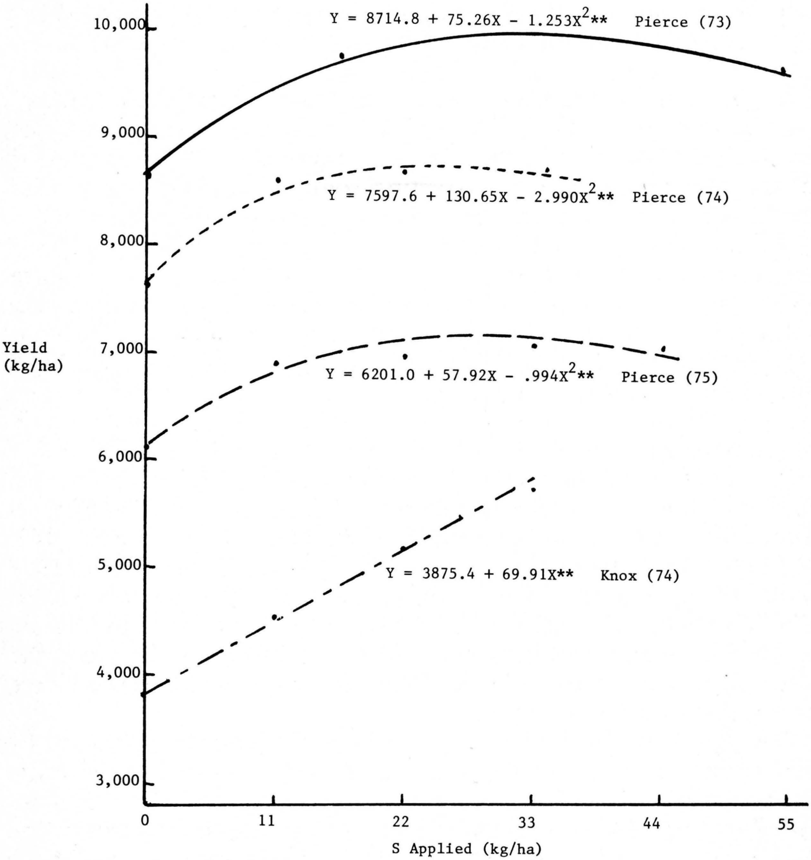

Figure 3. Effect of rate of applied S on the yield of irrigated corn grown on sandy soils in northeast Nebraska.

kg/ha, lower rates were used in both 1974 and 1975. The 11 kg/ha rate was sufficient to produce maximum yields at the responsive sites in both years. There was no interaction between source and rate of S throughout the study.

Although relatively low rates of S are needed to produce the highest yields, responses to S were substantial. Response to 17 kg/ha in 1973 was 1108 kg/ha (21 bu./acre) at the Pierce County site. In 1974, the response to 11 kg S/ha was 1038 kg/ha (19.8 bu./acre) at the Pierce County site and 710 kg/ha (13.7 bu./acre) at the Knox County site. A response of 776 kg/ha (12.4 bu./acre) to the use of 11 kg S/ha was observed at the Pierce County site in 1975.

Except for the Knox County site in 1974, the response to rate of fertilizer S was curvilinear (Figure 3). Hail severely damaged the corn at the Knox County site. If each increment of applied S helped the crop to recover, this would help to explain the linear response at this site.

In the past, researchers have studied several extracting procedures in an effort to find one suitable for predicting the S status of soils. In Nebraska trials, Fox, Olson, and Rhoades (1964) concluded that the calcium phosphate extracting solution was the most useful and relevant for predicting the S requirements of Nebraska soils.

Soil samples were collected from all experimental sites each year. The amounts of $SO_4^{=}-S$ extracted by the mono-calcium phosphate procedure as well as other soil properties for the sites planted to corn are listed in Table 23. There was a wide range in the $SO_4^{=}-S$ content of the surface soil. The data from this study, however, show that this value alone cannot be used to predict the requirement for S. For example, the $SO_4^{=}-S$ content of both sites in 1973 was nearly equal. Yet, there was no response to fertilizer S at the Holt County site.

Examination of the $SO_4^{=}-S$ content of the subsoil does not improve the ability to predict the response to fertilizer S. The $SO_4^{=}-S$ content of subsoil samples was lower at the Holt County site in 1973. Yet, there was a response to S at the Pierce County but not the Holt County site in that year. The situation was similar for sites selected in 1975. The $SO_4^{=}-S$ content of subsoil samples from the Holt County site was lower than the $SO_4^{=}-S$ content of subsoil samples from the Pierce County site. However, fertilizer S increased yields at the Pierce but not the Holt County site.

Data from this study show that the need for S can be predicted by utilizing the value for the organic matter content as well as the value for the amount of $SO_4^{=}-S$ extracted by the mono-calcium phosphate procedure. At all sites where there was a response to fertilizer S, the organic matter content as well as the $SO_4^{=}-S$ content was low. There was no response to applied S at the site where $SO_4^{=}-S$ content was low with a relatively high level of organic matter (Holt County, 1973).

The S content of the irrigation water appears to have little influence on predicting the need for S for irrigated corn on sandy soils. For example, irrigation water from both the Pierce and Holt County sites in 1974 contained 6.0 ppm S (Table 2). There was a response to applied S at the Pierce County but not the Holt County site.

Prior to 1973, S recommendations for corn were made on the basis of soil texture. The general suggestion was that S should be applied for corn production on all sandy soils. The results of this study show that S may not be needed for corn production on all sandy soils. The results further show that a consideration of the organic matter content as well as the $SO_4^{=}-S$ extracted by mono-calcium phosphate should provide a more accurate estimate of S needs for corn production on sandy soils.

Table 23. Properties of soils at sites selected to evaluate the application of sulfur to corn.

County	Year	Depth	pH	Soil property: acid soluble P (Bray)	$NH_3C_2H_3O_2$ extractable K	SO_4-S content	Organic matter content
		cm		ppm	ppm	ppm	-- % --
Pierce	1973	0-15	6.1	18.2	120	4.5	.84
		15-30	–	7.8	98	4.9	.51
		30-60	–	3.6	68	5.1	.50
		60-90	–	3.2	63	3.3	.59
		90-120	–	4.8	67	3.5	.40
		120-150	–	4.8	64	2.9	.36
Holt	1973	0-15	5.9	42.8	205	6.2	1.40
		15-30	–	17.5	145	4.0	1.21
		30-60	–	5.2	72	2.6	.53
		60-90	–	5.0	61	2.7	.33
		90-120	–	4.0	60	2.2	.20
		120-150	–	2.9	65	.6	.21
Pierce	1974	0-15	6.2	3.8	85	3.8	.97
		15-30	6.1	2.1	62	4.8	.68
		30-60	6.3	1.7	47	5.6	.32
		60-90	6.5	1.8	46	2.2	.15
		90-120	6.5	2.3	47	2.6	.14
		120-150	6.6	3.1	46	2.7	.07
Knox	1974	0-15	5.8	19.8	113	8.3	1.08
		15-30	5.6	6.0	86	9.2	1.16
		30-60	6.0	3.0	66	6.4	.73
		60-90	6.3	7.5	57	8.2	.32
		90-120	6.4	3.3	55	6.5	.18
		120-150	6.4	2.6	56	8.4	.17
Holt	1974	0-15	6.0	8.7	202	10.3	3.77
		15-30	5.9	6.4	89	8.7	1.89
		30-60	6.2	3.9	77	4.9	.62
Pierce	1975	0-20	5.2	8.0	115	3.6	.85
		20-40	5.6	—	—	3.6	.80
		40-60	6.7	—	—	3.3	.62
Holt	1975	0-20	5.4	31.0	181	5.2	2.15
		20-40	5.9	—	—	2.6	1.41
		40-60	6.2	—	—	2.2	.85
Antelope	1975	0-20	5.7	44.0	146	3.3	.68
		20-40	6.0	—	—	2.9	.44
		40-60	6.1	—	—	1.8	.31

Weight, S Content and S Uptake by Young Plants

At all sites except the Pierce County site in 1973, the sources of S had no influence on the weight of young corn plants collected about three weeks after emergence. The weight of plants was lower when the elemental S + bentonite product was used at the site in 1973 (Table 24). The lower plant weights can be attributed to the delay in

Table 24. Effect of source of sulfur on the weight of young corn plants.

County	Year	granular gypsum	elemental S + bentonite	ammonium sulfate	$K_2SO_4 \cdot MgSO_4$	fortified gypsum
		S Source				
		gm/plant				
Pierce	1973	8.2 b*	3.8 a	5.4 b	6.6 ab	—
Holt	1973	13.4 a	14.1 a	13.5 a	14.8 a	—
Pierce	1974	25.6 a	25.6 a	—	25.1 a	—
Holt	1974	10.3 a	9.8 a	—	10.0 a	—
Knox	1974	9.8 a	9.1 a	—	10.1 a	—
Pierce	1975	8.7 a	8.1 a	—	—	8.3 a
Holt	1975	5.2 a	4.8 a	—	—	5.1 a
Antelope	1975	4.8 a	4.5 a	—	—	4.6 a

*Treatment means in any one row followed by the same letter are not significantly different at the .05 confidence level.

Table 25. Regression equations for the relationship of applied S (kg/ha) to weight (gm./plant) of young corn plants (Y).

County	Year	Equation	Level of significance
Pierce	1973	$Y = 3.84 + .192X - .0034X^2$	.05
Pierce	1974	$Y = 5.16 + .507X - .0112X^2$	.01
Pierce	1975	$Y = 7.30 + .227X$	.01

the oxidation of the elemental S promoted by the cool spring temperatures at this site.

The plant weights were increased by rate of S applied at the sites in Pierce County in 1973, 1974, and 1975 (Table 25). The response was curvilinear at two of the three sites. Rate of applied S had no effect on plant weight at all other sites.

Sulfur percentages in the young plants were quite variable among locations and years (Table 26). There were no interactions between rate and source of S. At two of the eight sites (Knox, 1974 and Holt, 1973), the S content of young plants was lower when the elemental S

Table 26. Effect of source of sulfur on the sulfur content of young corn plants.

County	Year	granular gypsum	elemental S + bentonite	ammonium sulfate	$K_2SO_4 \cdot MgSO_4$	fortified gypsum
		S Source				
		%				
Pierce	1973	.216 a*	.219 a	.210 a	.155 a	—
Holt	1973	.309 b	.254 a	.316 b	.353 b	—
Pierce	1974	.198 a	.171 a	—	.180 a	—
Holt	1974	.303 a	.296 a	—	.326 a	—
Knox	1974	.210 b	.164 a	—	.227 b	—
Pierce	1975	.212 a	.216 a	—	—	.204 a
Holt	1975	.426 a	.397 a	—	—	.373 a
Antelope	1975	.278 a	.246 a	—	—	.251 a

*Treatment means in any one row followed by the same letter are not significantly different at the .05 confidence level.

Table 27. Effect of source of sulfur on the uptake of sulfur by young corn plants.

County	Year	S Source granular gypsum	elemental S + bentonite	ammonium sulfate	$K_2SO_4 \cdot MgSO_4$	fortified gypsum
		mg/plant				
Pierce	1973	17.4 a*	10.8 a	16.8 a	11.9 a	—
Holt	1973	42.1 a	36.4 a	42.5 a	52.4 b	—
Pierce	1974	51.2 a	43.9 a	45.5 a	—	—
Holt	1974	31.1 a	28.8 a	31.6 a	—	—
Knox	1974	21.3 a	16.0 a	24.3 a	—	—
Pierce	1975	18.5 a	17.7 a	—	—	16.9 a
Holt	1975	22.4 a	19.2 a	—	—	19.1 a
Antelope	1975	13.2 a	11.1 b	—	—	11.5 b

*Treatment means in any one row followed by the same letter are not significantly different at the .05 confidence level.

+ bentonite was used. In addition, there were no consistent relationships between the S content of the plants and rate of applied S. The S content of the plants was linearly related to rate of applied S at the Holt County site in 1973 ($Y = .260 + .00172X$), the Knox County site in 1974 ($Y = .177 + .0015X$), and the Pierce County site in 1975 ($Y = .173 + .00152X$).

The importance of these relationships is diminished by the fact that rate of S had no effect on yield at the Holt County site in 1973. This leaves only two sites in eight (Knox, 1974 and Pierce, 1975) where rate of S influenced both the S content of young corn plants and yields. Based on the data collected in this study, it would appear that the S content of young corn plants is not a good criterion for evaluation of either S sources or an indication of rate of S to be applied.

Sulfur uptake by the young corn plants was also computed. The effect of S source on S uptake by young corn plants was quite variable (Table 27). Sulfur uptake at the Holt County site in 1973 was increased when $K_2SO_4 \cdot MgSO_4$ was used. There was no difference among other sources. Sulfur uptake at the Antelope County site in 1975 was highest when granular gypsum was used. Source of sulfur had no significant effect on S uptake by young corn plants at all other sites.

There was no consistent relationship between rate of applied S and S uptake by young corn plants. Sulfur uptake was linearly related to rate of S for the Pierce County site in 1973 ($Y = 9.07 + .1538X$), Holt County site in 1973 ($Y = 37.1 + .235X$), and the Pierce County site in 1975 ($Y = 12.91 + .1860X$). This relationship was curvilinear for the Pierce County site in 1974 ($Y = 22.3 + 2.611X - .0604X^2$).

Yields were increased by fertilizer S at the Pierce County sites but not at the Holt County location. These data show that S uptake by young corn plants is related to neither S source nor rate of S application in any consistent manner for irrigated corn on sandy soils.

Table 28. Effect of sulfur sources on the sulfur content of the corn ear leaf at silking.

		S Source				
County	Year	granular gypsum	elemental S + bentonite	ammonium sulfate	$K_2SO_4 \cdot MgSO_4$	fortified gypsum
		% S				
Pierce	1973	.245 a*	.242 a	.244 a	.245 a	—
Holt	1973	.263 a	.248 a	.281 a	.282 a	—
Pierce	1974	.163 a	.149 a	.156 a	—	—
Holt	1974	.230 a	.201 a	.199 a	—	—
Knox	1974	.191 a	.184 a	.186 a	—	—
Pierce	1975	.160 a	.168 a	—	—	.197 a
Holt	1975	.308 b	.271 a	—	—	.292 b
Antelope	1975	.152 b	.134 a	—	—	.147 b

*Treatment means in any one row followed by the same letter are not significantly different at the .05 confidence level.

S Content of Ear Leaves

Sulfur source had no effect on the S content of the ear leaf in both 1973 and 1974. In 1975, the S content of the ear leaf tissue was lower when the elemental S + bentonite product was used as the S source (Table 28).

Rate of fertilizer S influenced the S content of the ear leaf tissue at four of the eight sites. Except for the Holt County site in 1974, this relationship was linear.

Several researchers have attempted to define a critical or adequate level of S in the corn ear leaf at silking. At this time, no one value has gained wide acceptance. Considering the three Pierce County and one Knox County locations where there was a response to S, the S level of the ear leaf was relatively low (Table 29). With the exception of the Pierce County site in 1973, the S content of the ear leaf at the responsive sites was less than .180% when maximum yields were recorded. The data do not provide an explanation for the high values from the Pierce County site in 1973.

Although maximum yields were achieved with a S content in the ear leaf of less than .180%, the data collected in this study do not provide an adequate base for the establishment of a critical S content in the ear leaf of corn at silking.

Table 29. Regression equations for the relationship of rate of applied S (kg/ha) to S content (Y) of the corn ear leaf at silking.

Year	County	Equation	Level of significance
Knox	1974	$Y = .156 + .0015X$	.01
Holt	1974	$Y = .144 + .0075X - .00018X^2$	.05
Pierce	1975	$Y = .134 + .0013X$	.01
Antelope	1975	$Y = .130 + .0006X$	.01

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