Summary of sulfur fertilization studies

1957-1998

Donald R. Christenson, Department of Crop and Soil Sciences, Michigan State University

Conclusions

Sulfur is not generally recommended for application to field crops in Michigan because yield responses have been rare and inconsistent. There is some indication that canola may respond to applied S, but the results are mixed. Conditions where a response will occur are not well defined.

A survey of 176 fields showed only one case where the corn ear leaf sulfur concentration was below the 0.16 percent critical level.

Soils test which measure sulfate-sulfur does not predict when sulfur should be applied in Michigan.

In Michigan studies, there is no evidence to suggest that protein can be increased by applying sulfur. Often an increase in protein is associated with an increase in yields.

There were no recent studies found which showed the amount of S received from the atmosphere. Smoke stacks clean up should be having an effect, but the distribution of S deposition across the landscape is uneven. Measurements need to be made to determine S contribution from the atmosphere.

Introduction

The purpose of this paper is to summarize the results of more than 50 locations-year studies over the past 40 years where yield response to sulfur was measured. The reason for including the past 40 years' result is to show that conditions, in so far as a response to sulfur is concerned, haven't changed appreciably. The data are presented in chronological order.

Results 1957-1966

The data in Table 1 were collected from 1957-1960. The sulfur was supplied from gypsum and was applied in the fertilizer band each year. There was no effect on either yield or protein level of any of the crops grown.

Soybeans grown on a Sims sandy clay loam soil did not respond to applied sulfur over a 5-year period (Table 2). In another study on this same soil, potassium chloride (0-0-60) and potassium sulfate were compared at equal rates of K on sugar beets. Neither yield nor quality were affected by the two sources (Table 3).

1967-76

Jansen and Vitosh (1974) showed that kidney beans responded to applied sulfur on an acid soil. However, when the soil was limed, there was no response to applied sulfur.

A series of experiments was conducted in 1972 and 1973 to measure the effect of applied sulfur on the yield of corn, dry beans, soybeans, and oats. Plots were located on fields where the farmer was regarded as a good producer. Soils were selected which would be most likely to respond to applied sulfur. These are the sandier soils which are low in organic matter. No animal manure was applied in recent years. Locations ranged from Van Buren, Hillsdale, and Lenawee counties in the south to Mason, Isabella and Huron counties in the north. There was a total of 16 locations. Sulfur was broadcast as ammonium sulfate with the control receiving a similar amount of nitrogen as ammonium nitrate. All treatments were in addition to the farmers normal fertilizer program.

Averaged across 21 location-years, corn yields were not increased by applied sulfur (Table 4). Percent nitrogen in young plants was not increased and percent sulfur was essentially unchanged. In this same series, soybean, dry bean and oat yields were not increased by applied sulfur (Table 5).

1977-1985

Sulfur fertilizer application was evaluated at eight locations in 1981. Broadcast gypsum and ammonium sulfate were the sources used. Since there were no differences between sources the yields for both sources were averaged.

Corn yields were not increased by applied sulfur (Table 6). Dry bean and soybean yields were similarly not increased (Table 7).

In 1982, a survey was conducted to evaluate the sulfur status of Michigan soils by analyzing corn ear leaf tissue samples. There were 176 samples analyzed. Table 8 shows the ranges by county and Table 9 the number and percent of samples falling into selected ranges. All of the samples except one tested in the sufficiency range (0.16-0.20%). That sample was from Lapeer County. There have been no further problems with that field.

Sulfur was applied to forages at two locations between 1982-1984. There was no effect on yield or total nitrogen on an alfalfa-grass mixture (Table 10). On a pure alfalfa stand, there was a significant yield response in 1982, but not the next two years (Table 11). In an earlier study at two locations from 1979-1982, sulfur did not increase alfalfa yields. The yield level was 6.5 tons on a sandy loam soil and 9 tons on a loam soil.

Robertson and Vitosh (1974) and Grates (1982) reported poor relationships between soil test for sulfate-sulfur and crop yields or response to applied sulfur. Part of the problem lies with the laboratory methods for analyzing for sulfate-sulfur. Available sulfur may also be present below the surface 6-8 inches. Grates (1982) found that five of the six locations where samples were taken to 40 inches that sulfur concentration increased with depth. Warncke (unpublished data) also found that a significant number of samples with a low soil test in the surface had higher test levels in the subsoil.

1986-1998

There were three S rate studies conducted in this period of time, two on canola and one on wheat.

A sulfur study on canola was done on a Conover loam soil in 1991 and 1992. The results in Table 12 are averaged across three varieties and both years. While there is a trend of increasing the yield between the 0 and 90 Ib rate of 4.6 bu/acre, there was not a significant difference between the treatments.

The second study on canola was conducted in the Upper Peninsula on a Trenary sandy loam soil in both 1997 and 1998 and in Iron County in 1998. There was a significant yield response to 10 Ib S/acre in 1997 increasing the yield from 16.3 to 23.7 bu/acre (Table 13). In 1998 at this location, there was a significant yield response to 10 Ib S. However, the yield was very low and the results should be discounted. There was no response to applied S at the Iron County location (Table 13).

Wheat was grown at 4 locations in 1997 comparing 0 and 20 Ib S/acre. There was not a significant difference between the two treatments and the overall average show a trend to lower yield with the 20 Ib rate (Table 14).

Reductions of Sulfur Dioxide Emissions

Sulfur is added to soils from precipitation. Emissions from industrial operations have been reduced. The focal point of much of the sulfur dioxide emissions is the electrical generating industry. Data for 1980 and 1994 were summarized by Christenson (1996). In the U.S. emissions declined by 20 percent during that period. However, SO2 emissions from industrial sources represent 35 percent of the total global budget. Consequently, if this reduction represented the total reduction on a global basis the total S budget would be reduced by 7 percent.

Sulfur deposition is not distributed evenly across the landscape. Measurements on the ground are necessary to determine the amount added. No results from systematic studies were found which showed the amount received in Michigan. Therefore, we cannot make an assessment of the amount of S received from the atmosphere or any changes in the amount of S added to the soil.

Summary

In more than 50 location-year experiments there have been three cases where there was a significant response to applied S. One was on kidney beans grown on an acid soil and there was a similar response to a lime application. The second was on alfalfa grown on a loam soil and the response was in one of three years. Canola responded to applied S in a study on a sandy soil in the Upper Peninsula.

S in not recommended for application to field crops in Michigan because yield responses are inconsistent and rare. However, there is a continuing need for evaluation of response to this nutrient.

Christenson, D. R. 1985. Effect of applied sulfur on yield of alfalfa grass hay. Crop and Soil Sciences Newsletter 11 (120): 4-5. Michigan State University.
Christenson, D. R. 1996. Changes in sulfur dioxide emissions. Crop and Soil Sciences Newsletter. 22 (224): 2-3. Michigan State University.
Christenson, D. R. and J. Islieb. 1998. 1997 sulfur trials on wheat and canola. Crop Advisory Team alert. 13 (1): 3-4. Michigan State University
Cressman, H. K. and J. F. Davis. 1962. Sources of sulfur for crop plants in Michigan and effect of sulfur fertilization on plant growth and composition. Agron. J. 54:341-344.
Grates, A. M. 1982. The effect of supplemental sulfur applications on the yield and sulfur content of Michigan field crops. M.S. Thesis. Michigan State University
Jansen. K. A. and M. L. Vitosh. 1984. Effect of lime, sulfur and molybdenum on N2 fixation and yield of dark red kidney beans. Agron. J. 66:736-740.
Meints. V. W.. M. L. Vitosh, D. R. Christenson, L. S. Robertson and D. D. Warncke. 1982. Sulfur survey on corn leaves. 9th Michigan Seed, Weed and Fertilizer School Proceedings. Michigan State University.
Robertson, L. S., R. L. Cook and J. F. Davis. 1976. The Ferden Farm Report: Part II. Soil management for sugar beets 1940-1970. Midi. State Univ. Agri. Exp. Sta. Res. Rep.
Robertson, L. S. and M. L. Vitosh. 1974. Recent field research on crop yields as affected by supplemental sulfur. Mich. State Univ. Agri. Sta. Res. Rep. 265.
Tesar, M. B. and B. D. Knezek. 1985. PPI/FAR 1984 Michigan alfalfa report. Crop and Soil Sciences Department. Michigan State University

Table 1. Effect of applied sulfur on yield and protein content of several crops grown on a Hodunk loam soil, Ingham County, 1957-1960.a NS

Sulfur Rate	Oats (57) yield	Wheat yield	(58) protein	Alfalfa (59) yield	Alfafla protein	Corn (60) yield	Corn protein
lb/A	Bu/A	Bu/A	%	t/a	%	Bu/A	%
0	59	59	11.9	4.4	14.2	92	9.2
14	59	60	11.8	4.3	14.6	95	9.3
LSD (5%)	NS	NS	NS	NS	NS	NS	NS

[a]Agron. 1.54:341-344. 1962.

Table 2. Effect of applied sulfur on yield of soybeans grown on a Sims sandy clay loam soil, 1957-1961.a

Sulfur rate lb.A	Yield bu./A
0	36.9
16	36.0

[a] Michigan State University Agri. Exp. Sta. Res. Rep. 327. 1977.

Table 3. Yield and quality of sugar beets as affected by potassium chloride (0-0-60) and potassium sulfate added at the same rate of K on a Sims sandy clay loam soil, 1965-1966.a

Potassium Source	Yield	Sugar	Clear juice purity
	t/A	percent	
Potassium chloride	18.4	14.8	95.3
Potassium sulfate	18.4	14.8	94.9

Michigan State University Agri. Hxp. Sta. Res. Rep. 324. 1976.

Table 4. Average yields of corn grain and percent nitrogen and percent sulfur of corn plants for 21 location-year combinations in 1972 and 1973.a

Sulfur rate	Yield	N	S
lb/A	bu/A	Percent (%)	
0	121	3.73	0.12
40	118	3.69	0.13

[a]Michigan State University Agri. Exp. Sta. Res. Rep. 265. 1974.

Table 5. Effect of applied sulfur on yield of soybeans, navy beans, kidney beans and oats in 1972 and 1973.a

Sulfur rate	Soybeans[b]	Navy beans[b]	Kidney beans[b]	Oats
lb/A	Bu/A			
0	30.1	36.1	32.5	98.6
40	29.0	37.6	31.6	101.6

a Michigan State Univ. Agri. Exp. Sta. Res. Rep. 265. 1974.
b Average of two locations
c One location

Table 6. Effect of applied sulfur on yield of corn at four locations in 1981a
Sulfur Rate

Sulfur rate	Branch County	Jackson County	Saginaw County	Washtenaw County	Average
lb/A	Bu/A				
0	138	122	128	84	118
15	143	119	130	83	119
30	143	126	128	84	120
45	137	123	131	85	119
LSD (5%)	NS	NS	NS	NS	—

Grates. A. M.S. Thesis, Michigan State University, 1982.

Table 7. Yield of dry beans and soybeans at four locations in 1981.[a]

Sulfur rate	Navy beans	Craberry beans	Soybeans5
lb/A	Bu/A		
0	45	36	57
15	46	34	57
30	49	34	56
45	43	33	–
LSD (5%)	NS	NS	–

Grates, A. 1982. M.S. Thesis. Michigan State University. Average of two locations.

Table 8. Number of samples submitted by each of the counties participating in the 1982 S survey and the range in S content in samples from the county.[a]

County	Number of samples	S Range (% S)	County	Number of samples	S Range (% S)
Allegan	7	0.26–0.31	Lingston	2	0.22–0.25
Arenac	6	0.22–0.31	Mecosta	4	0.25
Barry	7	0.20–0.28	Menoominee	10	0.23–0.28
Branch	4	0.22–0.25	Missaukee	10	0.19–0.25
Calhoun	8	0.22–0.28	Monroe	9	0.21–0.38
Cass	10	0.21–0.27	Montcalm	10	0.25–0.30
Eaton	4	0.23–0.28	Muskegon	11	0.17–0.28
Gratiot	7	0.22–0.34	Newago	4	0.20–0.28
Ingham	5	0.22–0.31	Ottawa	3	0.27–0.28
Ionia	4	0.22–0.28	St. Joseph	11	0.20–0.30
Jackson	2	—	Saginaw	9	0.20–0.30
Kalamazoo	10	0.22–0.38	Sanilac	7	0.20–0.29
Kent	2	0.22–0.23	Shiawassee	8	0.22–0.26
Lapeer	10	0.13–0.32	Van Buren	3	0.22–0.28
Lenawee	2	0.20	Washtenaw	7	0.27–0.28

[a]Proceedings of Ninth Michigan Seed, Weed and Fertilizer School.

Table 9. Number of samples and percent of samples falling into selected ranges. [a]

Range (% S)	Number of samples	Percent of samples	Range (% S)	Number of samples	Percent of samples
Less than					
0.16%	1	0.5	0.28–0.29	21	11.9
0.16–0.17	1	0.5	0.30–0.31	6	3.4
0.18–0.19	1	0.5	0.32–0.33	2	1.1
0.20–0.21	12	6.8	0.34–0.35	2	1.1
0.22–0.23	45	25.6	0.36–0.37	0	0
0.24–0.25	49	27.8	0.38–0.40	2	1.1
0.26–0.27	34	19.3			

[a] Proceedings of Ninth Michigan Seed, Weed and Fertilizer School.

Table 10. Effect of applied sulfur on total yield for 5 cuttings and average total nitrogen content of alfalfa-grass hay, Barry County, 1983-1984. [a]

Sulfur rate lb/A	Yield t/A	otal nitrogen (%)
0	7.34	2.50
15	7.25	2.48
30	7.19	2.54
45	7.37	2.56

[a] Crop and Soil Newsletter, May 1985.

Table 11. Effect of applied sulfur on yield of alfalfa grown on a Conover loam soil in 1982, 1983 and 1984. [a]

Fertilizer rate					
P_2O_5	K_2O	S	1982	1983	1984
lb/A					
225	1600	0	6.59	6.45	6.35
225	1600	70	7.29	6.78	6.55
LSD (5%)			0.58	NS	NS

[a] Mimeo, Crop and Soil Sciences Department

Table 12. Effect of applied sulfur on yield and percent protein of canola grown on a Conover loam soil. Average of three varieties across two years. [a]

Sulfur rate	Yield	Protein
lb/A	bu/A	Percent
0	20.6	26.4
45	23.6	26.9
90	25.2	26.7
LSD (5%)	NS	NS

a Hamza, Ben. 1993. Ph.D. Thesis. Michigan State University.

Table 13. Effect of applied sulfur on yield of canola grown on a Trenary sandy loam and the Upper Peninsula Experiment Station (UPES) in 1997 and 1998 and in Iron County in 1998. [a]

Sulfur rate	UPES 1997 ab	UPES 1998 b	Iron Co. 1998
I	bu/A		
0	16.3	2.7	25.4
10	23.6	6.7	25.4
20	23.2	7.4	20.0
LSD (5%)	5.37	2.28	NS

[a] Crop Advisory Team Alert. 1998. 13(1). b Averaged across two varieties.

Table 14. Effect of applied sulfur on yield of wheat grown in 4 counties, 1997.[a]

Sulfur rate	Huron	Saginaw	Tuscola	Kalamazoo	Average
	bu/A				
0	116	80	85	90	93
20	111	80	78	86	89
LSD (5%)	NS	NS	NS	NS	_

[a] Crop Advisory Team Alert. 1998. 13(1). The soil types were Shebeon, Tappan, Londo and Kalamazoo for Huron, Saginaw, Tuscola and Kalamazoo counties, respectively.