SULFUR RESPONSES AND THE WISCONSIN ALFALFA SULFUR SURVEY [1/]

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Introduction

For more than 30 years, agronomists, soil scientists, consultants and farmers have recognized the potential for significant responses to applied sulfur fertilizer in northern and western Wisconsin on lighter textured, low organic matter soils that had not recently received manure (Rand et al., 1969; Hoeft and Walsh, 1975; Schulte, 1976; Peters and Kelling, 1987). More recently, crop consultants and others have reported seeing sulfur responses on soils or in locations where they typically were not be expected. In addition, Kelling and Speth (1998) measured a sulfur response of alfalfa in the final 2 years of a 4-year experiment at Arlington on a 3.8% organic matter soil, where S responses have traditionally not been observed.

Part of the reason S responses may be occurring more frequently is that precipitation S levels have been decreasing. From 1969 to 1987, precipitation S decreased an average of 42% across Wisconsin (Andraski and Bundy, 1989). Furthermore, a Wisconsin Department of Natural Resources estimate showed Wisconsin S emissions have declined another 40% from the mid-1980s to the mid-1990s.

In the early 1970s, Wisconsin started testing soils for SO_4-S based on the work of Hoeft et al. (1973). However, while this testing procedure determines the amount of sulfate-S in the plow layer of agricultural soils, it does not account for the several other sources of plant-available sulfur. That means that these tests are most useful in identifying crop production situations where the amount of plant available sulfur in the plow layer at the time of sampling is sufficient to supply crop sulfur needs, but they do not adequately determine if sulfur should be added if the test is low since adequate S may be coming from the other sources. In 1991, based on survey data collected by Schulte (1976) and Schulte and Combs (1990), the Wisconsin soil test recommendation program switched its procedures in an attempt to account for available S from other sources. This somewhat crude "expert system," called the Wisconsin sulfur availability index, includes estimates of precipitation S, manurial S, soil organic matter S, subsoil S, and measured soil SO_4-S. Over the past several years, we have attempted to answer some specific questions about better identification of sulfur need and improved S management on Wisconsin alfalfa.

<u>Question #1</u> — Is a high rate of sulfur needed to improve alfalfa yield and quality?

We have conducted a trial at Spooner (a sulfur-responsive site) over 4 years that examined the effects of topdressed sulfur rate and source on alfalfa yield and quality. Data from this experiment clearly show that topdressed elemental S is not available quickly enough the first year it is applied (Table 1); however, by the second season, enough of the elemental S had oxidized that it performed as well as the sulfate-S. These data also show little benefit to rates of S higher than 25 lb S/acre/year except when elemental S was used the first year.

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Table 1. Effect of topdressed sulfur rate and source on alfalfa yield and average tissue S levels, Spooner, WI, 1997 to 2000.

S treatment					
Source	Rate †	1997 ‡	1998	1999	2000
	lb S/acre/year				
		Dry matter yield (ton/acre)			
Check	0	0.74	4.08	4.33	3.30
Sulfate-S	25	0.97	4.27	5.09	3.74
	75	0.93	4.22	5.04	3.67
	225	1.03	4.28	5.25	3.85
Elemental S	25	0.66	4.40	4.96	3.43
	75	0.85	4.04	5.12	3.92
	225	0.95	4.37	4.96	3.76
		Tissue S level (%)			
Check	0	0.25	0.20	0.15	0.19
Sulfate-S	25	0.35	0.26	0.23	0.30
	75	0.35	0.27	0.25	0.30
	225	0.36	0.31	0.30	0.33
Elemental S	25	0.23	0.26	0.23	0.28
	75	0.28	0.31	0.26	0.34
	225	0.29	0.31	0.29	0.36

† Sulfur applied topdressed following first cutting each year.
‡ Only two cuttings taken in 1997 (seeding year).

Evaluation of the tissue analysis data (Table 1) shows that when deficiency existed alfalfa tissue S levels were generally less than 0.23% S and usually below 0.20; when S was sufficient, tissue levels were generally above 0.25%. It is also interesting to note that even where large amounts of S were added, levels in the plant did not escalate dramatically.

Table 2 shows the influence of these treatments on harvested forage quality as measured by NIR scanning. There is no question that the addition of S at this S-deficient site increased the forage protein content and there is a slight tendency for the higher sulfur rates to increase protein slightly (0.3 to 1.0%) above the lowest S rate. However, since it took an extra 200 lb S/acre to achieve this increase, the cost to benefit ratio is very poor. Fiber analysis results as summarized by the relative feed value were apparently not affected by S treatment at any rate. We conclude that adding extra S in an attempt to bump yields more or to significantly increase crop quality is not a viable practice. Sufficient S should be used to optimize yield (about 25 lb S/acre/year), but adding excess is not cost effective.

Table 2. Effect of topdressed sulfur rate and source on alfalfa crude protein content and forage relative feed value, Spooner, WI, 1998 – 2000. †

S treatment		1998		1999		2000	
Source	Rate †	CP‡	RFV	CP	RFV	CP	RFV
	lb S/acre/year	%		%		%	
Check	0	21.2	145	18.9	139	20.7	128
Sulfate-S	25	22.2	136	20.5	140	22.4	136
	75	22.4	142	20.6	145	21.9	127
	225	22.5	139	21.1	146	22.3	135
Elemental S	25	21.7	136	20.1	139	22.3	131
	75	22.2	139	20.7	145	23.1	140
	225	22.7	147	21.0	149	21.5	133

† Average across three cuttings each year.
‡ CP, crude protein; RFV, relative feed value.

<u>Question #2</u> — Can a preplant application of sulfur last for the entire life of the stand?

One of the components of the Spooner S work was to include several S sources (K_2SO_4, $CaSO_4$, and elemental S) as preplant treatments at a moderately high rate (75 lb S/acre). This was applied only once and the crop growth was monitored for the four following years (Table 3). Even on this quite sandy soil, it appears that all three sulfur sources were equally effective. Evaluation of the yield data for 1999 and the tissue data for 1999 and 2000 suggests that the SO_4-S sources may have been tapering off compared to elemental S, but the yield data for 2000 show that the sulfate carriers were as strong as elemental S in this year.

Based on these data, we conclude that a moderately high rate of S preplant is adequate to carry the crop for three or four seasons on a sandy loam soil where deficiencies are likely. Similar results were seen by Hoeft and Walsh (1975) in the early 1970s. On heavier soils, the lasting power of preplant S treatments would be even better.

Question #3 — Are older stands more likely to show S responses than younger stands?

In an actual farming situation, the answer to this question is likely "Yes" if the soils have a tendency toward being responsive and manure is not applied to the alfalfa. In this scenario, older stands would have a longer time since the last manure application and, therefore, would be more likely to show a response to fertilizer S. We also speculated that since alfalfa is such a high S user that several years of alfalfa growth might out-strip the organic matter S mineralization and precipitation contributions.

Table 3. Lasting power of a moderately high rate of several S sources for alfalfa at Spooner, WI, 1997 to 2000.

S source †	1997	1998	1999	2000
		Alfalfa yield (ton/acre)		
None	0.74	4.08	4.33	3.30
K_2SO_4	0.87	4.20	5.23	4.00
$CaSO_4$	0.87	4.04	5.01	3.96
Elemental S	0.91	4.39	5.48	3.79
		Tissue S (%)		
None	0.25	0.20	0.15	0.19
K_2SO_4	0.33	0.27	0.20	0.23
$CaSO_4$	0.34	0.28	0.21	0.23
Elemental S	0.25	0.26	0.24	0.28

† All S sources applied at 75 lb S/acre preplant spring 1997.

To test these hypotheses, we selected alfalfa fields established in 1998 or 1999 that had not received manure in the last 3 to 5 years at the Arlington and Lancaster Agricultural Research Stations as well as a field in its third year of production at each location. Duplicate experiments were laid out using several treatments of topdressed S. In spite of the results we obtained at Arlington in the mid-1990s where we saw a sulfur response in the last 2 years of a 4-year trial (Kelling and Speth, 1998), the data from these trials (Table 4) show only slight yield responses to S and it is clearly not stand- age related. The forage quality data are also quite mixed.

Table 4. Effect of stand age on alfalfa yield and forage quality, Arlington and Lancaster, WI, 1999 – 2001.

Treatment			Newer stand			Older stand		
Source	N rate	S rate	Yield†	CP ‡	RFV‡	Yield	CP	RFV
	----- lb/acre ----		ton/acre	%		ton/acre	%	
				Arlington				
None	0	0	3.00	21.3	153	2.72	22.4	160
Gyp	0	48	3.08	20.7	142	2.72	22.7	163
AS	42	48	3.07	20.9	143	2.77	22.3	163
Gyp+AN	42	48	3.15	21.1	149	2.81	22.8	160
				Lancaster				
None	0	0	3.45	21.4	133	3.22	19.8	125
Gyp	0	48	3.68	22.1	140	3.06	20.2	130
AS	42	48	3.30	22.0	141	3.54	19.5	120
Gyp+AN	42	48	3.37	22.0	141	3.23	20.3	126

† Average from two cuts in 1999 and three cuts in 2000 and 2002 at Arlington and three cuts in 2000 and 2001 at Lancaster.

‡ CP, crude protein; RFV, relative feed value.

Question #4 — Are we more likely to need S fertilizer in southern and eastern Wisconsin than we were a few years ago?

To answer this question, in addition to the stand age trials we are conducting, we received help from three county faculty to conduct on-farm trials in Manitowoc in 1999 and 2000 and in Dodge and Fond du Lac counties in 2000 and 2001. Table 5 shows that yield responses were observed at all locations except Fond du Lac in 2001. It is interesting to note that when field responses were seen, the increases were mostly during first cut, sometimes second, but only occasionally for third and fourth cuts. Magnitudes of the responses were similar to those frequently seen at other responsive locations (0.2 to 0.7 ton/acre/year). These responses are noteworthy because these counties are in the eastern and southeastern part of the state where S responses have been less frequent.

The ICP tissue analysis for these trials show that, where yield responses were seen, control S concentrations were generally below 0.21 to 0.23%, whereas at the one non-responsive site, values were above 0.25%. Sulfur treatment had few other consistent or meaningful impacts on tissue levels of other nutrients. The forage quality analysis illustrates that while S addition, when deficiency existed, can increase protein content, it had little effect on other quality parameters (data not shown).

For the final assessment, we asked crop consultants, county faculty, and industry agronomists to collect alfalfa tissue and soil samples from fields that had not received sulfur fertilizer or manure for the past 2 to 3 years. Fifty-three sites were included in the survey in 2000 and another 82 sites in 2001. In addition, we asked the laboratories doing plant analysis in Wisconsin to provide us with all of the routine alfalfa plant analysis reports for the 1998–2001 period; this has generated an additional 60 samples. Of the samples collected to date, 46 of the 185 showed tissue S levels of less than 0.23% S (interpreted as deficient) and another 24 contained 0.23 or 0.24% S (interpreted as low). The map in Figure 1 shows the number of samples from each county and the number with less than 0.25% S.

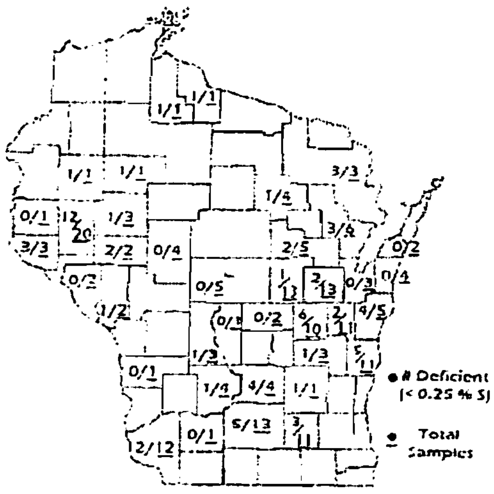

Figure 1. Alfalfa tissue samples testing < 0.25% S in 2000–2001. Total number of samples from each county is underlined.

Table 5. Effect of sulfur on alfalfa yields at several on-farm locations, 1999–2001.

S rate	Yield				
	Cut 1	Cut 2	Cut 3	Cut 4	Total
lb S/acre	ton/acre				
			Manitowoc 1999		
0	--	1.38	1.34	0.56	3.28
25	--	1.48	1.20	0.55	3.23
50	--	1.80	1.34	0.70	3.83
Pr > F		0.15	0.65	0.17	0.08
$LSD_{0.05}$		0.49	NS†	0.19	0.58
			Manitowoc 2000		
0	1.44	1.09	0.72	0.82	4.08
25	1.92	1.21	0.66	0.70	4.48
50	2.61	1.02	0.58	0.70	4.91
Pr > F	0.02	0.07	0.46	0.22	0.06
$LSD_{0.05}$	0.70	0.15	NS	NS	0.66
			Dodge 2000		
0	2.00	1.78	1.33	--	5.11
50	2.12	1.78	1.37	--	5.27
Pr > F	<0.01	0.93	0.47	--	0.15
$LSD_{0.05}$	0.07	NS	NS	--	0.24
			Dodge 2001		
0	2.15	0.45	1.11	--	3.70
50	2.22	0.45	1.81	--	4.08
Pr > F	0.48	0.50	<0.01	--	0.02
$LSD_{0.05}$	NS	NS	NS	--	0.31
			Fond du Lac 2000		
0	1.65	1.85	1.26	--	4.75
25	1.89	2.00	1.47	--	5.36
Pr > F	<0.01	0.01	0.05	--	<0.01
$LSD_{0.05}$	0.12	0.11	0.21	--	0.05
			Fond du Lac 2001		
0	2.16	2.04	1.36	--	5.56
25	2.28	2.03	1.37	--	5.68
Pr > F	0.15	0.91	0.86	--	0.45
$LSD_{0.05}$	0.17	NS	NS	--	NS

† NS, not significant.

Collectively these data suggest that the potential for S responses is higher in southern and eastern Wisconsin than it was a few years ago. On soils where manure or S fertilizer have not been applied for 2 or 3 years, where soil organic matter is less than 3%, where a high S-demanding crop is being grown, and where there is a tendency toward sandiness, there appears to be some potential for sulfur responses. In general, the sulfur availability index appears to work very well in that values below 30 to 32 indicate a clear S need and high potential for response and values above 40 are very likely unresponsive. As has been our recommendation in the past, any uncertainty about the need for sulfur can be addressed by doing plant tissue analysis. It is an excellent confirmation tool.

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