ADVANTAGES OF SULFUR IN STARTER FERTILIZER

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Sulfur application in the past has been targeted to alfalfa, corn, canola, and small grains. Normally the yield or growth response has occurred when responsive crops are grown on sandy soils or eroded knobs with a silt loam texture. The soil test for S has not been reliable for predicting S needs on soils that are not sandy in texture. Minnesota currently uses texture to base S recommendations.

Today sulfur needs may have changed. Some of the reasons for this is a greater occurrence of reduced tillage systems and less sulfur dioxide in the atmosphere. Ninety-five percent of the sulfur in the soil is found in the organic matter. The rest comes from sources such as the atmosphere and irrigation water.

Since organic matter is the major source of sulfur, then mineralization of the sulfur from organic matter is important. The mineralization process is a microbial process governed by soil moisture and temperature. This means the soil conditions early in the growing season are very important for supply of sulfur. Mineralization of sulfur from organic matter can be variable. The variability in mineralization of sulfur in Minnesota soils from a laboratory incubation study is presented in Table 1. Mineralization can vary from 1.8 pounds S per acre to 22.6 pounds S per acre. These differences are caused by differences in texture and organic matter. If you calculate the number of pounds of S mineralized for each % organic matter, the amount varied from 1.5 to 8.4 pounds S per % organic matter. This is quite variable.

Table 1. Sulfur mineralized in Minnesota soils, O Leary and Rehm.

County	Texture	OM	Int. S	12 wk S	Change
		%	ppm	ppm	lb S/acre
Wad	sl	1.2	2.1	3.0	1.8
Good	sil	1.6	3.7	7.1	6.8
Good	sil	2.4	6.2	11.7	11.0
Wab	sil	2.7	6/3	17.6	22.6

Atmospheric deposition of S has been noted as a source for crop production. Because of the reduction of S additions to the atmosphere by industrial emissions, the amount of S deposited has been reduced significantly. In Table 2, S reductions have ranged from 75% in Michigan to 42% in Wooster, Ohio.

Table 2. Changes in atmospheric sulfur deposition for three Midwest locations from 1979 to 2000.

Location	Initial year	2000	Change
	pounds S per acre		%
Kalamazoo, MI (1979)	27.5	6.8	-75
Wooster, OH (1979)	31.0	17.9	-42
Lamberton, MN (1979)	15.8	5.5	-65

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With the reduction in atmospheric S, there has been a concern that the plant needs supplemental S for optimum production. Some choices for S fertilizers include: elemental S, Sulfur clay mixes (90% elemental S), ammonium sulfate (21-0-0-24), ammonium thiosulfate (12-0-0-26) a liquid, and K-Mag (22% S) which is good for alfalfa and corn because of the 22 % K_2O. Sulfur can also be supplied by manure. Table 3 provides some S values from manure reported by Iowa State University.

Table 3. Average sulfur values for dry and liquid dairy and swine manure (Source: Iowa State University).

	Dry		Liquid	
Source	lb S per ton		lb S per 1,000 gal.	
Dairy	1.5	0.8	4.2	2.8
Swine	2.7	1.5	7.6	4.2

Research in Minnesota has shown soybean grain yields do not respond to the addition of S (Table 4). In a study with broadcast applied S rates of 0, 25, and 50 lb per acre and two forms, sulfate and elemental S, there was no significant difference in soybean yield.

Table 4. Soybean grain yield response to sulfur rate and form in Minnesota.

S rate	S source	Soybean grain yield
lb per acre		bushel per acre
0	--	38
25	Sulfate	37
25	Elemental S	38
50	Sulfate	38
50	Elemental S	36

Alfalfa in the past has been more responsive to S. These yield responses have occurred on sandy textured soils or in fields with eroded knobs. The reduction of organic matter because of erosion has played a role in whether or not a yield response occurs. The effect of soil texture and S rate on alfalfa yield response to S is reported in Table 5. The sandy soil had a large yield response to broadcast application of S while the silt loam did not.

Table 5. Alfalfa yield response to a broadcast application on sandy loam and silt loam soils in Minnesota.

S rate	Sandy loam	Silt loam
lb S per acre	--- ton dry matter per acre ---	
0	2.6	5.2
25	4.5	5.4
50	4.6	5.0
100	4.7	5.3

Yield responses to corn are dependent on several factors. Soil texture and organic matter are the most important. Corn yields were increased with the broadcast application of S on a loamy fine sand while yields were not affected on the silty clay loam soil, Table 6. Soil test S does not predict when the yield response to S will occur (Table 7). The soil with the greater soil test S value had a corn grain yield response to S application while the site with the lesser soil test S value did not.

Table 6. The effect of soil texture on corn grain yield response to S application in Minnesota.

Soil texture	No S	25 lb S per acre
	Corn grain yield (bushels per acre)	
silty clay loam	132	128
loamy fine sand	168	177

Table 7. The effect of soil test S and organic matter on corn grain yield response to S in Minnesota.

S rate	Goodhue Co.	Wabasha Co.
lb per acre	Corn grain yield (bushel per acre)	
0	155	169
10	169	170
40	169	174
Organic matter, %	1.6	2.7
Sulfate-S, ppm	9.0	6.0

Reduced tillage systems such as ridge-till and fertilizer placement can affect the response of corn grain yield to S. On a silt loam soil in Winona County Minnesota, corn grain yields were increased with a 2 x 2 or seed placement of S in a ridge-till system (Table 8). The check grain yield was 152 bushels per acre. The addition of 6 and 18 lb S per acre increased grain yields. The use of seed placement produced greater grain yields in this study compared to a 2X2 placement. This site was part of a six site study that included sandy and loamy textured soils. Five of the six sites had corn yields increased by the application of S. Plant stand was measured in these studies. When the S was applied directly on the seed at planting, plant populations were reduced on the dry sandy soils at the 12 and 18 pounds S per acre application rates. This reduction was most severe with the ammonium thiosulfate sources when compared to ammonium sulfate. This decrease in plant population was not measured in the heavier textured soils. Plant populations were not decrease by either S form when applied 2 inches to the side and 2 inches below the seed at planting.

Table 8. The effect of S rate and placement on corn grain yields in ridge-till system for a Minnesota silt loam soil.

P	S rate, lb S per acre	
Placement	6	18
	------ Corn grain yield (bushel per acre) -----	
2X2	159	178
Seed	164	183
Control = 152 bushels per acre, ridge-till, silt loam		

In recent years, there have been reports of corn yield responses to S application on heavy textured soils in Minnesota (Table 9). This occurred at the Southern Research and Outreach Center in 2004 and 2006. The S was applied as a seed placed starter. These reports have lead to other studies to understand the extent of the possible responses.

Table 9. Corn grain yield response to seed placed S on a heavy textured soil at Waseca, Minnesota, Randall and Vetch.

Treatment	2004	2005	2006	Mean
	----------- Corn grain yield (bushel per acre) -----------			
-S	192	167	207	188
+S	197	165	227	196

In 2007, a series of S strip studies were conducted across southern Minnesota on heavy textured soils. Soil test S ranged from 4 to 12 ppm while the organic matter ranged from 4.4 to 7.6 % (Table 10). The S was applied with the seed as a liquid at 5 of the 6 sites and as elemental S 2 inches below and two inches to the side of the seed at the sixth site. The amount of S applied ranged from 1.9 to 12 pounds S per acre. The strips were replicated 3, 4, or 6 times at each site. Plant populations and corn grain yields were measured. Plant population was only significant reduced at one location, YM-S (Table 11). At this site 2 gallons per acre of ammonium thiosulfate was applied. The soil was drier than normal at planting time and may have caused this small reduction. Corn grain yields were not increased at any sites in this study, Table 12. Corn grain yield were decreased significantly at the YM-S site. This decrease may have been caused by the plant population decrease.

Table 10. Soil test values for the seed placed S on heavy textured soils in Southern Minnesota trial, 2007, Lamb et al.

Property	Olm	Meek	Free	Wat	YM-A	YM-S
pH	6.4	7.2	5.4	7.8	6.9	7.7
P*	23	28	32	14	30	23
K*	122	208	149	191	165	180
OM, %	-	7.6	5.7	5.7	4.4	4.6
S †	4	11	5	12	5	7

† Values for P, K, and S are in ppm.

Table 11. Corn populations as affected by seed placed S on heavy textured soils in Southern Minnesota, 2007, Lamb et al.

	Olm †	Meek	Free	Wat	YM-A	YM-S
	---------------- Corn population (plants per acre) ---------------					
No S	25047	22700	31444	29261	29092	31872
S	28241	22900	32222	29123	28529	31186
lb S/A	12	5.7	3.7	1.9	5.7	5.7

† Olmsted was 2 x 2 placement of elemental S. The rest were liquids placed on seed.

Table 12. Corn grain yield response to seed placed S on heavy textured soils in Southern Minnesota, 2007, Lamb et al.

	Olm †	Meek	Free	Wat	YM-A	YM-S
	---------------- Corn grain yield (bushel per acre) ---------------					
No S	192	123	177	177	118	179
S	191	125	171	173	119	174
lb S/A	12	5.7	3.7	1.9	5.7	5.7

† Olmsted was 2 x 2 placement of elemental S. The rest were liquids placed on seed.

Thinking about Changes

1. Less atmospheric S deposition is occurring
2. Reduced tillage systems are being used more and thus less early season mineralization.
3. Response with alfalfa and corn is occurring on sandy textured soils and eroded soils.
4. We have observed significant corn yield responses on heavy textured soils at the Southern Research and Outreach Center in Minnesota
5. We have observed no corn yield responses at six heavy textured sites in Southern Minnesota in 2007.

Suggestions for Future S Guidelines

1. Soil texture is till a major consideration
2. Don't use the S soil test as a guide.
3. There is a good probability for S need when corn is planted with conservation tillage on low organic matter soils.
4. If soil texture is sandy or soil moisture is dry, do not apply S with corn seed.