Sulfur Emerges as a Nutritional Issue in Iowa Alfalfa Production

By John Sawyer, Brian Lang, and Daniel Barker

Sulfur is often classified as a "secondary" essential element, mainly due to a smaller plant requirement, but also because it is less frequently applied as a fertilizer compared to N, P, and K. This has certainly been the case in Iowa, where research had not documented S deficiency or fertilization need for optimal crop production. However, if deficient, S can have a dramatic effect on plant growth and crop productivity – more than the classification "secondary" would imply.

In Iowa, over 40 years of field research (before 2005) conducted at many locations across the state had measured a yield response to S application only three times out of approximately 200 trials with corn and soybean – an indication of adequate available S supply and quite limited S deficiency. This began to change in the early 2000s as producers in northeast Iowa began to notice yellow plant foliage and reduced growth in areas of alfalfa fields. After investigating several potential reasons, such as plant disease, demonstration of S fertilizer application documented improved coloration and growth of alfalfa in affected areas (example in **Figure 1**).

Figure 1. Alfalfa plant growth with and without S application, showing S deficiency symptoms of plant yellowing and poor growth in the non-S treated check.

Alfalfa Response to Sulfur Fertilization

The observations of poor alfalfa growth and production led to research trials at several northeast Iowa fields in 2005 where 40 lb S/A was applied as ammonium sulfate (AmS) and calcium sulfate (gypsum) in replicated plots and compared to a non-S treated control. The S fertilizers were applied after the first alfalfa cutting and before re-growth, and in paired locations in established alfalfa that had exhibited poor growth/coloration and alfalfa that appeared normal in growth and coloration. The alfalfa yields from those trials (**Table 1**) documented large increases from the S application in the poor growth areas and no increases in the good growth areas. This yield response was also measured in the first cutting of the second year.

Subsequent research was conducted with established alfalfa at multiple locations in northeast Iowa to study response to S rate (**Tables 2 and 3**). Four of six sites had a yield increase to S application, with the maximum dry matter increase occurring at 12 to 29 lb S/A. Most importantly, the S concentration in the plant tissue (6-in. plant top collected before cutting) indicated a critical concentration similar to that found in other research, 0.25% S. Combining data from all alfalfa research trials indicated a low to no increase in alfalfa dry matter when the tissue concentration (top 6-in. of growth) was greater than approximately 0.22 to 0.25% S (**Figure 2**). At the current price of alfalfa and S fertilizers, the economic breakeven point would be near 0.23% S. The same success (indicating S deficiency) was not found with the soil sulfate-S (SO_4-S) test of samples from the top 6-in. of soil (calcium phosphate extractant). Examples of this can be seen in **Tables 1, 2, and 3** where the responsiveness of a site was not related to soil SO_4-S concentration.

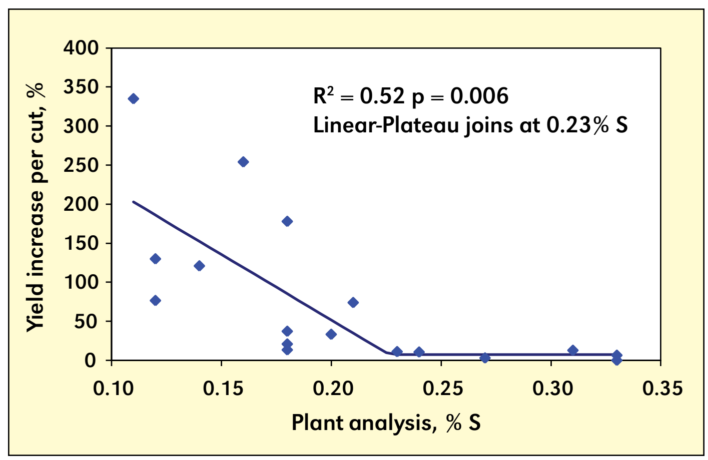

Figure 2. Yield increase per cut from S fertilization relative to the alfalfa plant tissue S concentration, 6-in. plant top with no S applied.

This research documented S deficiency problems in northeast Iowa alfalfa production fields. The majority of S deficiencies tended to occur in areas within fields, not entire fields. However, that non-uniformity can account for large economic losses on a field scale. Most of the soils involved are lower organic matter, side-slope position, silt loam soils. However, alfalfa grown on other soils has also responded to S fertilization. Need for S application was not present in all fields. For example, fields receiving livestock manure have no symptoms of S deficiency. If S deficiency is confirmed in alfalfa (through plant tissue analysis or field response trial), the amount of S fertilizer recommended is 20 to 30 lb S/A. Where deficiencies occurred in the 2006 rate trials, the first 15 lb S/A gave the largest incremental increase in yield, but the next 10 to 15 lb S/A was profitable at most sites. Also, S fertilizers do not need to be applied each year as alfalfa will respond to S applied in a prior year.

Abbreviations: S = sulfur; N = nitrogen; P = phosphorus; K = potassium; ppm = parts per million; OM = organic matter; $CaSO_4 \cdot H_2O$ = calcium sulfate (gypsum); $(NH_4)_2SO_4$ = ammonium sulfate (AmS).

Table 1. Alfalfa forage yield, plant S analysis, and harvest S removal with S fertilizer application in field areas with observed poor and good plant coloration/growth.

Sulfur application[¶]	2005[†] Cuts 2+3 Dry matter yield: Poor	Good	2005[†] Cut 2 Plant top S[§]: Poor	Good	2005[†] Cuts 2+3 S removal: Poor	Good	2006[‡] Cut 1 Dry matter yield: Poor	Good
	---- ton/A ----		----- % S -----		---- lb S/A ----		---- ton/A ----	
None	1.18d[#]	2.99ab	0.14d	0.22c	2.8e	10.6d	1.10b	2.04a
AmS	2.76bc	3.26a	0.40a	0.35b	16.5bc	18.2ab	2.18a	2.22a
Gypsum	2.49c	3.21a	0.41a	0.37b	15.3c	18.1ab	2.14a	2.19a

[†] Across three field sites in 2005: Elgin (Fayette silt loam), Gunder (Fayette silt loam), and West Union (Downs silt loam), Iowa. Extractable SO_4-S soil test and soil OM for the poor and good areas, respectively: soil SO_4-S – Elgin, 6 and 7 ppm; Gunder, 7 and 8 ppm; West Union, 6 and 7 ppm; and OM – Elgin, 2.3 and 2.3%; Gunder, 2.7 and 2.9%; and West Union, 2.3 and 2.6%.
[‡] Across two field sites in 2006 (S application in 2005): Elgin and Gunder, Iowa.
[§] Sulfur concentration for 6-in. plant tops collected before second cut.
[¶] Sulfur (AmS and gypsum) applied at 40 lb S/A after the first cut in 2005.
[#] Means followed by the same letter are not significantly different, $p \leq 0.10$.

Summary

This research indicates a change in need for S fertilization of alfalfa, especially in northeast Iowa and the associated soils. However, research also shows that alfalfa does not respond to S application in all fields or field areas. BC

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Table 2. Alfalfa plant tissue S concentration and site characteristics, 2006.

Sulfur rate[†], lb S/A	Wadena	Waucoma[‡]	Nashua	Waukon	West Union	Lawler
	% S[§]					
0	0.14	0.21	0.33	0.18	0.18	0.27
15	0.20	0.30	0.35	0.29	0.24	0.36
30	0.30	0.43	0.34	0.40	0.29	0.39
45	0.39	0.36	0.37	0.41	0.28	0.37
Soil SO_4-S, ppm[¶]	7	3	7	1	6	3
Soil OM, %[¶]	3.1	2.1	4.2	3.8	3.3	2.6
Soil type	Fayette silt loam	Wapsie loam	Clyde-Floyd loam	Fayette silt loam	Fayette silt loam	Ostrander loam

[†] Sulfur applied as gypsum in April at Nashua and in May at other sites.
[‡] Waucoma site had 10 lb of elemental S applied in the spring across the entire field.
[§] Sulfur concentration for 6-in. plant tops collected before second cut.
[¶] Soil samples collected after first cut, 0 to 6-in. depth.

Table 3. Alfalfa total dry matter for harvests collected in 2006.

Sulfur rate[†], lb S/A	Wadena	Waucoma[‡]	Nashua	Waukon	West Union	Lawler
	ton/A					
0	1.32	1.85	6.73	1.39	0.78	2.14
15	2.59	3.06	6.98	2.97	1.05	2.11
30	2.76	3.14	6.85	3.33	1.07	2.11
45	2.92	3.24	7.14	3.58	1.07	2.07
Statistics[§]	*	*	NS	*	*	NS
Max rate, lb S/A[¶]	25	22	0	29	12	0
Cut harvested	2+3	2+3	1+2+3+4	2+3	3	2+4

[†] Sulfur applied as gypsum in April at Nashua and in May at other sites.
[‡] Waucoma site had 10 lb of elemental S applied in spring across the entire field.
[§] Indicates statistically significant (*) or non-significant (NS) yield response to S rate, $p \leq 0.10$.
[¶] Applied S rate at the maximum dry matter yield response.

Suggestions for Managing S Applications in Alfalfa

- The S concentration in tissue samples from the top 6 in. of plants at the early bud stage is a good indicator of S deficiency and need for S application. Concentrations less than 0.23% S should be considered deficient and S applied, with concentrations of 0.23 to 0.25% S considered marginal.
- The extractable SO_4-S concentration in the 0 to 6-in. soil depth is not reliable for indicating potential S deficiency or need for S application.
- For confirmed S-deficient alfalfa fields, apply 20 to 30 lb S/A. Sulfur fertilizers do not need to be applied each year as alfalfa will respond to S applied in a prior year. Therefore, it is possible to apply the crop needs for multiple years in one application. That rate will be more than is needed for just one year, and some luxury uptake is possible. Since SO_4^{2-} forms of S fertilizers are immediately available for plant uptake, they can be applied after any cutting. Good yield response has been measured with applications in-season, even in dry periods. This flexibility allows for rapid correction of S deficiencies found through plant analysis. Elemental S, since it must be oxidized to the SO_4^{2-} form, should be applied some time ahead of crop need or at seeding.
- Manure is a good source of S, and eliminates the need for S fertilizer application.
- Common soil conditions where S deficiency has been found include low organic matter soils, side-slope landscape position, eroded soils, and coarse-textured soils.
- Work with alfalfa clearly showed differential response in poor and good coloration/growth areas within fields, indicating that whole fields would not respond to S application. However, it is likely most prudent to simply fertilize entire fields when deficiency exists rather than attempt site-specific applications because 1) S fertilization is relatively low cost, 2) many fields indicate considerable areas with S deficiency, 3) large yield increases have been observed with S application, and 4) there is a need to take plant tissue samples to determine S deficiency.