Fine tuning sulfur guidelines for alfalfa

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Introduction

Alfalfa is grown on nearly 1 million acres and is an important forage crop for dairy, beef, sheep, and horse industries.in Minnesota. As a perennial deep-rooted crop, alfalfa improves soil quality and contributes N to subsequent crops in rotations. Alfalfa has a high demand for sulfur. Sulfur deficiencies have been reported in alfalfa in fields with low organic matter concentration which may not mineralize sufficient sulfur to match crop demand. Sulfur has been noted to impact both forage yield and quality and sulfur application has been increasing for alfalfa as well as other crops. There have been few small trials focused on comparing various sulfur products for alfalfa in Minnesota in the last ten years. Current sulfur guidelines suggest 25 lbs of S be applied on sandy soils and 15 to 25 lbs of S be applied to medium and fine textured soils with soil organic matter concentration less than 3.0%. The sandy soil guidelines are old and have not been validated by current research and the guidelines for the medium to fine textured soil are based on data from corn or alfalfa data generated from neighboring states. Past research on sources has been inconclusive whether there are differences between sulfate and elemental sulfur fertilizer sources. Longer term research may be needed to better evaluate sources due to a slower availability of sulfur from elemental sulfur due to the slow oxidation of the material. With the high demand for S by alfalfa, more research is needed on rates and sulfur sources to fine tune guidelines to ensure forage yield and quality of alfalfa is not limited.

Objectives

1. Identify the optimum rate of sulfur for maximizing alfalfa forage yield and quality
2. Compare sulfate- and elemental sulfur fertilizer sources applied annually for an alfalfa production system.

Materials and Methods

Alfalfa trials were established at Rosemount and Morris in 2020 with the purpose of evaluating alfalfa sulfur response over four years (location information is given in Table 1). Poor stand establishment at Morris required the trial to be seeded again in Fall 2020. The current plan is to use the original Morris site seeded in Spring 2020 if possible. If alfalfa growth at Morris is poor in spring of 2021 the current site will be abandoned and new treatments will be applied which will re-start the 4-year growing cycle.

Treatments applied are a combination of sulfur source and rate utilizing a split plot design. Sulfur sources include no sulfur (control), potassium sulfate, and potash MST (potash combined with elemental sulfur in every granule ~ 14%S). Sulfur application rates are 10, 20, and 30 lbs S. Sulfur sources were grouped together in main plots for by S application rate. Sulfur was applied before seeding in 2020 and then will be applied after the first cutting in 2021, 2022, and 2023.

An additional treatment block was included where a high rate of S (120 lbs S) was applied at the initial treatment application in spring 2020 and will not be re-applied over the duration of the trial. The high rate block include three sources, potassium sulfate and potash MST used in the rate treatments plus Tiger 90 which is common elemental sulfur product containing 90% S (the no S control was not included in the high rate block). The high rate treatments will determine how much elemental S is released over time to potentially determine 1st and 2nd year availability of the product and how long sulfate-S will remain in the soil. A high rate of P was applied the first year of the study to increase soil test P allowing for smaller maintenance rates of P to be applied over time. Fertilizer K will be applied yearly to balance K rates applied across all treatments.

Starting in 2020 and for three additional years, we will intensively management alfalfa and harvest at bud-early flower stages of maturity resulting in three to four cuttings per year. No fall cutting will occur. Each spring and fall we will measure alfalfa populations. At each cutting we will measure alfalfa yield, forage quality (crude protein, NDF, digestibility using NIRS), maturity, and total S concentration. Conducting the studies on the same fields multiple years will be advantageous as we should be able to draw sulfur concentrations down over time hopefully seeing larger yield responses in future years as sulfur is depleted in the soil. Plots will be 12’ wide by 20’ long. Initial soil samples will be collected by rep at 0-6, 6-12” prior to treatment application and 0-24” in fall prior to, or after, the last cutting.

Table 1. Soil series information planted crop at each location, and initial potassium soil test data from new alfalfa seedings in 2020. Soil test data was collected prior to initial treatment application.

	Soil Test				SO_4-S		
Location	Bray-P1	K	pH	OM	0-6”	6-24”	Soil Series
	---ppm---			%	---ppm---		
Morris	33	171	7.3	4.7	8.4	5.8	Aazdahl-Formdale-Balaton
Rosemount	9	115	6.8	3.7	5.2	3.1	Tallula silt loam

† K, Soil test potassium (K-ammonium acetate).

Table 2. Summary of cultural practices for studies conducted in 2020.

Year	Location	Cultivar†	Date of Spring Fert.	Date of Planting	Date of Harvest
2020	Rosemount	P 55VR08-N221	23-Apr.	6-May	25-Aug

† Dk, Dekalb.

‡ Fall fertilizer (fert.) was applied the fall the previous year in which the study was harvested.

Results and Discussion

Location Characteristics

Initial soil test data and soil series information is given in Table 1. Information is given for the location at Morris which fertilizer was applied but the alfalfa seeded did not grow due to lack of moisture. Alfalfa was re-seeded at Morris in the Fall of 2020. We are in the process of determining whether to use the existing trial area or establish a new area in Spring 2021. Plots were established at Rosemount in spring 2020. There were two cutting at Rosemount. The first cutting yield data were not measured due volunteer wheat from the previous year and leaf hopper damage. Yield data was collected from the second cutting. A third cutting was not taken to limit stress on the crop for overwintering.

Table 3. Summary of ANOVA analysis for measured agronomic variables for data collected at Rosemount in 2020.

Main Effect	Cut 2 Yield	Cut 2 %S	Cut 2 S Removal	Cut 2 Protein	Cut 2 ADF	Cut 2 NDF
	-------------------------------------			*P*>F		-------------------------------------
				Rosemount		
S rate	0.76	*	0.06	0.61	0.72	0.64
S Source	0.10	***	***	0.34	0.51	0.50
Srt.xSource	0.82	0.40	0.48	0.83	0.84	0.80

Asterisks denote significance at the 0.05 (*), 0.01 (**), and 0,001 (***) probability levels.

Table 4. Summary of sulfur source and rate effects on alfalfa yield at Rosemount from the second cutting.

Location	S Rate (lb/ac)	Sulfur Source: Control	K_2SO_4	K-MST	Tiger 90	Rate Avg
		--------------------pounds per acre--------------------				
Rosemount	10	2747	3052	2818	--	3197
	20	2743	3096	2839	--	3153
	30	2744	2822	2950	--	3091
	120	--	2635	2200	2740	
	Source Avg.[1]	3092b	3265a	3084b	--	

Summary statistics for measured parameters for Rosemount cut 2 are given in Table 3. Alfalfa yield as affected by sulfur source, but not by sulfur rate, for the second cutting at Rosemount (Table 4. Average yield was greatest with the sulfate S and yield was not increased with MST compared to the no-sulfur control.

Data for the high fertilizer rates and for the Tiger 90 treatment are included in Table 4 as well as the following tables but was not included as part of the data analysis. For this report I only included an analysis of the three main sources applied at 10, 20, and 30 lbs of S. What is interesting is the numerical values were much less for the high fertilizer rates. This may indicate some phytotoxic impact of the high rate limiting yield. The high rate was a one-time application made in year 1 and will not be applied in subsequent years. I was curious whether the high rate of K needed to balance K across treatments would limit yield. Since the same rate of K was applied as KCl across most rates it is unlikely that any negative impacts were due to KCl. In fact, the only treatment which did not receive KCl was the 120 lb K-sulfate treatment. The lack of a difference among the sulfur rates does indicate that the 10 lb rate was sufficient supplying all sulfur needed by alfalfa in year 1.

Table 5. Sulfur source and rate impacts on forage total sulfur concentration from cut 2 at Rosemount in 2020.

Location	S Rate (lb/ac)	Sulfur Source: Control	K_2SO_4	K-MST	Tiger 90	Rate Avg
		--------------------% S--------------------				
Rosemount	10	0.17	0.19	0.21	--	0.19b
	20	0.19	0.21	0.25	--	0.22b
	30	0.19	0.27	0.28	--	0.25a
	120	--	0.32	0.36	0.22	
	Source Avg.[1]	0.18c	0.25b	0.28a	--	

Forage total sulfur concentration data are listed in Table 5 and total sulfur uptake is given in Table 5. In both cases, sulfur source and sulfur rate significantly differed while the source by rate interaction was not significant. In both cases there was no different between the 10 and 20 lb rate while the 30 lb sulfur rate sulfur concentration and uptake was significantly greater than the two lower rates. Source effects were not the same considering total sulfur concentration versus sulfur uptake. In fact, the MST treatment produced the greatest concentration of sulfur in forage followed by sulfate and lastly the control. However, sulfur uptake was similar for MST compared to sulfate S which results from the combination of greater tonnage and lower sulfur concentration with sulfate versus lower tonnage and greater S concentration with MST. Again the 120 lb application rates were not included in the data analysis even though tissue sulfur concentration appeared to increase while there did not appear to be an increase in tissue sulfur concentration when the high rate of S was applied as Tiger 90.

Table 6. Sulfur source and rate impacts on forage total sulfur uptake from cut 2 at Rosemount in 2020.

Location	S Rate (lb/ac)	Sulfur Source				Rate Avg
		Control	K_2SO_4	K-MST	Tiger 90	
		--------------------pounds S per acre--------------------				
Rosemount	10	4.6	5.9	5.9	--	5.4b
	20	5.2	6.5	7.1	--	6.3ab
	30	5.2	7.5	8.4	--	7.0a
	120	--	8.3	7.9	5.9	
	Source Avg.[1]	5.0b	7.0a	7.3a	--	

Forage quality parameters were not affected by sulfur source or rate. Forage protein concentration, ADF, and NDF are listed in Tables 7, 8, and 9, respectively.

Table 7. Sulfur source and rate impacts on forage protein concentration from cut 2 at Rosemount in 2020.

Location	S Rate (lb/ac)	Sulfur Source				Rate Avg
		Control	K_2SO_4	K-MST	Tiger 90	
		--------------------% Protein--------------------				
Rosemount	10	18.7	20.4	18.9	--	19.3
	20	18.8	19.3	19.4	--	19.2
	30	19.9	20.4	19.3	--	19.8
	120	--	20.3	17.4	18.6	
	Source Avg.[1]	19.1	20.1	18.8	--	

Table 8. Sulfur source and rate impacts on forage acid detergent fiber (ADF) concentration from cut 2 at Rosemount in 2020.

Location	S Rate (lb/ac)	Sulfur Source				Rate Avg
		Control	K_2SO_4	K-MST	Tiger 90	
		--------------------ADF--------------------				
Rosemount	10	35.4	33.5	35.4	--	34.8
	20	35.4	35.4	35.5	--	35.5
	30	33.9	34.1	35.7	--	34.6
	120	--	33.5	37.0	35.8	
	Source Avg.[1]	34.9	34.1	35.9	--	

Table 9. Sulfur source and rate impacts on forage neutral detergent fiber (NDF) concentration from cut 2 at Rosemount in 2020.

Location	S Rate (lb/ac)	Sulfur Source				Rate Avg
		Control	K_2SO_4	K-MST	Tiger 90	
		--------------------NDF--------------------				
Rosemount	10	47.4	45.8	47.9	--	47.0
	20	48.2	48.1	48.1	--	48.1
	30	45.7	46.4	48.3	--	46.8
	120	--	45.8	49.3	48.1	
	Source Avg.[1]	47.1	46.5	48.4	--	