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Progress Report

2021 South Dakota Nutrient Research and Education Council Invited Proposals

Progress Report Title:	Draft Final Report - Due December 1, 2021
Applicant Name:	Peter Kovacs
Application Title:	Sulfur source and application timing effect on soybean yield Year 3 of project
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Project Information

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Title of Project: Sulfur source and application timing effect on soybean yield Year 3 of project

Project Description:

Stricter environmental/emission regulations for industrial companies and lower emission levels from vehicles over the past few decades has decreased the level of pollutant emissions of sulfur (S). This decrease in S from pollutants along with S deficiencies being reported throughout the Midwest warrants the need to investigate the effect of additional S fertilizer on soybean yield in South Dakota. The goal of the project is to investigate the soybean yield response to S fertilizer. Specific objectives are 1) determine the effect of S source and rate on soybean yield response and nutrient uptake, and 2) determine the effect of S application timing on soybean yield response to fertilizer application. We propose two studies with two locations for the third year of this project. One study will compare S fertilizer sources and their ability to increase soybean yield. The other study will focus on the S fertilizer timing effect on soybean yield. At the end of these projects, we will be able to provide guidance to producers regarding the influence of S fertilizer on soybean yield.

Publications:

Mahato, G.R.*, T.M. Nleya, and **P. Kovács**. 2021. Is in-Season Foliar Application of Sulfur Beneficial in Soybean? ASA-CSSA-SSSA International Annual Meetings, Meetings. Salt Lake City, UT. November 7-10. 2021 (poster).

Mahato, G.R.*, T.M. Nleya, and **P. Kovács**. 2021. Soybean Response to Sulfur Application. ASA-CSSA-SSSA International Annual Meetings, Meetings. Salt Lake City, UT. November 7-10. 2021 (oral).

Sulfur source and application timing effect on soybean yield Year 3 of project
Preliminary Final Report December 1, 2021

PI: Dr. Péter Kovács, SDSU Department of Agronomy, Horticulture & Plant Science Email: peter.kovacs@sdstate.edu; Phone: (218) 280-2870
Co-PI: Dr. Jason Clark, Department of Agronomy, Horticulture & Plant
Graduate Student: Gena Mahato

Summary

Stricter environmental/emission regulations for industrial companies and lower emission levels from vehicles over the past few decades has decreased the level of pollutant emissions of sulfur (S). This decrease in S from pollutants along with S deficiencies being reported throughout the Midwest warrants the need to investigate the effect of additional S fertilizer on soybean yield in South Dakota. The goal of the project is to investigate the soybean yield response to S fertilizer. Specific objectives are 1) determine the effect of S source and rate on soybean yield response and nutrient uptake, and 2) determine the effect of S application timing on soybean yield response to fertilizer application. We propose two studies with two locations for the third year of this project. One study will compare S fertilizer sources and their ability to increase soybean yield. The other study will focus on the S fertilizer timing effect on soybean yield. At the end of these projects, we will be able to provide guidance to producers regarding the influence of S fertilizer on soybean yield.

Goal and objectives

The continued goal of the project is to investigate if there is yield response to S fertilizer in soybean. Specific objectives are 1) determine if S source and rate effect soybean yield response and nutrient uptake, and 2) determine if S application timing effects yield response to fertilizer application.

S source study

We conducted a field study between 2019 and 2021 at two locations in SD to investigate the effect of S sources and rates on soybean yield, seed protein content, and nutrient uptakes. The treatments were pre-plant application of 5 lbs S ac^{-1}, 10 lbs S ac^{-1}, 20 lbs S ac^{-1}, and 30 lbs S ac^{-1} from three S sources which included ammonium sulfate (21-0-0-24S), Microessential (MES 10; 12-40-0-10S), and Tiger XP (0-0-0-80S). Additional N and P were added to the treatments to provide equal amounts of nutrients within the same S rates from different S sources. Fertilizer treatments were broadcasted right after the planting. The soil organic matter was above 3 %. The treatment means for this study were separated at significance level of $\alpha = 0.05$.

Table 1. Pre-plant soil chemical properties for the S sources study at Brookings and Beresford, SD in 2019 and 2020 on top 0-6" layer of soil

Soil Parameters	Brookings		Beresford	
	2019	2020	2019	2020
Soil pH	6.1	5.6	6.2	5.8
Organic matter (%)	3.7	3.5	3.1	3.6
NO_3-N (ppm)	3	4.7	8.0	2.0
Bray-1 P (ppm)	13.4	28	18.7	21.4
SO_4-S (ppm)	2.8	6.8	3.3	6.3

Table 2. Sulfur sources and rates interaction effects on soybean yield at Brookings and Beresford, SD between 2019 and 2021.

S application	Yield (lbs ac^{-1})					
	Brookings			Beresford		
	2019	2020	2021	2019	2020	2021
Control	45.74	54.11	51.57	55.90	45.9	48.50 bcd
AMS 5	47.72	54.96	55.10	55.31	48.0	50.60 bc
AMS 10	46.90	57.31	49.41	54.27	47.5	57.80 a
AMS 20	48.92	55.76	54.44	56.92	46.4	46.80 cd
AMS 30	49.54	60.00	54.29	54.04	46.1	45.60 d
MES 5	47.51	56.75	52.13	54.70	45.6	49.80 bcd
MES 10	51.27	56.63	51.29	54.07	45.2	49.30 bcd
MES 20	51.18	54.35	57.55	53.98	40.6	52.00 b
MES 30	50.89	58.07	51.50	54.82	44.6	49.60 bcd
Tiger XP 5	48.85	57.27	50.31	53.86	46.2	46.90 cd
Tiger XP 10	47.65	57.99	52.07	55.21	44.8	46.00 d
Tiger XP 20	49.60	59.02	54.81	56.39	49.5	49.50 bcd
Tiger XP 30	52.65	60.47	53.66	53.93	45.4	49.30 bcd
p<F						
S sources	**0.044**	**0.032**	0.9	0.61	0.25	0.137
S rates	0.085	0.036	0.104	0.37	0.95	**0.004**
S source x S rate	0.55	0.72	0.616	0.56	0.37	**0.002**

Table 3. S sources effect on soybean yield 2019 and 2020 at Brookings and Beresford, SD

S Source	Yield (lbs ac^{-1})			
	Brookings		Beresford	
	2019	2020	2019	2020
Control	45.74 b	54.11 b	55.90	45.93
AMS	48.28 ab	57.01 ab	55.14	46.99
MES	50.21 a	56.45 b	54.39	44.01
Tiger XP	49.69 a	58.68 a	54.85	46.27

The S sources and rates interaction did not affect the soybean yield in either years or locations except at SERF in 2021 (Table 2). In this case the 10 lbs/ac AMS application resulted the highest yield, and the only statistical difference from the control treatment (Table 2). The S sources, averaged across the rates, affected the grain yield in Brookings but did not affect soybean yield in SERF location in 2019 and 2020. In Brookings, Tiger XP resulted about 4 bu/ac higher soybean yield as compared to control whereas AMS increased yield by about 5 bu/ac in 2019 compared to control but had similar yield in 2020 (Table 3). The S rates affected the soybean yield at Brookings in 2019 but did not affect soybean yield in SERF location in 2019 or 2020 (Table 4). In Brookings, the 30 lbs S/ac rate increased yield by about 5 bu/ac as compared to the control treatment, averaged across S sources, whereas all other S rates resulted similar soybean yield as compared to control.

Table 4. S rates effect on soybean yield 2019 and 2020 at Brookings and Beresford, SD

S rates (lb/a)	**Yield (lbs ac^{-1})**			
	Brookings		**Beresford**	
	2019	**2020**	**2019**	**2020**
30	51.03	59.51 a	55.90	45.93
20	49.9	56.38 b	54.63	46.30
10	48.61	57.31 ab	54.51	45.84
5	48.03	56.32 b	55.76	45.52
0	45.74	54.11 b	54.26	45.38
p<F				
S rates	0.085	**0.036**	0.37	0.95

Table 5. S sources and rates interaction effects on seed protein concentration at Brookings and Beresford, SD in 2019 and 2020.

S application	Seed protein %			
	Brookings		Beresford	
	2019	2020	2019	2020
Control	33.25 cd	32.03	33.6	34.5
AMS 5	33.57 abc	31.70	33.5	34.9
AMS 10	33.55 bc	31.58	33.4	34.9
AMS 20	33.55 bc	31.14	33.8	35.0
AMS 30	33.73 ab	31.08	33.5	34.3
MES 5	33.55 bc	31.85	33.5	35.1
MES 10	33.73 ab	31.60	33.2	35.0
MES 20	33.57 abc	31.28	33.5	34.9
MES 30	33.55 bc	30.75	33.8	34.9
Tiger XP 5	33.15 d	31.93	33.4	34.8
Tiger XP 10	33.45 bcd	31.95	33.9	34.8
Tiger XP 20	33.65 ab	32.03	33.6	34.9
Tiger XP 30	33.9 a	31.30	33.5	34.9
p<F				
S sources	0.074	**0.012**	0.94	0.4
S rates	**0.035**	**0.002**	0.82	0.69
S source x S rate	**0.048**	0.68	0.30	0.75

The S sources and rates interaction affected the seed protein content at Brookings location only in 2019 and the Tiger XP application at the rate of 30 lbs S ac^{-1} resulted highest seed protein content which was significantly higher as compared to control treatment (Table 5). S sources impacted the seed protein content at Brookings in 2019 and 2020 but not affected the seed protein content at SERF (Table 6). In 2019 at Brookings all the S Sources yielded to higher seed protein concentration, the AMS and MES sources resulted lower seed protein content in 2020 (Table 6). The Tiger XP resulted similar seed protein content as compared to control in 2020 (Table 6). Increasing S rate increased seed protein content in 2019 lowered seed protein content as compared to control in 2020 at Brookings, while S rates did not impact seed protein levels at SERF (Table 7).

Table 6. S sources effect on seed protein content 2019 and 2020 at Brookings and Beresford, SD

S Source	Yield (lbs ac^{-1})			
	Brookings		Beresford	
	2019	2020	2019	2020
Control	33.25 b	32.03 a	33.58	34.48
AMS	33.6 a	31.37 b	33.53	34.76
MES	33.6 a	31.37 b	33.48	34.95
Tiger XP	33.54 a	31.80 a	33.56	34.82
p<F				
S source	0.074	0.012	0.94	0.4

Table 7. S rates effect on seed protein content 2019 and 2020 at Brookings and Beresford, SD

S rates (lb/a)	Yield (lbs ac^{-1})			
	Brookings		Beresford	
	2019	2020	2019	2020
30	33.73 a	31.04 b	33.58	34.48
20	33.59 ab	31.48 a	33.45	34.90
10	33.58 ab	31.71 a	33.48	34.88
5	33.42 bc	31.83 a	33.58	34.92
0	33.25 c	32.03 a	33.58	34.68
p<F				
S rates	0.035	0.002	0.82	0.69

S season study

Field study was conducted to determine the effect of foliar S application timing on soybean yield and seed protein content. The study was conducted at Brookings and Beresford in South Dakota between 2019 and 2021. The applications included single foliar applications, double foliar application, and pre-plant application of ammonium sulfate (21-0-0-24S). Single foliar application with 5 lbs S ac^{-1} rate was applied at V4 (four fully extended trifoliate), R2 (full bloom), R3 (beginning pod), and R4 (full pod) growth stages and double foliar applications each with 5 lbs S ac^{-1} was applied at V4+R2, V4+R3, R2+R3 growth stages. Pre-plant applications at the rate of 5 lbs ac^{-1} and 10 lbs ac^{-1} were also included for comparison with single and double foliar applications. In addition, V4 S application with micronutrient package (32 fl oz ac^{-1} Brandt Quattro) was included. Pre-plant treatments were broadcast applied right after planting while in-season applications were foliar applied at 15 GPA rate. The treatment means for this study were separated at significance level of $\alpha = 0.1$.

Table 8. Pre-plant soil chemical properties for the S season study at Brookings and Beresford, SD in 2019 and 2020 on top 0-6" layer of soil

Soil Parameters	Brookings		Beresford	
	2019	2020	2019	2020
Soil pH	6.4	6.5	6.2	5.8
Organic matter (%)	3.8	2.9	3.1	3.6
NO_3-N (ppm)	3.8	4.1	8.0	2.0
Bray-1 P (ppm)	17.6	9.2	18.7	21.4
SO_4-S (ppm)	5	4.5	3.3	6.3

Table 9. Foliar S application effect on soybean yield at Brookings and Beresford, SD between 2019 and 2021.

S application timing	Yield (lbs ac^{-1})					
	Brookings			Beresford		
	2019	2020	2021	2019	2020	2021
Control	47.21	59.99 ab	52.50	58.92 a	45.24	52.06
Pre-plant 5 (lbs ac^{-1})	47.88	55.53 bcd	56.35	58.84 a	43.30	53.48
V4	48.48	53.83 cd	52.30	58.69 a	45.39	53.38
V4 dry (5 lbs ac^{-1})		56.71 abcd	52.93		44.23	54.00
R2	48.74	52.85 d	49.81	59.34 a	46.95	51.37
R3	47.69	56.41 abcd	53.25	59.28 a	43.97	53.09
R4	50.34	57.68 abc	54.23	51.71 b	42.58	53.58
V4 + micronutrient	46.58	60.35 a	54.30	58.59 a	44.35	52.79
Pre-plant 10 (lbs ac^{-1})	51.44	60.63 a	53.76	56.9 a	43.27	50.11
V4 + R2	49.63	54.75 cd	51.11	57.93 a	44.75	56.28
V4 + R3	50.60	56.73 abcd	52.71	58.24 ab	43.46	52.30
R2 + R3	49.31	55.42 cd	55.05	55.69 ab	44.22	51.76
p<F						
Application timing	0.64	0.089	0.302	0.006	0.8	0.896

At Brookings location, foliar S application affected soybean yield in 2020 only (Table 9). The result showed that none of the foliar and pre-plant applications resulted higher soybean yield as compared to control. Single foliar application at V4 and R2 and double foliar application at V2+R2 and R2+R4 resulted lower soybean yield as compared to control. Moreover, pre-plant application at the rate of 10 lbs ac^{-1} resulted higher soybean yield as compared to double foliar application at V2+R2 and R2+R4 (Table 9). Pre-plant application at the rate of 5 lbs ac^{-1} resulted similar soybean yield as compared to single foliar applications except V4+micronutrient application.

At Beresford location, foliar S application affected the soybean yield in 2019 only and all foliar applications resulted similar soybean yield as compared to control treatment except the R4 application (Table 9).

Table 10. Foliar S application effect on seed protein content at Brookings and Beresford, SD in 2019 and 2020

S application timing	Seed protein %			
	Brookings		Beresford	
	2019	2020	2019	2020
Control	33.50	32.5 a	33.4	34.2 ab
Pre-plant 5 (lbs ac^{-1})	33.70	31.98 bcd	33.5	34.1 ab
V4	33.80	31.78 cd	33.6	34.1 ab
V4 dry (5 lbs ac^{-1})		31.8 bcd		34.0 ab
R2	33.58	31.98 bcd	33.7	34.0 ab
R3	33.55	31.85 bcd	33.6	33.9 ab
R4	33.75	32.25 ab	33.2	34.0 ab
V4 + micronutrient	33.45	32.08 abc	33.8	34.0 ab
Pre-plant 10 (lbs ac^{-1})	33.53	31.88 bcd	33.6	33.3 b
V4 + R2	33.70	31.68 cd	33.4	33.7 ab
V4 + R3	33.65	31.7 cd	33.7	34.1 ab
R2 + R3	33.60	31.53 d	33.3	34.6 a
p<F				
Application timing	0.198	**0.071**	0.63	**0.02**

At Brookings location, foliar S application affected the seed protein content in 2020 only and control treatment resulted highest seed protein content. All S applications resulted lower seed protein content compared to control treatment except the R4 application and the V4 application with the micronutrient package (Table 9).
At Beresford location, foliar S application affected the seed protein content in 2020 only and all foliar S application resulted similar soybean yield as compared to control treatment.
The soil organic matter % was higher in soil surface of the soil in both studies. The organic matter can release SO_4^{2-} throughout the growing season which could reduce the impact of S application on soybean yield and seed protein content.

Tasks need to complete:
We are processing the R8 biomass samples and we have to determine the seed protein levels for the 2021 samples. In addition, this is the last year of this research so we have to analyze results across the three years.