SOYBEAN RESPONSE TO SULFUR PLACEMENT AND STARTER FERTILIZER APPLICATION

L.L. Thurgood and K. Steinke
Michigan State University, East Lansing, Michigan

Abstract

Reduced rates of early season nutrient mineralization from earlier planting dates, increased nutrient removal from greater yields, and reductions in atmospheric sulfur (S) deposition have increased concern regarding S availability for optimal soybean (*Glycine max* L.) growth. A field study was established to determine the effects of 25 lbs. S per acre with or without starter fertilizer consisting of 20 lbs. nitrogen (N) per acre and 50 lbs. P_2O_5 per acre on soybean grain yield and quality. Main plots consisted of four S placements (no S, pre-plant incorporate, at planting in a 2x2 inch band, or split-banded at planting and at R1) while the sub-plot consisted of with or without N and phosphorus (P) starter fertilizer applied at planting in a 2x2 inch band. Data collection included relative SPAD measurements (V4 and R5), plant height (V4 and R5), petiole nutrient analysis (R1), root nodule counts (R3), grain oil and protein, yield, moisture, and test weight. Early season (V4) SPAD measurements indicated the application of a starter fertilizer significantly increased plant greenness by 4% compared to no starter. The data show that S application had no effect on grain yield when compared no S application, 41 vs. 42 bu/A, respectively. Although not statistically significant, the application of a starter fertilizer resulted in a two bushel improvement when compared to no starter application. The data suggest that S placement had no effect on soybean yield. Treatment differences did not significantly affect grain oil and protein, but results suggest the application of S and starter fertilizer may increase oil and protein levels as compared to no application. First year preliminary data suggest applying S may not be necessary to increase soybean yield for Michigan fields testing 6 ppm S or greater, but S and starter fertilizer applications may improve early-season plant growth and seed quality.

Introduction

Sulfur is a constituent of the amino acids cysteine and methionine, a building block of protein, and may be particularly important in soybean production due to grain quality which can average 40% protein and 20% oil (Naeve and Shibles, 2005). Presently S management has become a concern in soybean production due to changes in the environment, industry, and cultural practices. The reduction of S deposition in southern Michigan where atmospheric deposits of S have historically been a primary S source continues to be a concern. In the early 1980's, S deposition averaged 24 lbs. wet SO_4^{2-} acre^{-1} yr^{-1} whereas current deposition is as low as 7 lbs. wet SO_4^{2-} acre^{-1} yr^{-1} (Environmental Protection Agency, 2013). Genetic improvements in soybean have resulted in greater yields which may require additional S for optimum plant growth. Recent research investigating S requirements has demonstrated that maximum soybean yields were obtained by applying 14 lbs. S per acre on a silt loam soil with 2.5 % OM, but pre-plant soil S levels were not discussed (Dick et al., 2005).

When not replenished, soil S may become limited for soybean production when grown in rotation with other high S-requiring crops such as corn and alfalfa (Lamond, 1997). Fertilizer selection can contribute to the maintenance of soil S levels. Growers that select high analysis fertilizers [urea (46-0-0), MAP (11-52-0), and MOP (0-0-62)], provide little to no S to supplement S removal from cultivated soils. A large percentage (56 to 59%) of total soybean S is accumulated during vegetative development and later remobilized for grain fill (Naeve and Shibles, 2005). Soil organic matter (OM) may contribute 3 lbs. S per percentage OM once mineralization occurs, yet significant mineralization may not occur before the end of the vegetative development in earlier planted soils. Early S uptake may result in an S deficiency if residual sulfate and mineralized S levels are not sufficient to meet soybean S requirements. There are increased concerns that as farmers continue to plant soybeans earlier in the spring (late April/early May) S mineralization may be limited by cool soil temperatures.

As growers attempt to capture a longer growing season through earlier soybean planting into cool soils, minimal soil microbial activity may affect soybean N supply from rhizobia (*Bradyrhizobium japonicum*) (Lynch and Smith, 1993). A starter application of N and P may be useful when planting in cool soil conditions to promote early season growth and root system establishment. However, growers must consider whether early season N application may be outweighed by inhibition of root nodule development.

Objectives

1. Determine the effects of S and S placement on soybean growth, yield, and quality.
2. Determine the effects of N and P starter fertilizer on soybean growth, yield, and quality.

Methods and Materials

The study was established 22 May 2012 at the Michigan State University agronomy farm in East Lansing, MI on a Capac Loam (44.8% sand; 41.2% silt; 14% clay) following corn. The trial was arranged as a split-plot randomized complete block with four replications. Sulfur placement was the main plot factor while the application of N and P starter fertilizer was the sub-plot factor. Sulfur was applied at 25 lbs. SO_4^{-2} per acre at four placements: 1) pre-plant broadcast and incorporated, 2) at planting in a 2x2 inch band as a liquid, 3) split application with 15 lbs. S applied at planting as a liquid in a 2x2 inch band and the remaining 10 lbs. applied as a liquid at R1 on the soil surface 4" from the base of the stem, and 4) no S control treatment. Sub-plot treatments consisted of applying 20 and 50 lbs. per acre of N and P_2O_5, respectively, in a 2x2 inch band at planting or applying no starter fertilizer. Fertilizer sources were calcium sulfate (0-0-0-16) and diammonium phosphate (18-46-0). Potassium was applied to the entire trial at 120 lbs. K_2O per acre, (0-0-62) pre-plant incorporated. Precipitation was limited throughout the growing season (Fig. 1) as only 1.59 inches of rainfall was received between planting and R1.

Pre-plant soil properties included 3.0% organic matter, 7.3 pH, 31 ppm P, 132 ppm K, and 5.8 ppm S. Chlorophyll meter readings were collected at V4 using a Minolta SPAD-502 chlorophyll meter (Spectrum Technologies Inc., Plainfield, IL). Twenty-five plants were sampled per plot and the average recorded. A relative SPAD output was calculated for each plot by dividing the plot SPAD reading by the highest SPAD reading from each replication. Plant height was collected at V4 from 20 plants per plot and mean height recorded.

Twenty petiole samples were collected at R1 and analyzed for P, K, and S. Soybean root nodules were counted at R3. Twenty root samples were extracted from each plot by inserting a shovel 4-6" to the side of the stem and pushing down to a depth of approximately 6 inches. Stems were removed and the root balls were soaked in water to remove soil that was adhering to the root surface. Roots were washed over a 2 mm mesh screen. Nodules that washed through the screen were not counted. Plant height and SPAD measurements were repeated at R5. At physiological maturity several plant measurements were taken in addition to grain yield, test weight, and moisture. Ten plants were collected from each plot to determine mean total nodes, pod producing nodes, pods per node, beans per pod, and weight of 100 beans. Grain was also sampled to measure percent oil and protein.

Statistical analysis was performed using PROC MIXED in SAS. All measurements were analyzed assuming fixed main effects of sulfur placement and starter fertilization and random replication effects. When significant ($P<0.1$) main effects were indicated treatment means were separated using LSMEANS and compared using the PDIFF command.

Preliminary Results and Discussion

SPAD V4 data resulted in significant main effects for both S placement and starter application (Table 1). The V4 SPAD data demonstrated a 2 and 3% increase for S placement at planting and starter application when compared to no application, respectively. The R5 relative SPAD demonstrated no differences among S placement treatments. The main effects of starter fertilizer maintained a significant 1% increase in relative SPAD when compared to no application (Table 1).

Plant heights at V4 and R5 did not result in significant differences from S placement or starter application (Table 2). The application of starter at planting resulted in a significant 6% increase in petiole P concentrations (Table 3). Petiole S concentration increased when a starter fertilizer was applied, however, the increase was not significant. Sulfur placement did not affect petiole S concentration. Control plots with no S did not express S deficiency symptoms in petiole nutrient analysis. The number of nodules per plant at R3 was not affected by S placement, but there was a slight decline in nodules when starter was applied at planting. The two nodule per plant decrease from starter fertilizer application was not significantly less than the no starter application treatment (Table 4).

Grain yield, moisture, and test weight did not demonstrate significant main effects for S placement or starter application (Table 5). Applying S pre-plant incorporated resulted in 44 bu/A which was 2 bushels higher than all other S treatments including the control (no S applied). The application of starter fertilizer resulted in a yield increase of 1.4 bushels. Soybean grain was tested for percent grain oil and protein to determine differences in quality (Table 6) but there were no significant effects from S or starter application. Although no significant main effects occurred, individual treatment results for grain quality are presented (Tables 7 and 8) to demonstrate S and starter fertilizer application effects as compared to no application. Though no significant main effects of S or starter application on grain quality occurred, treatment differences from the check plot may pique some interest as soybean grain quality concerns continue to increase worldwide. Grain protein and oil percentages increased 35 and 33%, respectively, from starter fertilizer and S application as compared to the control.

Summary

Preliminary data suggest that a starter application of 20 lbs. N and 50 lbs. P per acre and applying 25 lbs. S per acre at planting in a 2x2 inch band may increase overall soybean greenness. Increased greenness may suggest improved plant vigor and growth yet may have no yield effects. Minor P petiole increases may have been the result of applying P at planting though lack of application did not result in P deficiencies. There were no differences in percent petiole S from the control, suggesting that residual, mineralized, and S deposition satisfied soybean S requirements pre- R1. Although the data suggest the application of S or starter fertilizer may increase soybean grain quality there were no effects on grain yield. These year one preliminary data suggest that for this area of Michigan, S was adequately supplied from organic matter mineralization and S deposition for optimal soybean production despite low soil S test levels. A second year of research is underway for this project and will be available early 2014.

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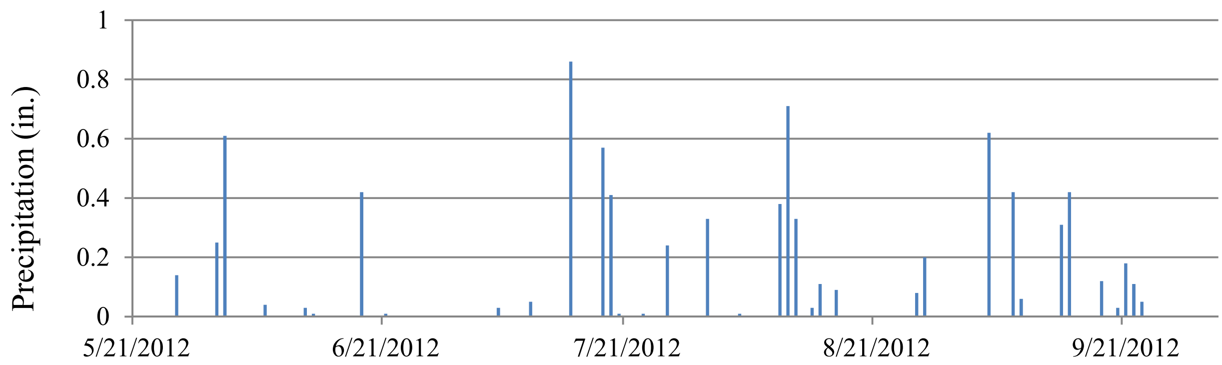

Figure 1. Daily precipitation in East Lansing, MI for 2012 growing season.

Table 1. Sulfur placement and starter fertilizer effects on V4 and R5 SPAD measurements, East Lansing, MI, 2012.

Treatment	Relative V4 SPAD	Relative R5 SPAD
S Placement		
Pre-plant Incorporated	0.963 a*	0.960 a
At Planting	0.982 b	0.974 a
Split	0.955 a	0.979 a
No Sulfur	0.961 a	0.982 a
Starter		
20 N and 50 P	0.981 b	0.981 b
No Starter	0.949 a	0.967 a
Treatment Effects (*P*>*F*)		
Placement	0.047	0.444
Starter	<0.001	0.066
Timing x Starter	0.601	0.309

* values in the same column followed by the same lower case letter are not significantly different (α=0.1).

Table 2. Sulfur placement and starter fertilizer effects on V4 and R5 plant height, East Lansing, MI, 2012.

Treatment	V4 Height	R5 Height
	-------------in.-------------	
S Placement		
Pre-plant Incorporated	6.7 a*	33.1 a
At Planting	6.8 a	32.5 a
Split	6.6 a	32.9 a
No Sulfur	6.7 a	32.2 a
Starter		
20 N and 50 P	6.7 a	33.0 a
No Starter	6.6 a	32.4 a
Treatment Effects (*P*>*F*)		
Placement	0.723	0.925
Starter	0.267	0.328
Timing x Starter	0.648	0.311

*values in the same column followed by the same lower case letter are not significantly different (α=0.1).

Table 3. Stage R1 petiole tissue nutrient analysis as affected by S placement and starter fertilizer application, East Lansing, MI, 2012.

Treatment	R1 Total P	R1 Total K	R1 Total S
	------------------------------%------------------------------		
S Placement			
Pre-plant	0.35 a*	1.76 a	0.26 a
At Planting	0.30 a	1.64 a	0.25 a
Split	0.33 a	1.75 a	0.27 a
No Sulfur	0.32 a	1.82 a	0.24 a
Starter			
20 N and 50 P	0.33 b	1.73 a	0.26 a
No Starter	0.31 a	1.76 a	0.25 a
Treatment Effects (*P*>*F*)			
Placement	0.421	0.502	0.154
Starter	0.086	0.732	0.787
Timing x Starter	0.228	0.756	0.336

*values in the same column followed by the same lower case letter are not significantly different (α=0.1).

Table 4. Stage R3 nodule counts as affected by S placement and starter fertilizer application, East Lansing, MI, 2012.

Treatment	Nodule Counts
S Placement	
Pre-plant Incorporated	23 a*
At Planting	23 a
Split	23 a
No Sulfur	23 a
Starter	
20 N and 50 P	22 a
No Starter	24 a
Treatment Effects (*P*>*F*)	
Placement	0.999
Starter	0.188
Timing x Starter	0.933

* values in the same column followed by the same lower case letter are not significantly different (α=0.1).

Table 5. Sulfur placement and starter fertilizer effects on soybean yield, moisture, and test weight, East Lansing, MI, 2012.

Treatment	Yield	Moisture	Test Weight
	-----bu/A-----	-----%-----	----lbs/bu----
S Placement			
Pre-plant Incorporated	44.0 a*	10.9 a	56.0 a
At Planting	37.9 a	10.8 a	56.0 a
Split	41.9 a	10.8 a	56.0 a
No Sulfur	42.0 a	11.0 a	55.0 a
Starter			
20N, 50P	42.1 a	10.9 a	56.0 a
No Starter	40.7 a	10.8 a	55.0 a
Treatment Effects (*P*>*F*)			
Placement	0.579	0.890	0.134
Starter	0.483	0.499	0.503
Timing x Starter	0.430	0.521	0.795

* values in the same column followed by the same lower case letter are not significantly different, α=0.1.

Table 6. Sulfur placement and starter fertilizer effects on grain percentage oil and protein, East Lansing, MI, 2012.

Treatment	Grain Oil	Grain Protein
	--------------------%--------------------	
S Placement		
Pre-plant Incorporated	19.7 a*	35.9 a
At Planting	19.6 a	36.0 a
Split	19.6 a	36.2 a
No Sulfur	17.1 a	31.4 a
Starter (lbs. / A)		
20N, 50P	19.6 a	35.9 a
No Starter	18.4 a	33.8 a
Treatment Effects (*P*>*F*)		
Placement	0.40	0.46
Starter	0.35	0.36
Timing x Starter	0.38	0.48

* values in the same column followed by the same lower case letter are not significantly different, α=0.1.

Table 7. Lack of interaction between sulfur placement and starter fertilizer application on soybean grain percent oil, East Lansing, MI, 2012.

		S Placement		
	Pre-Plant	At Planting	Split	No Sulfur
Starter	--------------------	------%------	--------------------	
20 N and 50 P	19.6 b*	19.6 b	19.5 b	19.7 b
No Starter	19.8 b	19.7 b	19.6 b	14.6 a

* values in the same column followed by the same lower case letter are not significantly different, α=0.1.

Table 8. Lack of interaction between sulfur placement and starter fertilizer application on soybean grain percent protein, East Lansing, MI, 2012.

		S Placement		
	Pre-plant	At Planting	Split	No Sulfur
Starter	--------------------	------%------	--------------------	
20 N and 50 P	36.1 b*	35.9 b	36.3 b	35.6 b
No Starter	35.7 b	36.2 b	36.1 b	27.1 a

* values in the same column followed by the same lower case letter are not significantly different, α=0.1.

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PROGRAM CHAIR:
Carrie Laboski
University of Wisconsin
1525 Observatory Dr.
Madison, WI 53706-1207
(608) 263-2795
laboski@wisc.edu

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