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To What Extent Does Sulfur and Ammonium Sulfate Impact Soybean Yields and When Does It Work Best?

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Background [i]

History of Recommendations

Recent studies in Minnesota generally find that using sulfur on soybeans increases plant growth but not yields.[1] However, measuring sulfur levels in the soil is difficult because soil testing alone can provide highly variable results. The most accurate readings on S typically come from tissue tests in conjunction with soil tests.[4]

In lieu of testing, Kaiser, D., Lamb, J., (2012) suggest that in most cases sulfur mineralized from the soil will be enough for in-season needs. However on soils low in organic matter (top six inches is 2.0% or less) where crops that are susceptible to deficiency will be planted, University of Minnesota soil fertility guidelines suggest a sulfur application of10-15 lbs of S).[1,2,5]

Two forms of sulfur are recommended to address plant requirements. Sulfate-sulfur, which is immediately available to plants in-season, or elemental sulfur which needs time, temperature and moisture before becoming available and so cannot be counted on to meet short term needs.[3]

In conjunction with sulfur, in-season soybean nitrogen applications can be a strategy to increase yields. Some research suggests that certain environmental conditions limit the ability of the soybean nodules to supply adequate amounts of N late in the growing season.[1] As with sulfur, the full range of conditions for which these circumstances exist are not wholly understood, but generally include excessive rainfall (timing and amounts), soil type, variety, pH levels, and salinity.

Studies throughout the 1990's by the University of Minnesota found that the application of various types of in-season fertilizer N had no effect on soybean yield.[1] But exceptions existed. Applying 50 to 75 lb. of N per acre was found to be potentially beneficial for some soybean fields in the Red River Valley. The caveat to applying additional fertilizer is that growers should soil test a field first to measure carryover nitrogen where iron deficiency chlorosis can be a problem because additional nitrogen can exacerbate it. [1]

Recent Studies

Dr. Daniel Kaiser received funding from the MN Soybean Research and Promotion Council in 2011 and 12 to investigate the effects of Microessentials SZ on soybean yields in comparison to: 1) N only (as ammonium nitrate), 2) N and P as MAP, 3) N, P, and S as MAP, 4) ammonium sulfate, and 5) elemental sulfur (50/50 blend).Treatments were intended to supply nutrients in the same amount as MEZ which was applied at 200lbs. of product per acre.

Eleven sites over two years were studied across Minnesota. Two sites showed significant yield increases as a result of additional nitrogen and sulfur fertilizers. Treatment mean comparisons indicate that ammonium nitrate increased yield by an average of 8 bu/ac at the Warroad '11 site (treatment was 49 bu/ac and the control (no nitrogen) was 41 bu/ac). And it increased yield 3 bu/ac at Rochester '12 (treatment was 51 bu/ac and the control (no nitrogen) was 48 bu/ac). The additional sulfur provided no yield benefit.[6,7]

Reasons for responses to N at these two sites were not evident. Kaiser 2013 speculates that the beans were low on soil nitrogen since the organic matter levels were the lowest at these two sites and the soil's coarse texture indicated a poor N holding capacity due to high leaching potential.[7]

A 2007 study near Mahnomen in heavy fine soils with a medium organic matter evaluated three sulfur fertilizer products: MESZ, ammonium sulfate and elemental sulfur at four different rates, 0lbs S, 12.5lbs S, 25lbs S, 50lbs S. They found no differences in yields in any of the studies for any of the products. Limiting factors to the studies include: lack of diverse soil types studied, 15x30 plots (no field strips) and it was a one year study only.[2]

Methods

Products Used

MicroEssentials® SZ otherwise known as MESZ is a granulated fertilizer that incorporates nitrogen, phosphorus, sulfur and zinc within each granule in order to overcome issues with uneven distribution of micronutrients in the starter band. MESZ ® contains: total nitrogen 12%, available P_2O_5 40%, total sulfur 10% (sulfur as sulfate 5%, sulfur as elemental S 5%), total zinc 1% http://www.microessentials.com/ . The material is produced by Mosaic, Inc., using dry mono-ammonium phosphate (MAP), ammonium sulfate, elemental sulfur, and zinc oxide.

Ammonium sulfate, $(NH_4)_2SO_4$ contains 21% nitrogen and 24% sulfate sulfur. This is a widely available non-proprietary bulk fertilizer.

Table 1.

Condition	Control	Treatment
Field 1	75lbs MESZ + 25lbs Potash –pre-plant broadcast.	75lbs MESZ + 25lbs Potash –pre-plant broadcast. 100lbs/A AMS broadcast at 2-3 trifoliate stage
Field 2	No MESZ	No MESZ 100lbs/A AMS broadcast at 2-3 trifoliate stage

- Two field locations were used in this study, both owned/operated by the same grower. Both in close proximity to one another.
  - Treatment and control conditions within can be seen in Table 1.
- Randomized complete block design was used. Two blocks with two replications in different portions of the field were completed in field one and in field two one block of four replications was used.
- Sample yields were standardized to 13.0% moisture and 60lb test weight.
- Each trial strip was approximately 1 acre.
- The participant was paid $1,500 to help meet costs associated with their involvement in the study.
- All fertilizer, equipment and applications were made by the participant.
- Soil type(s) at the site were light, sandy soils with <2% organic matter.
- Weather conditions during the growing season were slightly cooler on the average with precipitation greater earlier on and then below average in August (See Table 2).

Table 2

2014 Precipitation (in inches) by Month-TRF					
Precip	**April**	**May**	**June**	**July**	**August**
TRF Site	1.50	2.28	5.02	2.65	1.18
Hist. Ave.	*.94*	*2.60*	*3.39*	*3.43*	*3.15*
Diff Ave	**+.56**	**-.32**	**+1.63**	**-.78**	**-1.97**

Results

Field 1

	Yield (bu)	
	Control	**Treatment**
Strip 1	37.37	39.07
Strip 2	37.27	39.36
Strip 3	38.18	39.60
Strip 4	36.88	36.79
Average Yield	**37.32**	**39.22***
*Sig difference at p<.10		

» Field 1 found a 1.90 bu/acre greater yield for treatment than control
» The treatment mean (M=38.70) was significantly higher than the control mean (M=37.43) (t(3)=2.68, p<.10).
» There were four treatment strips and four control strips.

Field 2

	Yield (bu)	
	Control	**Treatment**
Strip 1	35.68	40.49
Strip 2	41.39	35.78
Strip 3	36.32	35.60
Strip 4	32.94	31.61
Average Yield	**36.58**	**35.87**

√ Treatment condition was -.71 bu/ac less than control.
√ There were no significant difference between the control and treatment.
√ The MESZ plus AMS treatment condition in Field 1 yielded significantly higher than either condition in Field 2. The additional nitrogen and sulfur appeared to provide a substantial benefit to yield.

Discussion

To what extent does sulfur and ammonium sulfate impact soybean yields?

Results from past studies and as well from this one suggest that sulfur and nitrogen may have an impact on soybean yields. Findings from this study indicate a 2 bu./ac yield increase.

In Field 1, results showed significant differences in yield between the treatment and control condition suggesting that the additional 100lbs of AMS at the 2-3 trifoliate stage had a positive impact of nearly 2 bu/ac on yields. Comparing Field 1 to Field 2 we also found differences which may have been due to extra nitrogen and sulfur, but phosphorous also may have played a role given that the MESZ product contains 40% P. Soybeans planted in soils that are deficient in P have been shown to respond to additional phosphorous applications. This study did not control for that nutrient.

Furthermore, in some instances where soil fertility is extremely low, regional agronomists have suggested that it is possible to see an increase in yield with the application of nitrogen. The challenge is that if too much fertilizer is applied, the beans use the applied N rather than the rhizobia fixation process.

In Field 2, yields decreased in the treatment condition. The most obvious reason for this outcome was a ditch and several potholes that contained water for some time during several periods over the growing season.

When does it work best?

The greatest response to sulfur in soybeans appears to be found in fields having a sandy texture or soils with a high degree of slope with low soil organic matter. These types of soils are known to be at risk of sulfur deficiency.[9] However, conditions where a sulfur response will occur are still not well understood or clearly defined.[10]

Studies suggest that in years of high rainfall oxygen is limited in the soil which is unhealthy for rhizobia growth. Our findings as well as others indicate that additional nitrogen could aid the bacteria in the nitrogen fixation process in that environment.[8]

Suggestions for Future Research

» Future on-farm soybean studies need to collect more comprehensive temperature, rainfall and relative humidity data in study fields.
  - o Complete mobile weather stations have grown relatively inexpensive.
  - o Future data analysis will be better able to relate timing of interventions to timing of site specific environmental conditions.

» Future on-farm studies need to do comprehensive soil tests at the beginning and completion of the study to assess soil nitrate levels and soil/tissue tests to assess in-season sulfur needs.

» Studies need to determine best practices based on soil type and weather conditions relative to the addition of nitrogen and sulfur on soybeans.
  - o Conditions where a sulfur response will occur are not well defined.[10]

» Measurements need to be taken to assess how much S contribution comes from the atmosphere during particular growing seasons.[10]

» No longitudinal studies exist that explore the impacts of the previous (multiple) years crop ping histories effects on the yields produced.

» Few studies exist examining how tillage impacts the use of nitrogen and sulfur in soybeans.

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[i] The mission of the NWMN On-Farm Research collaborative is to address priority production concerns through field scale research. Activities are funded through support from the Minnesota wheat check-off and the Minnesota Department of Agriculture.