Comparison of ATS placement methods to enhance yield of continuous corn

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INTRODUCTION

Research has identified a need for sulfur for corn in Minnesota (Kim et al., 2013). In their study, Kim et al (2013) banded ammonium thiosulfate liquid fertilizer with the planter two inches beside and below the corn seed with and without 28% UAN (urea ammonium nitrate solution) and/or ammonium polyphosphate (APP, 10-34-0). Significant yield responses to ATS were found when corn was grown on soils with less than 3.0% organic matter concentration in the top six inches of soil. Increased yield of corn in low organic matter soils follows with research by Sawyer and Barker (2002). However, research by Kaiser (2013) showed that yield response to sulfur may be more likely in continuous corn in Minnesota for soils with greater than 3.0% organic matter concentration. Research by Vetsch et al. (2012) found benefits of sulfur (ATS) banded on the soil surface beside the row with the planter in continuous corn production. This research has clearly demonstrated to farmers the value of incorporating sulfur into their fertility management programs.

Elemental S and dry sources of sulfate sulfur such as ammonium sulfate (AMS) are commonly applied to corn. Based on older data, the fertilizer guidelines for corn in Minnesota suggest that banding sulfur is more efficient (Kaiser et al., 2011). Because of the options available to farmers for applying sulfur there have been questions as to the best course of action. Ammonium thiosulfate (ATS) is a popular liquid fertilizer source of sulfur in Minnesota. Starter fertilizer use is prevalent in Minnesota but the risk for stand loss with ATS applied directly on the seed typically precludes the use of ATS as a pop-up starter fertilizer source (Kaiser and Rubin, 2013). High clay soils make banding fertilizer beside and below the seed, such as the old 2 x 2 banding method, difficult. Farmers rely on either surface band applications, such as those used by Vetsch et al. (2012), or applying ATS as a broadcast with their early pre-emergence weed control. The effectiveness of pre-emergence broadcast application of ATS has not been researched in Minnesota.

With the high amounts of surface residue it can be questioned whether broadcast application of ATS over the soil surface and crop residue is effective or if some of the sulfur applied is tied up in the decomposition of residue by soil microbes. Our current research has shown that dry ammonium sulfate can be surface applied up to the V5 growth stage and be as effective as pre-plant application. However, granular fertilizer can bounce off of residue when applied and reach the soil surface. Liquid fertilizer would have the tendency to dry on residue. Research in Minnesota (Kent et al., unpublished data) studied the effects of fall and spring applied UAN (pre-plant) and potassium thiosulfate on decomposition rates of corn residue and corn yield response to sulfur. No yield responses to sulfur were found; therefore, the data were inconclusive as to the benefits of liquid fertilizer containing sulfur broadcast on top of corn residue and there was no direct comparison to dry fertilizer sources.

Objectives

1) Determine if a surface band application of S as ATS is more efficient than broadcast application of ATS or AMS
2) Determine if pre-emerge broadcast application of ATS is as an effective source of applying S compared to AMS broadcast at or before planting in continuous corn.

METHODS

Table 1. Initial soil test data for samples collected spring prior to treatment application.

	Soil		Soil Test (0-6")					0-2'
Location	Series	County	P	K	SO_4-S	OM	pH	SO_4-S
			-----------ppm-------			-%-		-lb/ac-
New Richland	Clarion	Waseca	20	134	7	2.9	5.7	42
Waseca	Webster	Waseca	13	165	6	5.5	6.3	33

P, Bray-P1 phosphorus; K ammonium acetate potassium; SO_4-S, mono-calcium phosphate extractable sulfate sulfur; OM, organic matter loss on ignition; pH, 1:1 soil:water.

Two field trials were conducted during the 2015 growing season (Table 1). Previous crop was corn at both locations. Treatments were arranged as a factorial design within a randomized complete block design replicated four times. Factor 1 was fertilizer source and placement (1, ATS banded on the soil surface 1-2 inches beside the row with the corn planter; 2, ATS broadcast to the surface with flat fan nozzles after planting prior to corn emergence; 3, AMS broadcast pre- or at-planting). Factor 2 consists of sulfur rate (0, 2.5, 5, 10, and 20 lbs S/acre). The combination of the two factors resulted in 15 treatments (5 rates x 3 sulfur source treatments). Corn planters were equipped with row cleaners such that the surface banded ATS is applied to the soil surface and not on corn residue. Broadcast ATS treatments were applied using standard spray equipment in a total of 12-15 gallons of water/fertilizer mix. Urea ammonium nitrate (28 or 32% solution) was used to equilibrate N application so that all plots receive the same amount of N at planting for the banded ATS application and with the broadcast ATS application (N rate will be calculated based on the amount of N applied with the highest ATS application). Prior to planting, 200 lb of N per acre was applied as either Urea or a combination of Urea and AMS for treatments that received broadcast AMS. Phosphorus and potassium were kept at non-limiting rates and 5 GPA of 3-18-18 plus 1 qt of 9% fully chelated zinc was applied directly on the corn seed to all plots. Plot size was 10' wide by 50' long (4-30" rows). Pioneer P0157AM1 was planted at a rate of 35,000 plants per acre at both locations.

Soil samples were collected from depths of 0-6 and 6-24". A single composite sample of 6 cores was collected for each replication at each site. The 0-6" samples were analyzed for P, K, pH, organic matter, and sulfate-S. The 6-24" samples will be analyzed for sulfate-S only. Residue levels at planting were assessed for each replication using the line transect method. Treatment performance will be assessed by taking ear leaf samples at R2 from the middle two rows in each plot. Ear leaf samples were analyzed for total S concentration. Additional tissue samples were collected at V10 (uppermost fully developed leaf). Total S concentration in all samples was measured with and ICP. Corn was sensed using a Crop Circle model 430 at the V5 growth stage. Harvest data (corn grain yield and grain moisture concentration) was collected by hand harvesting 20' of the middle two rows from each plot or with the use of a plot combine.

SUMMARY OF 2015 DATA

Table 2. Summary of statistical significance for main treatments consisting of sulfur source and sulfur rate and the interaction between sulfur source and rate.

	V5 NDRE†		V10 Leaf S†		R2 Leaf S†		Yield†	
Effect	NR	Was	NR	Was	NR	Was	NR	Was
	----------------------				*P*>F		----------------------	
Source	**	***	0.50	0.71	0.40	0.31	*	0.16
Rate	0.07	*	0.38	**	*	*	0.20	0.45
S x Rate	0.09	0.14	0.59	**	*	*	*	0.75

†Asterisks indicate treatment significance of $P \leq 0.05$ (*), ≤ 0.01 (**), and ≤ 0.001 (***).

Table 3. Summary of normalized difference red edge (NDRE) index sensed at the V5 growth stage with a Crop Circle 430.

	New Richland†				Waseca†			
S Rate	AMS-Br	ATS-Br	ATS-Ba	Avg.‡	AMS-Br	ATS-Br	ATS-Ba	Avg.‡
-lb S/ac-								
0	0.307	0.320	0.319	0.315a	0.317	0.316	0.308	0.314b
2.5	0.302	0.312	0.308	0.307b	0.327	0.322	0.327	0.325a
5.0	0.303	0.307	0.319	0.310ab	0.319	0.318	0.308	0.315b
10.0	0.307	0.301	0.317	0.308b	0.332	0.317	0.309	0.319ab
20.0	0.312	0.303	0.309	0.308b	0.341	0.315	0.311	0.322ab
Avg.‡	0.306b	0.309b	0.314a		0.327a	0.318b	0.313b	

† Sulfur source: ATS-Ba, Ammonium thiosulfate banded; ATS-Br, ammonium thiosulfate broadcast; AMS-Br, ammonium sulfate broadcast.

‡ Avg., treatment mean; within rows and columns, numbers followed by the same letter are not significantly different at the $P \leq 0.05$ probability level.

Sulfur source and rate affected plant greenness at the V5 growth stage at both locations (Table 3). Plant greenness was measured using the normalized difference red edge (NDRE) index. The normalized difference vegetative index (NDVI) was also assessed with the Crop Circle 430 but there were not differences among the treatments at both sites and the data are not summarized.

The effect of rate on NDRE was odd as the NDRE tended to decrease with an increase in sulfur rate. It would be expected to see an increase in greenness with the addition of sulfur. The effect of sulfur source was inconsistent between the sites. At New Richland the plots that received Banded ATS were greener while the AMS treatment resulted in greener plants at Waseca. While different, the effects of source and rate on NDRE were relatively minor and could not be readily noticed when examining the trials early in the growing season.

Table 4. Summary of the effect of sulfur source and rate on the concentration of S (measured with ICP) in the newest fully developed corn leaf sampled at the V10 growth stage.

	New Richland†				Waseca†			
S Rate	AMS-Br	ATS-Br	ATS-Ba	Avg.‡	AMS-Br	ATS-Br	ATS-Ba	Avg.‡
-lb S/ac-	----------------	----------------	----------------	---------------- %	----------------	----------------	----------------	----------------
0	0.17	0.18	0.17	0.17	0.17	0.17	0.17	0.17c
2.5	0.18	0.17	0.16	0.17	0.17	0.18	0.20	0.18bc
5.0	0.17	0.18	0.17	0.17	0.19	0.19	0.18	0.19ab
10.0	0.18	0.16	0.17	0.17	0.21	0.19	0.19	0.20a
20.0	0.18	0.19	0.18	0.18	0.19	0.21	0.17	0.19ab
Avg.‡	0.18	0.17	0.17		0.19	0.19	0.18	

† Sulfur source: ATS-Ba, Ammonium thiosulfate banded; ATS-Br, ammonium thiosulfate broadcast; AMS-Br, ammonium sulfate broadcast.
‡ Avg., treatment mean; within rows and columns, numbers followed by the same letter are not significantly different at the $P \leq 0.05$ probability level.

Sulfur content in the newest fully developed corn leaf at the V10 growth stage is summarized in Table 4. Differences in sulfur concentration in leaf samples were relatively small among the treatments. There was no effect of sulfur source or rate at the New Richland site. At Waseca, sulfur rate affected the concentration of S in the corn leaf samples. In general, sulfur concentration increased with increasing rate of S applied at Waseca. There was a significant interaction between sulfur source and rate. However, there was not enough evidence that one source was more or less efficient at applying S than the other sources used. The interaction was more likely due to differences among sources within individual sulfur rates. However, the differences were not limited to the low or high application rates and appeared to happen more at random due to within plot variability.

Sulfur concentration in corn ear leaf samples is summarized in Table 5. Sulfur concentration in the ear leaf tissue differed due to rate of sulfur at both locations while the main effect of source was not significant at either location. Sulfur concentration increased with increasing sulfur rate at both locations. There was only a small difference between the low and high sulfur concentration at each site and the concentration of sulfur increased up to the last rate of sulfur applied (response was linear when significant). There were significant interaction between sulfur source and rate at both locations. However, there was no evidence that sulfur rate differed for only one or two of the sources or that the effect of rate was greater for one source than another. Similar to data collected at V10, the interaction appears to be due to random variation in the data where sources differed within specific sulfur rates. There is not enough data to determine if the interaction provides enough evidence to say that ATS either banded or broadcast provides more or less available sulfur than a similar rate of AMS applied at or before planting.

Table 5. Summary of the effect of sulfur source and rate on the concentration of S (measured with ICP) in the corn ear leaf (leaf opposite and below the ear) sampled at the R1-R2 growth stage.

	New Richland†				Waseca†			
S Rate	AMS-Br	ATS-Br	ATS-Ba	Avg.‡	AMS-Br	ATS-Br	ATS-Ba	Avg.‡
-lb S/ac-	%							
0	0.15	0.15	0.14	0.14b	0.14	0.17	0.16	0.16b
2.5	0.14	0.15	0.14	0.14b	0.16	0.13	0.16	0.15b
5.0	0.16	0.13	0.14	0.14b	0.16	0.14	0.16	0.15b
10.0	0.14	0.16	0.15	0.15ab	0.16	0.15	0.15	0.15b
20.0	0.16	0.16	0.15	0.16a	0.18	0.18	0.17	0.18a
Avg.‡	0.15	0.15	0.15		0.16	0.15	0.16	

† Sulfur source: ATS-Ba, Ammonium thiosulfate banded; ATS-Br, ammonium thiosulfate broadcast; AMS-Br, ammonium sulfate broadcast.
‡ Avg., treatment mean; within rows and columns, numbers followed by the same letter are not significantly different at the $P \leq 0.05$ probability level.

Table 6. Summary of the effect of sulfur source and rate on corn grain yield (adjusted to 15.5% moisture).

	New Richland†				Waseca†			
S Rate	AMS-Br	ATS-Br	ATS-Ba	Avg.‡	AMS-Br	ATS-Br	ATS-Ba	Avg.‡
-lb S/ac-	%							
0	222	225	229	225	212	213	204	210
2.5	221	241	216	226	204	215	206	209
5.0	218	242	228	229	213	213	212	213
10.0	231	218	216	222	210	221	209	213
20.0	225	233	227	228	220	216	214	216
Avg.‡	223b	232a	223b		212	216	209	

† Sulfur source: ATS-Ba, Ammonium thiosulfate banded; ATS-Br, ammonium thiosulfate broadcast; AMS-Br, ammonium sulfate broadcast.
‡ Avg., treatment mean; within rows and columns, numbers followed by the same letter are not significantly different at the $P \leq 0.05$ probability level.

Corn grain yield was not affected by sulfur source at either location (Table 6). There was evidence that sources differed only at the New Richland site. At New Richland, corn grain yield was greater for the ATS broadcast treatment versus the AMS broadcast and ATS banded application which did not differ from each other. There was also an interaction that occurred between sulfur source and rate at New Richland. There was some evidence that sulfur rate when

ATS was broadcast applied but not for the other two application methods. It is unclear why the yield potential may have been greater when ATS was broadcast. The ATS treatments had a greater percentage of the total nitrogen applied as ammonium. In addition, ATS has been known to act as a nitrogen inhibitor when mixed with UAN. A response would have also been expected for the banded ATS if the ATS had any inhibitor effect, but there was no evidence of greater grain yield with banded ATS. It is also plausible that since the ATS broadcast application was last among the treatments that more of the sulfur would have been in the upper soil surface if significant leaching would have occurred. It does not seem likely that leaching could have presented a major issue since there was only a two day delay in application timing between the banded and broadcast ATS treatments. At this time we cannot definitively say that the ATS broadcast application was better. The P value for sulfur source was close to significance at Waseca and the effect, if significant, would have been due to higher yield with the ATS broadcast treatment. We expected that the ATS broadcast treatment would have resulted in less yield due residue intercepting some of nutrients applied. More locations would be beneficial to further study potential benefits of ATS on increasing grain yield of corn.

PRELIMINARY CONCLUSIONS

The effect of sulfur source and rate were studied at two locations. Tissue concentration of S measured at the V10 and R2 growth stages were affected by sulfur rate and not by sulfur source. Tissue S concentration increased up to the greatest rate of sulfur applied. Corn grain yield was not affected by rate of sulfur application considering all sulfur sources. There was some evidence that sulfur applied as ATS broadcast after planting increased corn grain yield at one location. The lack of an increase in corn grain yield when AMS was broadcast or ATS was banded at planting would indicate that the yield response from broadcast AMS was not due to sulfur.

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APPENDIX

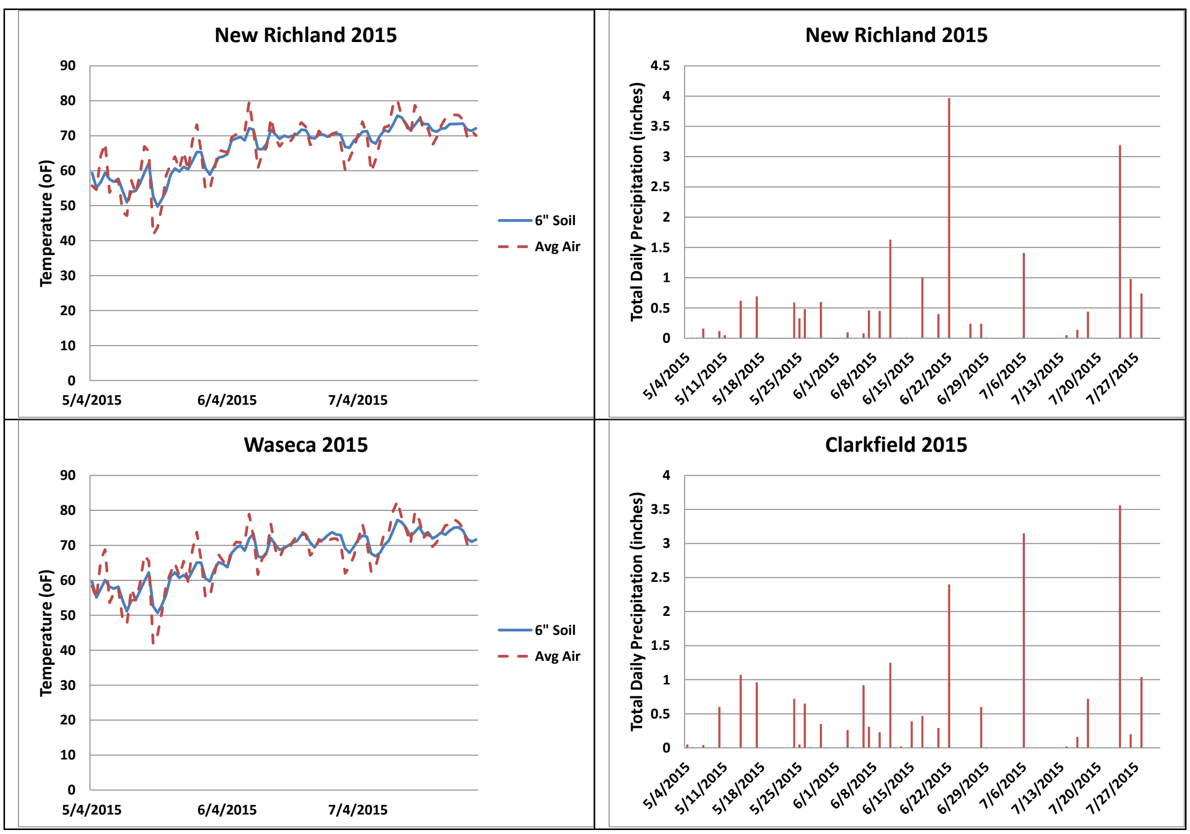

Figure 1. Summary of soil and air temperature and total daily rainfall at two locations where sulfur rate and source trials were conducted in 2015.