SULFUR AND NITROGEN STARTER FERTILIZER FOR CORN IN NORTHERN CLIMATES

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Abstract

The combination of cool and wet weather in early spring can reduce the amount of S and N released in soil by decomposition and mineralization of organic matter, particularly in reduced-tillage or no-till cropping systems. Recent changes to S emission regulations have decreased the amounts of S that is deposited to the soil through atmospheric channels. Field studies were initiated in 2005 at five corn (*Zea mays* L.) sites in Michigan to evaluate the effects of S and N starter fertilizer on nutrient uptake, plant growth, and grain yield. Three sites were on-farm strip trials with treatments of ammonium sulfate (21-0-0-24S) band-applied at planting at rates of 0, 5, 10, and 20 lb S ac^{-1}. Two additional sites on Michigan State University research farms included additional starter fertilizer treatments of 25 lb N ac^{-1}, 25 lb N ha^{-1} + 25 lb P_2O_5 ac^{-1}, 25 lb N ac^{-1} + 25 lb P_2O_5 ac^{-1} + 10 lb S ac^{-1}, and 10 lb S ac^{-1} as gypsum (16% S). In 2005, corn grain yield responded positively to the 20 lb S ac^{-1} application at two of the five sites in the study, with an average of 18.1 bu ac^{-1} increase in grain yield over the control. Responses observed for chlorophyll meter readings and grain yield at sites may be attributed to crop response to starter N rather than S. When S was applied as gypsum, there were no measured differences compared with the control plots.

Introduction

Recent improvements in corn genetics have allowed for relatively early spring planting, even in northern US climates. In Michigan, early season conditions are typically cool and wet resulting in less than optimal early season growth and development of young plants. These conditions also slow the decomposition of organic matter and mineralization of organic N and S to plant-available inorganic forms. Pirela (1988) showed a greater rate of S mineralization in soils at 30°C soils compared with soils at a temperature of 20°C. Over a 14 week incubation period, 16-20 mg kg^{-1} was mineralized at 30°C compared with 4-10 mg kg^{-1} for 20°C soils. Microbial activity will generally be the greatest for organic matter decomposition when the soils are approximately 30°C (Miller, 1995).

When corn is planted early in the spring in these conditions a negative effect on growth can occur due to the less than optimal availability of S and N to seedlings. This problem is exasperated on coarse textured soils, which often have less organic matter relative to finer textured soils thus lower mineralization potential. Rehm (2005) reported no grain yield response to S fertilization in no-till corn planted in a silty clay loam, but did find significantly greater yields for S fertilization when applied to coarse textured soils.

The Federal Clean Air Act of 1990 restricted the amounts of S that can be introduced into the atmosphere. This legislation was designed to impose reductions on the amount of allowable SO_2

emissions so that a 40% reduction (relative to 1980 emission levels) would occur by the year 2000 (Environmental Protection Agency, 2006). The National Atmospheric Deposition Program (NADP) compiled data from the Kellogg Biological Station at Hickory Corners, MI (1979 to present) which indicates that atmospheric SO_4 deposition had decreased from a maximum rate of 34.14 kg ha^{-1} in 1986 to 7.64 kg ha^{-1} by 2000 (NADP, 2006). The trend has been that the yearly amount of atmospheric S deposition is being reduced. Prior to the recent reductions in SO_2 emissions, atmospheric deposition (in addition to S mineralized from soil organic matter) has often provided S adequate to meet most agronomic crop requirements. As these reductions continue to occur, there is a potentially growing need for supplemental S fertilizer application to sustain crop yields. The objective of our study is to evaluate the effects of S and N starter fertilizer combinations on nutrient uptake, plant growth, and grain yield for corn grown in Michigan growing conditions.

Approach

Field studies were initiated in 2005 at five corn sites in Michigan. Three sites (located in Clinton, Lapeer, and Monroe Counties) were on-farm strip trials with treatments of ammonium sulfate (AS; 21-0-0-24S) applied at planting at rates approximately 0, 5, 10, and 20 lb S ac^{-1}. Two additional sites were established on Michigan State University (MSU) research farms and included additional starter band fertilizer treatments of 25 lb N ac^{-1}, 25 lb N ha^{-1} + 25 lb P_2O_5 ac^{-1}, 25 lb N ac^{-1} + 25 lb P_2O_5 ac^{-1} + 10 lb S ac^{-1}, and 10 lb S ac^{-1} as gypsum (16% S). Plots at the research farms were 15 by 50 ft, arranged in a randomized complete block design with four replications. Fertilizer was applied in a 2" by 2" band at planting at all sites except Lapeer, where AS was applied at sidedress just after planting. Strip size at the producer farm sites was six to twelve rows wide (15 to 30 ft) and ranged from 120 to 800 ft in length; plot size at the university farms was six rows (15 ft) wide by 50 ft long. All sites were planted as no-till systems. Management practices other than starter fertilizer (i.e. fertilizer, weed control, insect control, etc.) were performed by cooperating producers or, at the university farms, were consistent with methods commonly accepted for the region.

Intensive sampling was conducted throughout the growing season at the research farm sites. Soil samples were collected to a depth of 8" prior to planting. Samples were dried, ground to pass a 2 mm sieve, and were analyzed for P, K, pH, OM, inorganic N, and SO_4-S following procedures recommended for the North-Central Region (Brown, 1997). Plant stand counts were recorded 7-10 days after emergence. Plant height was measured at the V4 growth stage (vegetative leaf stage was determined as the number of fully mature leaves with a visible leaf collar, included the first round-tipped leaf) and the average height value for 12 plants per plot was recorded. Chlorophyll readings were also collected at V4 using a Minota 502 SPAD (Konica Minota, Hong Kong) chlorophyll meter (CM) on 20 leaves (most recently-mature leaf below the whorl) from the middle 4 rows of each plot. Three whole plants were then removed from the middle 4 rows of each plot (12 plants total per plot) and were weighed, dried, reweighed, ground, and analyzed for total N and S content. Control plots were soil sampled (0-8") at V4 to evaluate changes in temporal variability of soil SO_4-S. Plant height measurements, chlorophyll readings, and plant tissue collection was repeated again two weeks after the V4 growth stage (approximately V6) following the same procedures described above. At R1 (silking), CM readings were recorded and 20 ear leaves were collected , processed, and analyzed using the same procedure described above for plant tissue. Grain yield, moisture, and test weight were determined by harvesting the entire length of the center two rows via plot combine. Grain yields reported for all sites were adjusted to 15.5% standard moisture content. Grain subsamples were collected, dried, ground, and analyzed for total N and S content. After harvest, 0 to 8" soil samples were collected from the control plots and analyzed for inorganic N and S content.

Sampling was less intensive at the on-farm strip trials. Ear leaf samples were collected at V6 and were analyzed for total elemental content. Soil samples from 0-8" were taken from the control strips at the same time as the Ingham and Saginaw sites and were analyzed for SO_4-S content. Yield was measured for the strip trials via combine yield monitor, and a sample of the grain from each plot was ground and analyzed for total N and S content.

Results and Discussion

Selected soil properties for each site are reported in Table 1. Chemical properties reported in Table 1 are results from 0-8" samples collected prior to planting. Soil pH ranged from 5.5 to 8.2, values typical for these areas of Michigan. Sulfate-S analysis indicated values ranging from 0.1 to 1.9 ppm among the sites, and did not appear to demonstrate a close relationship with soil texture.

No statistical differences in yields were observed at the Saginaw, Clinton, or Lapeer sites in 2005 (Tables 2 and 3). However, grain yields were increased with the addition of N and S starter fertilizer at the Ingham and Monroe sites. In Ingham County, there was a 21.8 bu ac^{-1}difference between the 20 lb S ac^{-1} (plus 25 lb N ac^{-1}) rate and the control. In Monroe County, there was a 14.4 bu ac^{-1} difference between the 20 lb S ac^{-1} rate and the control. The two sites where a response to starter was observed generally had coarser textured soils than the other study sites. The relatively low %OM at the Ingham site could partially explain the response observed. While the Monroe County site had relatively greater soil OM content compared with the other study sites, the fact that this site was a loamy sand could have influenced the observed response to starter (eg. increased susceptibility to SO_4-S leaching).

Corn leaf CM readings taken at the V4, V6, and R1 growth stages at the Ingham and Saginaw sites indicated some differences in relative leaf greenness in response to starter treatments (Table 4). Statistical differences in CM readings among treatments was observed at both Ingham (V4 and V6) and Saginaw (V6). At Ingham V4 sampling, starter treatments containing combinations of N and S resulted in greater CM values than treatments containing N or S alone. At both sites for the V6 sampling, the combination of N and P in the starter resulted in greater CM values than check or the S-only (gypsum) application, but there were no differences among any of other the treatments containing S, N, or P. By the time CM readings were collected at R1, the crop had likely out-grown the visual early season response to starter combinations, as reflected by the lack of significant difference in CM values among treatments.

Summary

The addition of S and N starter fertilizer combinations resulted in improved corn grain yields in two of five sites in Michigan in 2005. Sites where a positive response was observed were typically those with coarser textured soils, relative to the other study locations. The average yield increase at the two responsive sites was 18.2 bu ac^{-1} over the plots receiving no starter. Chlorophyll meter readings collected during the growing season indicated differences in leaf chlorophyll content (greenness) in relation to applied starter treatments, particularly early in the growing season. Differences in CM readings among treatments had disappeared by the R1 growth stage. Responses observed for chlorophyll meter readings and grain yield at sites may be attributed to crop response to starter N rather than S. When S was applied as gypsum, there were no measured differences compared with the control plots. Results from the first year of this study are indicative that starter fertilizer with S addition may be beneficial for corn grown in coarse textured soils in Michigan, though additional data is needed to support this finding.

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Table 1. Selected soil physical and chemical properties for all study sites. Soil sulfur analysis was completed using the monocalcium phosphate extraction procedure (Brown, 1997).

Location	Soil Series	Texture	pH	% OM	SO_4-S
					ppm
Clinton	Blount	Loam	6.5	2.7	1.6
Ingham	Metea	Loamy sand	5.5	1.2	1.6
Saginaw	Mistegay	Silty clay	8.2	2.9	0.1
Monroe	Thetford	Loamy sand	6.9	3.0	1.9
Lapeer	Metamora	Sandy loam	7.2	2.8	0.1

Table 2. Response of corn grain yield to starter fertilizer treatments at Michigan State University research farms in Saginaw and Ingham counties.

Treatment†	Saginaw	Ingham
	- - - - - bu ac^{-1} - - - - -	
Control	188.9	160.7
N	190.7	178.2
N+P‡	194.2	172.3
N+S5	193.1	174.7
N+S10	192.2	167.7
N+S20	189.0	182.5
N+P+S10‡	188.1	176.4
Gypsum	189.1	165.1
$LSD_{0.05}$	NS	20.6
CV	2.7	5.0

† N = 25 lb N ac^{-1} final rate at all plots receiving N
‡ 25 lb P_2O_5 ac^{-1}

Table 3. Response of corn grain yield to starter fertilizer treatments at producer strip-trials in Lapeer, Clinton, and Monroe counties.

Treatment	Clinton	Monroe†	Lapeer‡
	- - - - - bu ac^{-1} - - - - -		
Control	149.4	174.4	156.8
N+S5	154.7	175.3	162.9
N+S10	157.5	174.6	160.6
N+S20	157.2	188.8	162.9
$LSD_{0.05}$	NS	14.3	NS
CV	4.8	3.6	4.5

† Actual applied S rates were as 0, 4.4, 8, 12.7 lb ac^{-1}
‡ Starter fertilizer at Lapeer site applied as sidedress rather than 2x2 band

Table 4. Relative leaf chlorophyll meter readings for Saginaw and Ingham county sites.

	V4		V6		R1	
Treatment[1]	Saginaw	Ingham	Saginaw	Ingham	Saginaw	Ingham
	- - - - - - - - - - - - Relative chlorophyll meter reading - - - - - - - - - - - -					
Check	33.4	31.1	39.9	37.3	56.3	58.1
N	33.4	29.5	45.0	42.8	55.9	58.8
N+P	33.0	32.0	47.7	46.9	56.4	58.6
N+S5	30.9	36.6	45.3	41.8	55.6	58.8
N+S10	34.3	35.8	44.7	41.2	56.7	58.7
N+S20	34.1	34.2	46.2	42.8	56.2	59.9
N+P+S10	33.2	37.2	45.0	44.6	56.0	58.7
Gypsum	33.1	30.4	40.1	36.5	55.7	59.3
LSD	NS	3.6	5.9	6.2	NS	NS
CV	5.3	4.5	5.7	6.2	2.3	2.5

[1] N = 25 lb N ac^{-1}; P = 25 lb P_2O_5 ac^{-1}; S = indicated pounds of S ac^{-1}

Table 5. Total N and S content in corn whole plant (V6), ear leaf (R1), and grain tissue in relation to sulfur applied in starter fertilizer at Ingham County.

	V6		R1		Grain	
Treatment†	N	S	N	S	N	S
	- - - - - - - - - - - - - - % - - - - - - - - - - - - - -					
Control	2.54	0.16	2.83	0.19	1.13	0.085
N	3.39	0.14	3.64	0.20	1.11	0.085
N+P‡	3.68	0.16	3.48	0.21	1.11	0.085
N+S5	3.42	0.20	3.42	0.22	1.07	0.087
N+S10	3.39	0.23	3.65	0.24	1.13	0.084
N+S20	3.62	0.27	3.49	0.28	1.11	0.086
N+P+S10‡	3.93	0.25	3.51	0.30	1.15	0.087
Gypsum	2.63	0.21	2.73	0.21	1.10	0.082
$LSD_{0.05}$	0.30	0.02	0.29	0.02	0.06	0.005
CV	6.2	5.4	6.0	4.9	3.9	3.8

† N = 25 lb N ac^{-1} final rate at all plots receiving N

‡ 25 lb P_2O_5 ac^{-1}

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