Corn Production Response to Sources and Rates Of Fluid Nitrogen Fertilizers 2008

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Abstract

Three fluid sources of N [conventional UAN (28%N), UAN + eNhance, and High NRG-N] were applied at various rates and times to determine the economic optimum N rate (EONR) for corn following soybeans and to determine if time of application and N source affected corn production and N use efficiency. The EONR with conventional UAN was 163 lb N/A in 2008, while the 3-year average (2006-2008) was 145 lb N/A. Corn grain, stover, and silage yields, N recoveries, and nitrogen use efficiencies were greatest with conventional UAN (28%), intermediate with UAN + eNhance, and least with High NRG-N. Split applying 30 lb N/A at V3 and 60 lb/A at V7 gave yields similar to a 90-lb preplant application. When 15 lb N/A was applied at V3 and 75 lb N/A was applied at V7 or V12, yields were reduced compared to a 90-lb application at V3. Relative chlorophyll content of the ear leaf at VT indicated limited N uptake for the late split-applied N treatments (V12) compared to the early (V3) treatment. Remote sensing indices (NDVI), at V7 and V9 with the GreenSeeker and Crop Circle instruments, were effective at delineating the most severe N deficiencies in the control and 15 lb N/A at V3 treatments. A six-week period of dry weather from July 18 through September probably affected N availability and grain yield, because of reduced mineralization from organic matter, positional unavailability, and moisture stress, during these critical reproductive stages of corn.

Introduction

Using the correct amount of nitrogen (N) optimizes crop yield and profitability while minimizing loss of N to the environment. Using the wrong amount reduces profitability for the farmer and can result in excess nitrate being delivered to ground and surface waters. Many research studies have been conducted in southern Minnesota to determine optimum N rates for corn. However, as corn genetic materials and pest management strategies change, it is imperative that on-going N rate studies be conducted with these new hybrids to validate or adjust present recommended N rates.

In addition, spring application of fluid sources of N will become more popular as anhydrous ammonia declines due to manufacturing challenges in the U.S. and transportation issues, namely safety. The prominence of UAN has generated an additional question; namely will split applications of UAN be more beneficial than preplant applications of urea. Also, other sources of fluid N with claims of higher performance and/or greater N availability are available for farmers. The purposes of this study were to determine: (1) the economic optimum N rate (EONR) of injected UAN at the V3 stage for corn following soybeans, (2) if various times and ratios of sidedress-applied N affected corn production and N use efficiency, (3) if “alternative, high performance” fluid N sources were superior to traditional 28%N (UAN), and (4) if remote sensing techniques could be used to assess fluid fertilizer N management for in-season application to corn.

Experimental Procedures

A field study containing 18 N treatments replicated four times in a randomized, complete-block design was conducted at the University’s Southern Research and Outreach Center at Waseca in 2008. The site was located on an inherently poorly drained Webster–Canisteo clay loam soil that is pattern drained with tile lines spaced at 75-foot intervals. Soil test values for the site were pH = 5.5, Buffer pH = 6.2, OM = 6%, Bray P_1 = 19 ppm (High), and exchangeable K = 178 ppm (Very high). Soybeans grown in 2007 were not tilled after harvest. Prior to treatment application in 2008, the site was field cultivated twice on May 1. Each plot measured 10’ wide (4-30” rows) by 50’ long.

Corn (DeKalb 50-44) was planted at 34,000 seeds/A on May 8. Excellent weed control was obtained with a pre-emerge application of Harness (1.5 pt/A) and Callisto (5 oz) on May 14 and a post emerge application of Roundup WeatherMax (24 oz./A) and AMS on June 19. Stand counts were taken on June 10, and the corn was thinned to a uniform population on June 12.

Three sources of fluid N fertilizer were compared: (1) conventional UAN (28%N), (2) 28% N + eNhance and (3) High NRG-N. The latter two products are sold by Agro-Culture Liquid Fertilizers and claim enhanced N availability allowing application at a reduced rate (80% for eNhance and 60% for High NRG-N) compared to conventional UAN (28%N). At the V3 stage (June 11), all three sources were injected about 4” deep midway between the rows. UAN (28%) was applied to six treatments at rates of 10, 20, 30, 40, 50 and 60 gal/A for a total N rate of 30, 60, 90, 120, 150, and 180 lb N/A. Eight additional N treatments using 28%N + eNhance at four application rates (16, 24, 32, and 40 gal/A for target total N rates of 60, 90, 120, and 150 lb N/A) and High NRG-N at four application rates (12, 18, 24, and 30 gal/A for target total N rates of 60, 90, 120, and 150 lb N/A) were also applied.

UAN (28%) was split applied at a total N rate of 90 lb N/A to three treatments at rates of 10 gal at V3 + 20 gal at V7, 5 gal at V3 + 25 gal at V7, and 5 gal at V3 + 25 gal at V12. The V7 application was injected on June 26 with the same equipment as V3 applications. The V12 application was dribble-applied by hand next to the row on July 15.

At the V7 stage (June 26) and V9 stage (July 7), NDVI indices were taken using the GreenSeeker and Crop Circle meters. Leaf chlorophyll measurements, using a SPAD meter, were taken at R1 (July 28). Stover yields were taken from 15’ of row 2 at physiological maturity on September 24. Grain yield and moisture were obtained on October 16 and 18 by combine harvesting the center two rows. Stover and grain samples were dried, ground, and analyzed for total N. Soil samples were taken to a 4’ depth in 1-foot increments on October 29 from the 0, 90, 120, 150, and 180 lb N/A treatments [using UAN (28%)] to determine the carryover of residual soil nitrate-N from the “higher” N treatments.

Results and Discussion for 2008

Weather conditions varied greatly during the 2008 growing season which affected planting, crop development, and yield. A wetter (+0.92”) and cooler (-2.7° F.) than normal April delayed planting throughout Minnesota. Air temperatures continued below normal in May and June, while precipitation was near normal during that period. Growing degree units (GDUs) for the period May through September were near normal due to a warm September and a later-than-normal first frost on October 2. Even though precipitation varied during the growing season, the primary yield limiting factor was a 75-day period from July 18 through October 1, when only 4.04” of rainfall was recorded (4.2” below normal). Many corn and soybean fields showed drought stress symptoms in August and early September and some corn hybrids on high ground “shut down” prior to physiological maturity. On September 2 soil moisture was only 5.1” (46% of field capacity) in the 5’ profile with only 0.6” in the top 2’. These dry conditions reduced corn yield potential. For the 5-month May-September growing season, precipitation was 17.01” or

3.41” below normal. However, no 90° plus days were recorded after July 12th, which probably helped corn manage the late summer drought stress.

Grain yield response to fertilizer N (up to 95 bu/A) resulted in yields reaching 192 bu/A (Table 1). The economic optimum N rate (data not shown) for conventional UAN (28%) using a fertilizer N price: corn price ratio of 0.10 was 163 lb N/A, which was similar to last year (169 lb/A). When comparing the three N sources across the four target N rates (60, 90, 120, and 150 lb N/A), grain yield was optimized at the 150-lb target N rate. Yields were greatest with conventional UAN (168.4 bu/A), intermediate with UAN + eNhance (163.0 bu), least with High NRG-N (155.9 bu) [Table 1]. There was no significant interaction between fluid N source and target N rate, however grain yields at the 120 lb target N rate were similar with UAN and UAN + eNhance (Fig. 1).

Drought stress undoubtedly reduced biomass production and increased stover and silage yield variability (Table 1). Silage yields trended higher with the 150 lb/A fertilizer N rate, but statistically there was no difference between the 120- and 150-lb rates. Stover yields were statistically similar among the 90, 120, and 150 lb N/A rates. Nitrogen source did not affect stover yield, but High NRG-N had lower silage yields compared with UAN and UAN + eNhance. Split applying UAN (28%) at rates of 30 lb N/A at V3 and 60 lb N/A at V7 gave grain, stover, and silage yields equal to the 90-lb preplant application. However, when only 15 lb N/A was applied at V3 and 75 lb/A at V7 silage yields were reduced by 0.41 TDM/A. When the 75-lb sidedress rate was delayed until the V12 stage, grain and silage yields were reduced 18 bu/A and 0.54 TDM/A, respectively, compared with the 90-lb preplant treatment. Nitrogen concentrations in the stover were greatest with the 150-lb UAN rate. Stover and grain N concentrations were greatest with conventional UAN, intermediate with UAN + eNhance, and least with High NRG-N.

Nitrogen uptake in the grain and silage was optimized at the 150-lb target N rate and was greatest for conventional UAN (28%), intermediate with UAN + eNhance, and least with High NRG-N (Table 2). Nitrogen uptake in the stover was optimized at the 120-lb target N rate and was reduced by High NRG-N compared with conventional UAN and UAN + eNhance. Apparent fertilizer N recovery using conventional UAN (28%) was 59% in the total above-ground dry matter (silage) and 48% in the grain at the 150 lb N/A rate. When averaged across the target N rates of 60, 90, 120, and 150 lb N/A, apparent fertilizer N recovery in the total above-ground dry matter (silage) was 59, 53, and 39% for UAN (28%), UAN + eNhance, and High NRG-N, respectively. Nitrogen use efficiency (NUE), measured as bushels per pound of N, using conventional UAN was 1.17 from total N (fertilizer plus soil N) and 0.52 from fertilizer N at the 150 lb N/A rate (data not shown). When averaged across the target N rates of 60, 90, 120, and 150 lb N/A, NUE from fertilizer N was 0.72, 0.66, and 0.60 bu./lb N for UAN (28%), UAN + eNhance, and High NRG-N, respectively.

Grain moisture content was lower at the 150-lb N rate, but was not affected by N source (Table 3). A significant N source × N rate interaction had no practical explanation. Grain oil concentration was reduced with High NRG-N compared with UAN + eNhance. Grain starch concentration was not affected by the treatments. Plant population was slightly greater with UAN + eNhance compared with High NRG-N, but this 500-plant/A difference was not considered meaningful.

Vegetative (NDVI) indices, a measure of plant growth determined by remote sensing, were significantly less in the control plots when measured with GreenSeeker and Crop Circle sensors at the V7 and V9 stage (Table 4). At the V7 stage for both the GreenSeeker and Crop Circle, the 120-lb N rate had the greatest NDVI readings, however, the 60-lb N rate had the least. Nitrogen source did not affect NDVI readings at V7, but High NRG-N did reduce NDVI at V9. At V9, no effect of N rate on NDVI was found with the GreenSeeker, but NDVI increased with increasing N rate up to 120 lb N/A with the Crop Circle. Measureable differences in the infrared and visible yellow bands were only found in the check (zero N) plots. Relative leaf chlorophyll (RLC) content at R1 was increased quadratically by N rate, and was greatest with conventional UAN, intermediate with UAN + eNhance, and least with High NRG-N (Fig. 2). Split applying the UAN at (V3 and V7) increased RLC compared with the V3 treatment, but delaying the split-applied treatment until V12 (15 lb at V3 + 75 lb at V12) reduced RLC considerably. These data show two potential problems with sidedress applications: (i) uptake of N from V12 applications can be severely limited and/or delayed and not meet the plant’s requirement during the reproductive stage, resulting in marked yield reduction; (ii) the application of very low rates of N (i.e. 15 lb/A, as in treatments 17 and 18) can produce early season N deficiencies that ultimately reduce yield potential.

Carryover of residual soil nitrate (RSN) increased slightly with increasing N rates up to 150 lb N/A and was significantly greater with the 180-lb rate (Table 5). The majority of the RSN was found in the 0 to 1 foot depth, which is explained by the relatively dry growing season observed during the late summer and early fall of 2008.

Results and Discussion Three-year Summary (2006 – 2008)

Significant treatment differences were found for grain and silage yield and N uptake (Table 6a). Grain yield responses up to 79 bu/A to N resulted in yields reaching 200 bu/A. Grain yields increased quadratically for conventional UAN and UAN + eNhance, but increased linearly with High NRG-N (Fig. 3). The economic optimum N rate (data not shown) for conventional UAN (28%) using a fertilizer N price: corn price ratio of 0.10 was 145 lb N/A. Significant year × treatment interactions for all production parameters may be explained by a greater N requirement in 2007 and 2008 than in 2006.

When comparing the four target N rates (60, 90, 120, and 150 lb N/A), averaged across three N sources, grain and silage yield and N uptake were optimized at the 150-lb target N rate (Table 6b). Grain and silage yield and N uptake were greatest with conventional UAN, intermediate with UAN + eNhance, and least with High NRG-N. Significant year × source interactions for corn grain and silage yield were shown by the conventional UAN and UAN + eNhance sources producing similar yields in 2006, when averaged across target N rates, but conventional UAN having greater yields in 2007 and 2008. Significant year × N rate interactions for grain and silage N uptake were explained by the 120-lb target N rate maximizing grain and silage N uptake in 2006, whereas 150 lb N/A was required in 2007 and 2008. Significant source × N rate interactions for grain and silage N uptake were explained by the 120-lb target N rate maximizing grain and silage N uptake with UAN + eNhance, whereas N uptake increased with increasing N rate with conventional UAN and High NRG-N.

Apparent fertilizer N recovery using conventional UAN (28%) at the 150 lb N/A rate was 58% in the total above-ground dry matter (silage) and 44% in the grain. When averaged across the target N rates of 60, 90, 120, and 150 lb N/A, apparent fertilizer N recovery in the total above-ground dry matter (silage) was 63, 55, and 40% for UAN (28%), UAN + eNhance, and High NRG-N, respectively; while NUE from fertilizer N was 0.73, 0.66, and 0.54 bu./lb N for UAN (28%), UAN + eNhance, and High NRG-N, respectively (data not shown).

Conclusion and Recommendation

These data show: (i) in two of three years the economic optimum N rate required for corn using conventional UAN was 15 – 20 lb N/A greater than current U of M recommendations; (ii) when averaged across the target N rates of 60, 90, 120, and 150 lb N/A, grain and silage yield and N uptake, apparent N recovery, and nitrogen use efficiency were greatest with conventional UAN (28%), intermediate with UAN + eNhance, and least with High NRG-N.

Based on these data we do not recommend using High NRG-N™ at reduced rates (60% of a conventional UAN rate) which is based on its claim of "enhanced availability". Adding eNhance™ to conventional UAN and then reducing rates (80% of a conventional UAN rate) resulted in inconsistent performance. In 2006, UAN + eNhance produced corn grain yields similar to that of conventional UAN with 20% less UAN. However in the other two years of the study it reduced grain and silage yields and N uptake compared with conventional UAN (28%). The authors suggest farmers compare the cost savings of the reduced rates vs. the added cost of the eNhance product and the added risk associated with the potential for reduced yields before they decide to use this product.

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Table 1. Corn grain, stover, and silage yield and N concentration in the grain and stover as influenced by N source, rate, and time of application for corn after soybean at Waseca in 2008.

	N management					Grain	Stover	Silage	Stover	Grain
Trt	Source	Rate	Tar*	Act**	Timing	Yield	Yield	Yield	[N]	[N]
#		gal/A	lb N/A			bu/A	- T DM/A -		%	%
1	UAN	0	0	0	V3	96.7	2.05	4.34	0.365	0.85
2	UAN	10	30	30	V3	140.6	2.58	5.90	0.353	0.98
3	UAN	20	60	60	V3	148.0	2.59	6.09	0.393	1.00
4	UAN	30	90	90	V3	167.9	2.64	6.61	0.375	1.09
5	UAN	40	120	120	V3	173.9	2.86	6.98	0.445	1.19
6	UAN	50	150	150	V3	183.8	2.90	7.25	0.540	1.27
7	UAN	60	180	180	V3	192.1	2.98	7.52	0.473	1.28
8	UAN+eNhance	16	60	48	V3	141.9	2.76	6.12	0.383	0.97
9	UAN+eNhance	24	90	72	V3	163.9	2.79	6.67	0.340	1.07
10	UAN+eNhance	32	120	96	V3	175.5	2.94	7.10	0.490	1.18
11	UAN+eNhance	40	150	120	V3	170.5	2.77	6.81	0.435	1.19
12	High NRG-N	12	60	35	V3	139.8	2.43	5.74	0.330	0.94
13	High NRG-N	18	90	52	V3	158.2	2.60	6.34	0.350	0.97
14	High NRG-N	24	120	70	V3	154.7	2.74	6.40	0.380	1.02
15	High NRG-N	30	150	88	V3	171.1	2.82	6.87	0.453	1.06
16	UAN	10+20	90	90	V3+V7	164.4	2.48	6.37	0.418	1.13
17	UAN	5+25	90	90	V3+V7	157.0	2.48	6.20	0.415	1.14
18	UAN	5+25	90	90	V3+V12	150.3	2.51	6.07	0.390	1.11
Stats for RCB Design (All Treatments)										
P > F:						<0.001	<0.001	<0.001	<0.001	<0.001
LSD (0.10):						11.8	0.27	0.37	0.058	0.08
CV (%):						6.3	8.6	4.8	12.1	5.9
Contrasts (P > F):										
Linear (trts 1 -7)						<0.001	<0.001	<0.001	<0.001	<0.001
Quadratic (trts 1 - 7)						<0.001	0.107	<0.001	0.440	0.284
Stats for RCB with 2 Factor Factorial Arrangement (treatments 3-6 & 8-15)										
N Source										
UAN						168.4	2.75	6.73	0.438	1.14
UAN+eNhance						163.0	2.82	6.67	0.412	1.10
High NRG-N						155.9	2.65	6.34	0.378	1.00
P > F:						0.002	0.212	0.002	0.002	<0.001
LSD (0.10):						5.5	NS	0.18	0.026	0.04
Target Rate, lb N/A										
60						143.2	2.59	5.98	0.368	0.97
90						163.3	2.67	6.54	0.355	1.04
120						168.0	2.85	6.82	0.438	1.13
150						175.1	2.83	6.98	0.476	1.17
P > F:						<0.001	0.072	<0.001	<0.001	<0.001
LSD (0.10):						6.3	0.19	0.21	0.030	0.04
N Source x Rate Interaction										
P > F:						0.324	0.852	0.273	0.024	0.220
CV (%):						5.7	9.8	4.6	10.7	5.9

* = Target N rate ** = Actual N rate

Table 2. Nitrogen uptake in the stover, grain, and silage (total dry matter) and apparent fertilizer N recovery in the total dry matter as influenced by N source, rate, and time of application for corn after soybean at Waseca in 2008.

	N management					Nitrogen Uptake			Target Apparent
Trt	Source	Rate	Target	Actual	Timing	Stover	Grain	Silage	N Recovery
#		gal/A	lb N/A			- -	lb N/A	- -	%
1	UAN	0	0	0	V3	15.0	38.9	53.9	
2	UAN	10	30	30	V3	18.3	65.6	84.0	100
3	UAN	20	60	60	V3	20.4	69.7	90.1	60
4	UAN	30	90	90	V3	19.9	86.8	106.7	59
5	UAN	40	120	120	V3	25.7	97.9	123.6	58
6	UAN	50	150	150	V3	31.7	110.6	142.3	59
7	UAN	60	180	180	V3	28.5	115.8	144.3	50
8	UAN+eNhance	16	60	48	V3	21.2	65.1	86.3	54
9	UAN+eNhance	24	90	72	V3	19.0	82.6	101.6	53
10	UAN+eNhance	32	120	96	V3	29.5	98.3	127.8	62
11	UAN+eNhance	40	150	120	V3	24.3	95.5	119.7	44
12	High NRG-N	12	60	35	V3	16.3	62.5	78.8	41
13	High NRG-N	18	90	52	V3	18.4	72.5	90.9	41
14	High NRG-N	24	120	70	V3	20.8	73.8	94.6	34
15	High NRG-N	30	150	88	V3	25.5	85.7	111.3	38
16	UAN	10+20	90	90	V3+V7	20.7	87.2	107.9	60
17	UAN	5+25	90	90	V3+V7	20.8	85.0	105.8	58
18	UAN	5+25	90	90	V3+V12	19.6	79.2	98.8	50
Stats for RCB Design (All Treatments)									
P > F:						<0.001	<0.001	<0.001	
LSD (0.10):						4.6	7.7	8.9	
CV (%):						17.5	8.0	7.3	
Contrasts (P > F):									
Linear (trts 1 -7)						<0.001	<0.001	<0.001	
Quadratic (trts 1 - 7)						0.976	0.014	0.030	
Stats for RCB with 2 Factor Factorial Arrangement (treatments 3-6 & 8-15)									
N Source									
UAN						24.4	91.2	115.7	59.0
UAN+eNhance						23.5	85.4	108.9	53.1
High NRG-N						20.3	73.6	93.9	38.7
P > F:						0.014	<0.001	<0.001	
LSD (0.10):						2.4	3.3	3.9	
Target Rate, lb N/A									
60						19.3	65.8	85.1	51.9
90						19.1	80.6	99.7	50.9
120						25.4	90.0	115.3	51.2
150						27.2	97.3	124.4	47.0
P > F:						<0.001	<0.001	<0.001	
LSD (0.10):						2.7	3.9	4.5	
N Source x Rate Interaction									
P > F:						0.096	0.003	<0.001	
CV (%):						17.4	6.7	6.1	

Table 3. Grain moisture, final plant population, grain oil, and grain starch content as influenced by N source, rate, and time of application for corn after soybean at Waseca in 2008

Trt	Source	N management Rate	Target	Actual	Timing	Grain H_2O	Plant Population	Grain Oil	Grain Starch
#		gal/A	- - lb N/A - -			%	$p*10^3/A$	%	%
1	UAN	0	0	0	V3	21.3	33.6	2.57	75.0
2	UAN	10	30	30	V3	20.8	33.5	2.77	74.0
3	UAN	20	60	60	V3	20.9	33.3	2.38	74.1
4	UAN	30	90	90	V3	19.7	34.1	2.67	73.8
5	UAN	40	120	120	V3	20.2	34.2	2.88	74.4
6	UAN	50	150	150	V3	19.5	33.6	2.60	73.5
7	UAN	60	180	180	V3	19.9	33.7	2.49	73.3
8	UAN+eNhance	16	60	48	V3	20.6	34.1	2.83	75.3
9	UAN+eNhance	24	90	72	V3	21.0	34.1	2.75	74.3
10	UAN+eNhance	32	120	96	V3	19.6	33.9	2.77	74.3
11	UAN+eNhance	40	150	120	V3	20.3	34.1	2.61	73.6
12	High NRG-N	12	60	35	V3	20.3	33.0	2.47	75.1
13	High NRG-N	18	90	52	V3	20.6	33.9	2.65	74.7
14	High NRG-N	24	120	70	V3	21.2	33.6	2.37	74.5
15	High NRG-N	30	150	88	V3	19.3	33.4	2.67	74.0
16	UAN	10+20	90	90	V3+V7	20.5	33.5	2.59	74.6
17	UAN	5+25	90	90	V3+V7	19.2	33.8	2.69	74.2
18	UAN	5+25	90	90	V3+V12	20.0	33.9	2.66	73.9
Stats for RCB Design (All Treatments)									
P > F:						0.002	0.304	0.178	0.314
LSD (0.10):						0.9	NS	NS	NS
CV (%):						3.8	1.7	9.1	1.4
Contrasts (P > F):									
Linear (trts 1 -7)						<0.001	0.465	0.878	0.023
Quadratic (trts 1 - 7)						0.308	0.389	0.294	0.838
Stats for RCB with 2 Factor Factorial Arrangement (treatments 3-6 & 8-15)									
N Source									
UAN						20.1	33.8	2.63	73.9
UAN+eNhance						20.4	34.0	2.74	74.4
High NRG-N						20.3	33.5	2.54	74.6
P > F:						0.413	0.051	0.069	0.278
LSD (0.10):						NS	0.4	0.14	NS
Target Rate, lb N/A									
60						20.6	33.5	2.56	74.8
90						20.5	34.0	2.69	74.2
120						20.3	33.9	2.67	74.4
150						19.7	33.7	2.63	73.7
P > F:						0.020	0.159	0.517	0.125
LSD (0.10):						0.5	NS	NS	NS
N Source x Rate Interaction									
P > F:						0.011	0.581	0.048	0.944
CV (%):						3.7	1.8	8.6	1.5

Table 4. GreenSeeker and Crop Circle NDVI and relative leaf chlorophyll content as influenced by N source, rate, and time of application for corn after soybean at Waseca in 2008

	N management					GreenSeeker		Crop Circle	Crop Circle	Relative Leaf chloro
Trt	Source	Rate	Tar*	Act**	Timing	V7	V9	V7	V9	R1
#		gal/A	lb N/A			------------	NDVI		------------	%
1	UAN	0	0	0	V3	0.596	0.761	0.556	0.630	67.3
2	UAN	10	30	30	V3	0.659	0.829	0.605	0.696	85.7
3	UAN	20	60	60	V3	0.633	0.821	0.601	0.693	87.2
4	UAN	30	90	90	V3	0.666	0.833	0.616	0.716	91.9
5	UAN	40	120	120	V3	0.660	0.837	0.618	0.719	97.0
6	UAN	50	150	150	V3	0.652	0.843	0.615	0.723	98.3
7	UAN	60	180	180	V3	0.647	0.839	0.618	0.719	99.0
8	UAN+eNhance	16	60	48	V3	0.651	0.817	0.603	0.695	84.9
9	UAN+eNhance	24	90	72	V3	0.642	0.809	0.605	0.701	89.9
10	UAN+eNhance	32	120	96	V3	0.683	0.841	0.631	0.721	95.9
11	UAN+eNhance	40	150	120	V3	0.643	0.830	0.608	0.715	95.8
12	High NRG-N	12	60	35	V3	0.610	0.809	0.582	0.681	83.3
13	High NRG-N	18	90	52	V3	0.643	0.829	0.594	0.693	86.5
14	High NRG-N	24	120	70	V3	0.666	0.799	0.620	0.711	92.2
15	High NRG-N	30	150	88	V3	0.637	0.830	0.605	0.709	94.2
16	UAN	10+20	90	90	V3+V7	0.604	0.804	0.562	0.676	95.7
17	UAN	5+25	90	90	V3+V7	0.615	0.791	0.564	0.668	95.6
18	UAN	5+25	90	90	V3+V12	0.614	0.774	0.566	0.650	87.5
Stats for RCB Design (All Treatments)										
P > F:						0.006	<0.001	<0.001	<0.001	<0.001
LSD (0.10):						0.036	0.022	0.018	0.014	0.007
CV (%):						4.7	2.3	2.5	1.7	7.8
Contrasts (P > F):										
Linear (trts 1 -7)						0.040	<0.001	<0.001	<0.001	<0.001
Quadratic (trts 1 - 7)						0.024	<0.001	<0.001	<0.001	<0.001
Stats for RCB with 2 Factor Factorial Arrangement (treatments 3-6 & 8-15)										
N Source										
UAN						0.653	0.834	0.613	0.712	93.6
UAN+eNhance						0.655	0.824	0.612	0.708	91.6
High NRG-N						0.639	0.817	0.600	0.699	89.1
P > F:						0.331	0.069	0.074	0.003	<0.001
LSD (0.10):						NS	0.012	0.010	0.006	1.7
Target Rate, lb N/A										
60						0.631	0.816	0.595	0.690	85.1
90						0.650	0.824	0.605	0.703	89.5
120						0.669	0.826	0.623	0.717	95.0
150						0.644	0.835	0.609	0.716	96.1
P > F:						0.046	0.154	0.002	<0.001	<0.001
LSD (0.10):						0.022	NS	0.011	0.007	1.9
N Source x Rate Interaction										
P > F:						0.681	0.129	0.640	0.659	0.977
CV (%):						4.9	2.4	2.7	1.5	3.0

* = Target N rate ** = Actual N rate

Table 5. Residual soil nitrate in the 0-4' profile in late October as influenced by N rate in 2008.

N		Residual soil nitrate-N (feet)				
Rate	Source	0-1	1-2	2-3	3-4	0-4
lb N/A		--------------------	ppm	--------------------		lb NO_3-N/A
0	--	4.4	0.6	1.1	2.5	34
90	UAN (28%)	7.1	0.8	1.4	2.4	47
120	UAN (28%)	9.8	1.0	1.6	2.4	59
150	UAN (28%)	9.7	1.6	2.5	2.5	65
180	UAN (28%)	15.1	1.3	2.6	2.4	86

Table 6a. Grain yield, silage yield, N uptake in the grain and silage, and apparent N recovery as influenced by N source, rate, and time of application, averaged across 2006-08.

	N management					Grain	Silage	N uptake		Target
Trt	Source	Rate	Tar*	Act**	Timing	Yield	Yield	Grain	Silage	Appar. N rec.
#		gal/A	lb N/A			Bu./A	TDM/A	-- Lb N/A --		%
1	UAN	0	0	0	V2-3	111.0	4.83	53.6	71.6	
2	UAN	10	30	30	V2-3	144.8	6.20	71.8	96.0	81
3	UAN	20	60	60	V2-3	164.4	6.76	86.5	112.7	68
4	UAN	30	90	90	V2-3	182.0	7.36	101.4	130.0	65
5	UAN	40	120	120	V2-3	190.1	7.51	112.3	144.9	61
6	UAN	50	150	150	V2-3	195.9	7.80	120.0	159.0	58
7	UAN	60	180	180	V2-3	200.5	7.99	127.2	165.8	52
8	UAN+eNhance	16	60	48	V2-3	156.4	6.49	78.9	105.2	56
9	UAN+eNhance	24	90	72	V2-3	176.2	7.18	94.2	122.1	56
10	UAN+eNhance	32	120	96	V2-3	188.6	7.57	109.4	142.8	59
11	UAN+eNhance	40	150	120	V2-3	188.2	7.57	111.4	144.5	49
12	High NRG-N	12	60	35	V2-3	149.8	6.34	75.5	98.1	44
13	High NRG-N	18	90	52	V2-3	159.3	6.57	81.9	106.3	39
14	High NRG-N	24	120	70	V2-3	171.2	7.00	90.8	116.8	38
15	High NRG-N	30	150	88	V2-3	181.3	7.32	102.0	133.9	42
16	UAN	10+20	90	90	V2+V7	183.1	7.22	103.6	134.4	70
17	UAN	5+25	90	90	V2+V7	171.5	6.84	98.2	125.5	60
18	UAN	5+25	90	90	V2+V12	154.0	6.27	84.4	108.3	41
Stats for RCB Design across years (All Treatments)										
Year										
P > F:						0.007	0.012	0.007	0.001	
LSD (0.10):						14.2	0.50	9.4	9.5	
Treatment										
P > F:						<0.001	<0.001	<0.001	<0.001	
LSD (0.10):						7.6	0.25	5.5	6.6	
CV (%):						6.6	5.2	8.5	8.0	
Contrasts (P > F):										
Linear (trts 1 -7)						<0.001	<0.001	<0.001	<0.001	
Quadratic (trts 1 - 7)						<0.001	<0.001	<0.001	<0.001	
Interaction (P > F):										
Year x treatment						0.002	0.002	<0.001	<0.001	

* = Target N rate ** = Actual N rate

Table 6b. Grain yield, silage yield, N uptake in the grain and silage, and apparent N recovery as influenced by N source, rate, and time of application, averaged across 2006-08.

	N management					Grain	Silage	N uptake		Target
Trt	Source	Rate	Tar*	Act**	Timing	Yield	Yield	Grain	Silage	Appar. N rec.
#		gal/A	lb N/A			Bu./A	TDM/A	-- Lb N/A --		%
Stats for RCB with 2 Factor Factorial Arrangement across yr (treatments 3-6 & 8-15)										
Year (Yr)										
2006						197.6	7.77	109.3	139.1	51
2007						165.8	7.02	98.4	133.8	57
2008						162.4	6.58	83.4	106.1	50
P > F:						0.006	0.009	0.005	0.001	
LSD (0.10):						14.5	0.49	9.5	9.7	
N Source										
UAN						183.1	7.36	105.1	136.7	63
UAN+eNhance						177.4	7.20	98.5	128.7	55
High NRG-N						165.4	6.81	87.6	113.8	40
P > F:						<0.001	<0.001	<0.001	<0.001	
LSD (0.10):						3.8	0.12	2.7	3.3	
Target Rate, lb N/A										
60						156.8	6.53	80.3	105.3	56
90						172.5	7.04	92.5	119.5	53
120						183.3	7.36	104.2	134.9	53
150						188.5	7.56	111.1	145.8	49
P > F:						<0.001	<0.001	<0.001	<0.001	
LSD (0.10):						4.4	0.14	3.1	3.8	
CV (%):						6.4	4.9	8.1	7.8	
Interactions (P > F):										
Yr x source						0.073	0.066	0.238	0.097	
Yr x target rate						0.357	0.773	0.044	0.042	
Source x target rate						0.442	0.130	0.055	0.021	
Yr x source x target rate						0.369	0.073	0.088	0.178	

* = Target N rate ** = Actual N rate

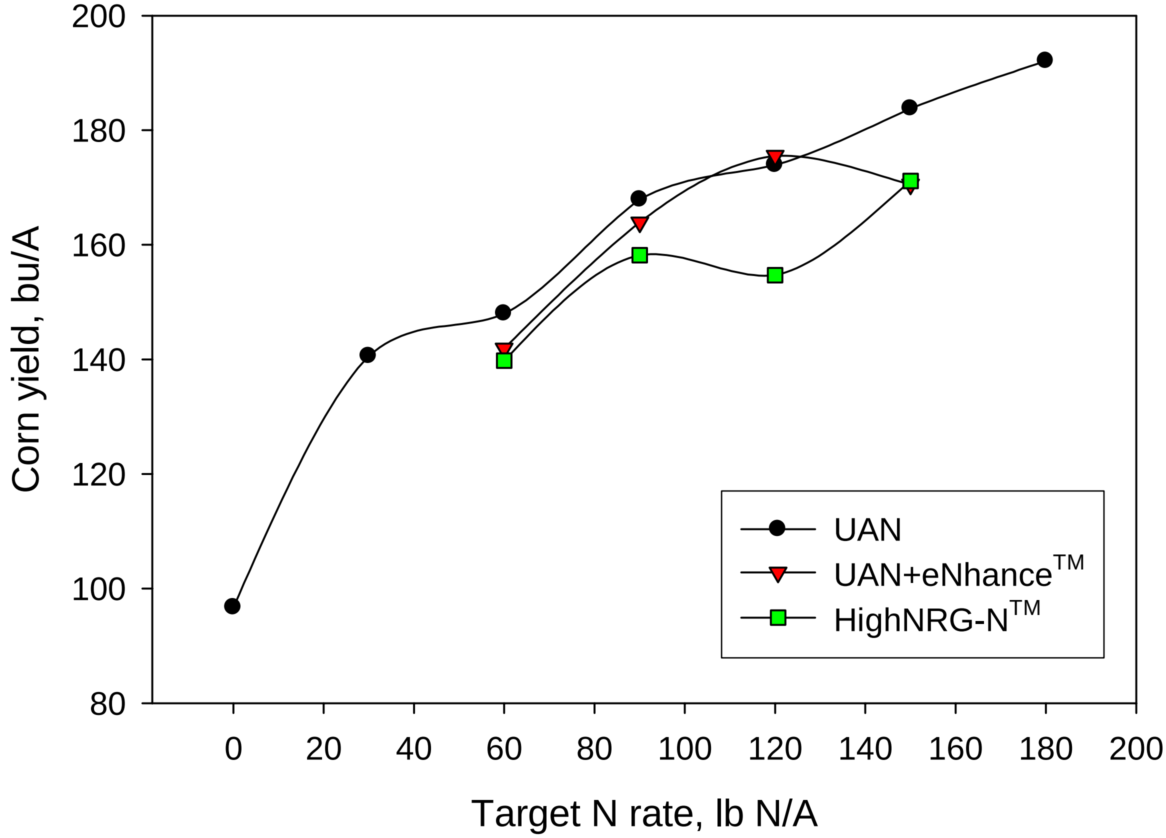

Figure 1. Corn grain yield as influenced by source of fluid N in 2008.

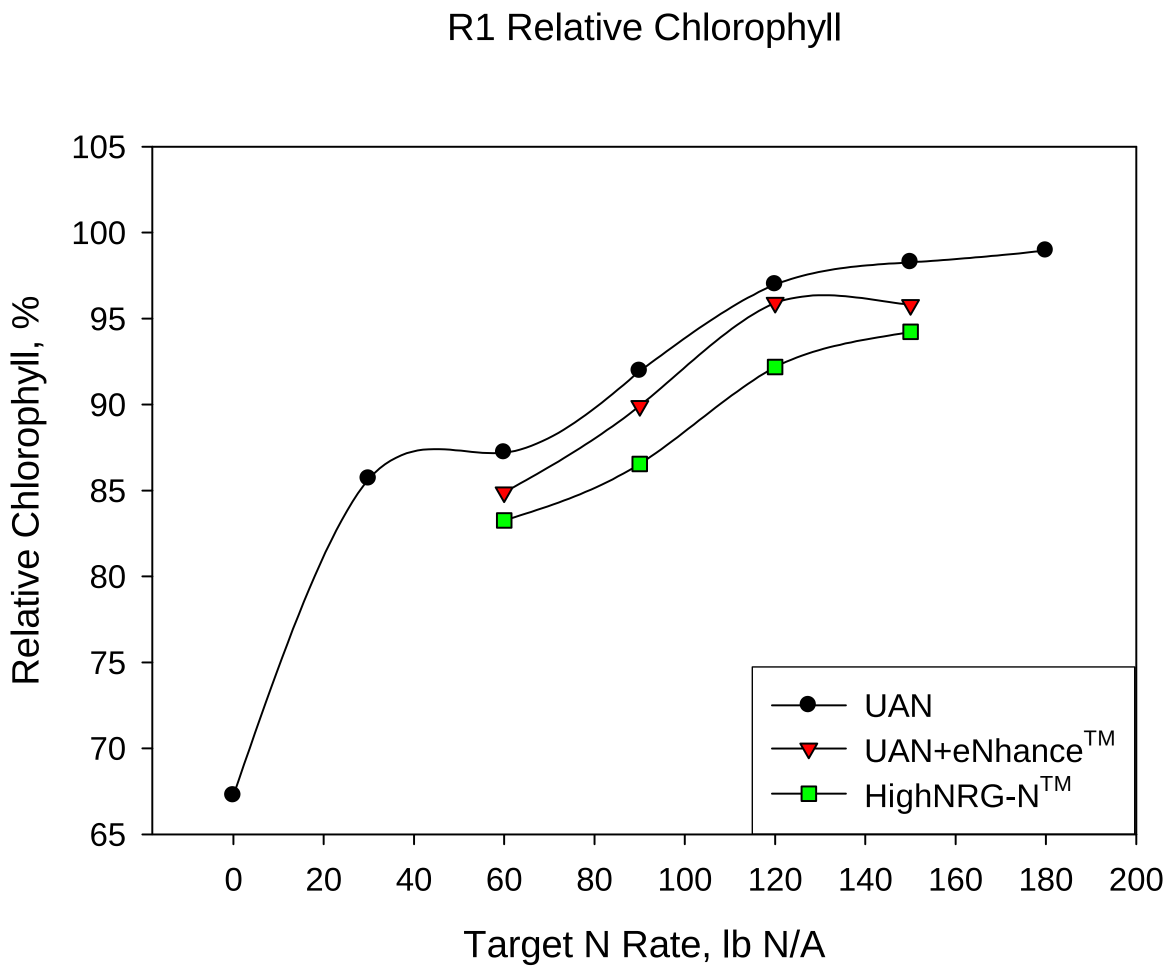

Figure 2. Relative leaf chlorophyll at R1 as influenced by source of fluid N in 2008.

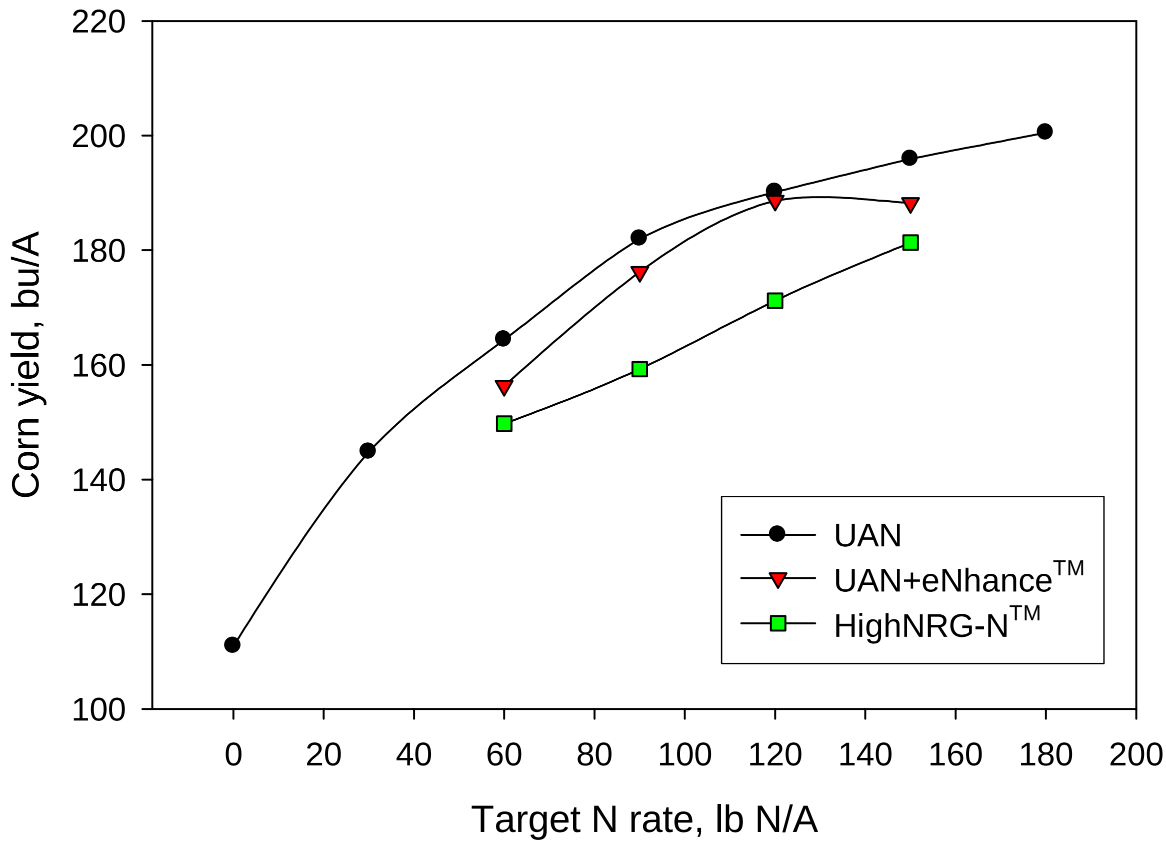

Figure 3. Corn grain yield as influenced by source of fluid N from 2006 through 2008.