EVALUATION OF NITRATE LEACHING POTENTIAL FROM SLOW AND CONTROLLED RELEASE NITROGEN FERTILIZER APPLICATION TO IRRIGATED CORN

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Abstract

The use of slow and controlled release nitrogen (N) fertilizers as a practice to reduce nitrate leaching from irrigated corn was evaluated on coarse-textured soils in the Central Platte River Valley of Nebraska in 2007 & 2008. Slow-release methylene urea (MU) and polymer-coated urea (PCU) were compared to a standard fertilizer of urea ammonium nitrate (UAN) solution. Flooding in 2007 severely impacted the study site, and results are not reported here. Saturated soils were common at the site in 2008 as well, but conditions were considered more representative of the treatments. However, stalk breakage from a mid-July storm resulted in a high degree of variation, with stalk breakage severity confounded with N rate. Thus there were no significant differences in grain yield among N sources. There were trends for reduced dry matter yield and N uptake, and increased N leaching, with sidedress application of UAN-MU, suggesting potentially reduced N availability with this treatment. Little to no N leaching occurred through most of the season; in fact a high water table associated with above-average rainfall resulted in upward movement of soil water and nitrate during parts of the growing season. Nitrate leaching in general did not occur until after early September, when crop uptake of N was basically complete. Cumulative nitrate N leached ranged from -27 lb N/acre for the unfertilized check to 182 lb N/acre for the UAN-MU sidedress treatment at 250 lb N/acre.

Introduction

This study, initiated in 2007, was designed to evaluate the effects of controlled and slow release formulations of nitrogen on irrigated corn production in Nebraska. The study in particular evaluated nitrate leaching during the growing season from slow release N formulations and compared them to nitrate leaching from UAN solution applied at planting. A liquid formulation of methylene urea (Georgia Pacific) and polymer-coated urea (Agrium) were the slow and controlled release N products evaluated.

Materials and Methods

The study was conducted in 2008 on a producer's field in Merrick County, Nebraska. The field was selected due to coarse-textured soils, location in the Phase III area of the Central Platte Natural Resources District groundwater management area, and relatively low levels of nitrate in irrigation water. Field results in 2007 were affected by flooding during much of the season. For 2008, the study was located in the same field but in an area with higher elevation. The farmer/cooperator was responsible for most agronomic activities - management practices (hybrid selection, fertilizer other than N, pesticides, irrigation, etc.) were at the discretion of the farmer with the intent to optimize yield potential. The soil at this location (Inavale loamy fine sand) and the production systems used are typical of irrigated corn production in the Central Platte Valley region of Nebraska.

The previous crop at this location was corn (cattle-grazed stalks). Site-preparation consisted of a spring disking. Spring soil sampling took place April 2 (Table 1). The cooperator planted the field April 29 to Pioneer 34R67- RR2/Liberty Link corn. On May 5, UNL applied 3 qt/ac Lexar herbicide (pre-emergent broadcast) to the study area to avoid the farmer's use of UAN as an herbicide carrier on the surrounding field.

The study was a randomized complete block design with 18 treatments and 4 replications. Specific treatments were:

Trt.	Fertilizer Source, Timing	N-Rate (lb N/acre)
1.	Check	0
2.	UAN solution - 30% at planting / 70% sidedress	177 (UNL REC)
3.	UAN solution – at planting	50
4.	UAN solution – at planting	100
5.	UAN solution – at planting	150
6.	UAN solution – at planting	250
7.	80/20 UAN / methylene urea (MU) – at planting	50
8.	80/20 UAN / MU – at planting	100
9.	80/20 UAN / MU – at planting	150
10.	80/20 UAN / MU – at planting	250
11.	30% UAN-at planting; 70% 70/30 UAN / MU – sidedress	50
12.	30% UAN-at planting; 70% 70/30 UAN / MU – sidedress	100
13.	30% UAN-at planting; 70% 70/30 UAN / MU – sidedress	150
14.	30% UAN-at planting; 70% 70/30 UAN / MU – sidedress	250
15.	Polymer-coated urea (PCU) – at planting	50
16.	PCU – at planting	100
17.	PCU – at planting	150
18.	PCU – at planting	250

Plot dimensions were 4 rows (10 ft) wide by 35 ft long. At-planting fertilizer treatment application took place May 9. All treatments were applied by hand. Polymer-coated urea treatments were worked into the soil surface with garden rakes. Sidedress applications (treatments 2, 11-14) took place June 17, 2008 (49 days after planting). In-season weed control consisted of a post-emergent broadcast of 1 qt/ac Roundup herbicide to the study area June 13, then spot spraying Roundup using backpack sprayers July 14.

In-season sampling and evaluation occurred throughout the growing season. Watermark sensors were installed May 14 at 1, 2, and 3 ft depths to monitor soil moisture conditions. Lysimeters were installed to allow collection of soil pore water samples from a 3 ft depth. An automated weather station was installed in the SW corner of the field outside the irrigated area. A tipping-bucket rain gauge was also installed within the study area to determine irrigation amounts.

Plant population was measured at V3 and at physiological maturity. Chlorophyll readings were collected from the uppermost fully expanded leaf approximately bi-weekly. Soil pore water was collected from lysimeters weekly to bi-weekly. Above-ground biomass and grain yield were measured at physiological maturity. Residual soil nitrate-N was determined by sampling in November to a depth of 3 ft.

Table 1. Pre-study nutrient levels.

Rep	pH	Buffer pH	OM (%)	M-3 P (ppm)	K (ppm)	Zn (ppm)	0-8 in. NO_3-N (ppm)	8-20 in. NO_3-N (ppm)	20-36 in. NO_3-N (ppm)
1	5.6	6.5	1.1	32	212	2.78	6.7	4.3	2.4
2	5.3	6.7	1.0	29	183	3.21	5.0	3.3	1.1
3	5.2	6.5	1.3	23	166	2.58	5.9	4.4	3.0
4	5.3	6.6	1.2	24	195	2.52	6.4	3.5	1.7
Mean	5.4	6.6	1.2	27	189	2.77	6.0	3.9	2.1

Note: UNL N recommendation for 200 bu. yield goal = 220 lb N/acre
-6 lb N/acre credit for preplant broadcast dry N by farmer
-22 lb N/acre credit for starter fertilizer
-15 lb N/acre credit for irrigation water (7.5 ppm NO_3-N)

177 lb N/acre adjusted UNL N recommendation.

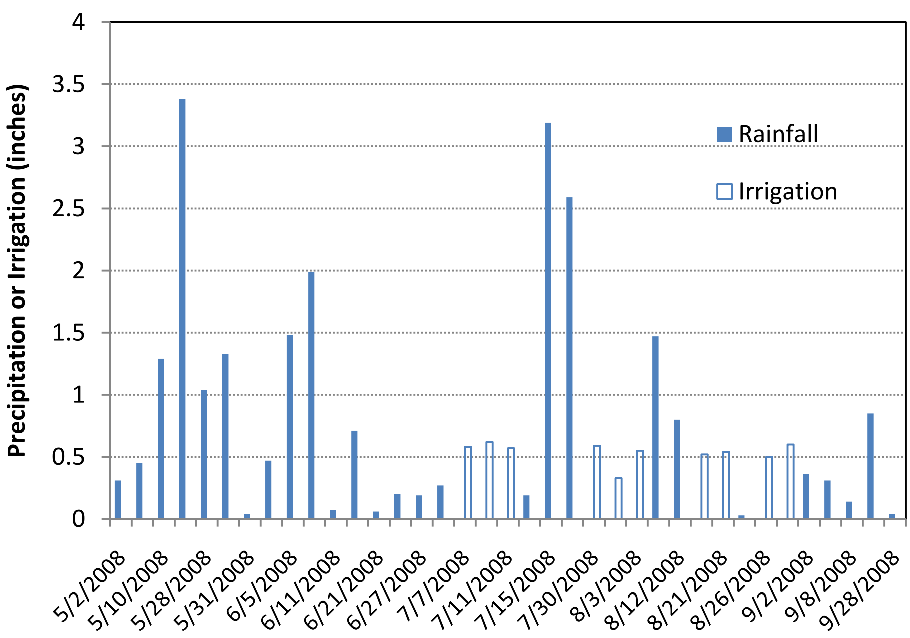

Figure 1. Growing season precipitation and irrigation (May – September.)

Results and Discussion

Initial May 20th corn stand counts of the 72 plots showed an average 30,038 plants per acre. A July 15 windstorm (50+ mph winds) caused stalk breakage that averaged 28%. Stalk breakage was correlated with treatments – treatments resulting in more rapid growth and greater biomass suffered greater stalk breakage (Figure 2).

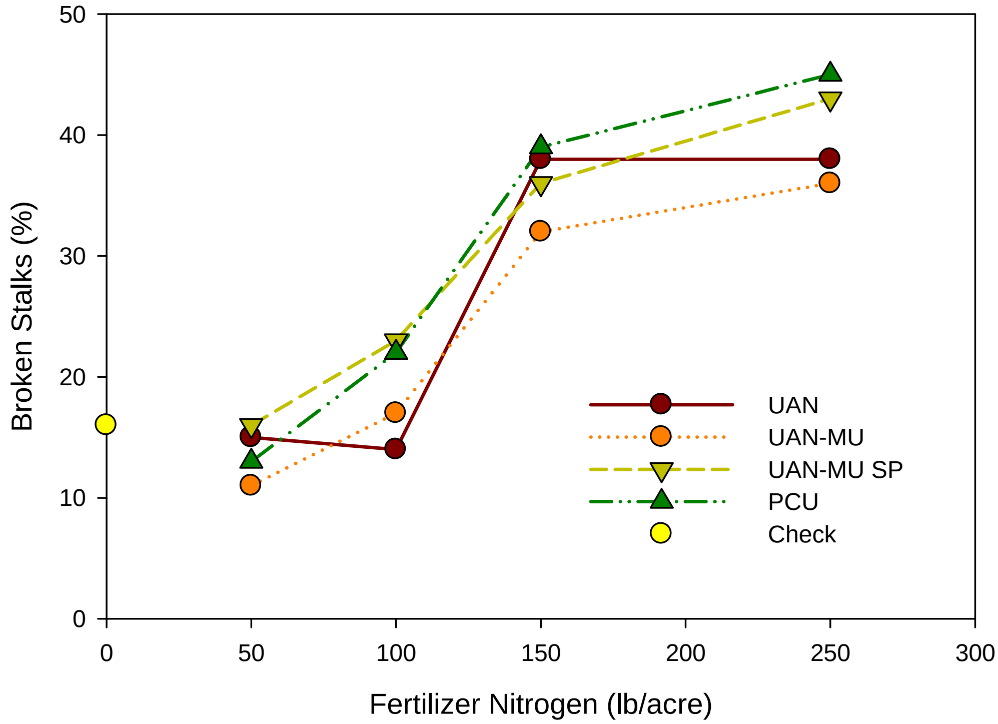

Figure 2. Wind-broken stalks as influenced by fertilizer N rate and source.

Due to the reduction in stand, the average population at harvest was 25,815 plants per acre. Rainfall during the May 1 through Oct. 1, 2008 growing season totaled 23.29 inches (138% of normal) (Figure 1). Due to persistent rains in May, June, and July, nearby areas of the field were affected by the high water table that developed, causing prolonged flooded conditions. Fortunately, the study area was only slightly affected by this problem, though some plant stunting and invasive foxtail weed pressure resulted. A drier August led to frequent irrigations throughout that month. Total season irrigation applied was 5.40 inches (10 events). Following harvest, 5.91 inches of rain fell in October (348% of normal).

Table 2. Chlorophyll data.

			(avg. SPAD values)							
		N	V5	V6	V7	V8	VT	Pollin.	Blister	Dough
Trt	Fertilizer		June	June	July	July	July	July	July	Aug
No.	Source & Timing	(lb/ac)			1	9				14
1	Check	0	**29.3**	**34.7**	**36.5**	**42.8**	**46.5**	**47.9**	**48.3**	**53.4**
2	UNL REC - UAN	177	**30.6**	**41.1**	**43.9**	**51.7**	**50.0**	**54.7**	**54.3**	**54.1**
3	UAN	50	30.6	37.6	38.9	43.7	48.0	46.7	46.9	55.8
4	UAN	100	31.1	36.7	38.9	42.4	47.3	48.5	46.7	53.2
5	UAN	150	33.5	43.1	45.6	51.1	53.1	55.5	52.7	58.2
6	UAN	250	33.5	42.6	45.1	50.9	53.1	52.4	49.3	53.2
		AVG	**32.2**	**40.0**	**42.1**	**47.0**	**50.4**	**50.8**	**48.9**	**55.1**
7	UAN - MU	50	28.7	36.4	39.2	43.2	45.6	47.0	44.9	56.0
8	UAN - MU	100	32.2	39.2	41.0	48.5	51.5	52.1	50.8	53.5
9	UAN - MU	150	33.0	40.5	41.5	49.1	51.2	53.5	52.9	55.6
10	UAN - MU	250	35.7	43.2	44.6	53.0	53.1	54.3	52.7	55.9
		AVG	**32.4**	**39.8**	**41.5**	**48.4**	**50.3**	**51.7**	**50.3**	**55.2**
11	UAN – MU SP	50	28.7	37.8	37.8	45.1	47.0	49.6	50.1	57.2
12	UAN – MU SP	100	32.2	38.4	42.4	48.1	51.3	52.0	52.1	53.1
13	UAN – MU SP	150	27.5	37.0	41.1	47.9	50.2	51.8	50.8	56.3
14	UAN – MU SP	250	29.2	40.1	43.9	52.1	51.5	53.1	53.1	54.9
		AVG	**29.4**	**38.3**	**41.3**	**48.3**	**50.0**	**51.6**	**51.5**	**55.4**
15	PCU	50	30.4	36.0	37.8	44.3	46.6	48.9	46.7	54.2
16	PCU	100	29.2	41.1	42.9	48.0	51.2	51.0	52.7	56.7
17	PCU	150	30.5	43.6	43.9	50.6	51.9	52.8	53.1	57.1
18	PCU	250	31.4	43.7	46.1	50.9	51.9	56.0	55.2	52.5
		AVG	**30.4**	**41.1**	**42.6**	**48.4**	**50.4**	**52.2**	**51.9**	**55.1**

Chlorophyll

The N status of the growing corn was measured at 8 growth stages during the season (Table 2). There was more N treatment effect on chlorophyll at early vegetative growth stages than was evident after pollination. The highest N application rate usually had the highest chlorophyll meter readings. There appeared to be some slight benefit to the slow N release products in chlorophyll level, especially after VT. The PCU (treatments 15-18) and MU (treatments 7-14) showed slightly higher chlorophyll levels than UAN-only plots and check plots at pollination and blister growth stages.

Table 3. Dry matter, grain yield, and fall soil residual nitrate-N.

Trt No.	Fertilizer Source & Timing	N Rate (lb/acre)	Grain Yield (bu/acre)	**Total Dry Matter Yield (ton/acre)	** Total Dry Matter N Recovery (lb/acre)	3 ft Soil NO_3-N (lb N/acre)
1	Check	0	**131.5 b**	**7.77 b**	**165.4 b**	**24.7 a**
2	UNL REC - UAN	177	**188.9 a**	**10.75 a**	**233.9 a**	**25.9 a**
3	UAN	50	154.0	9.29	188.2	18.0
4	UAN	100	144.0	8.70	176.0	18.4
5	UAN	150	195.3	11.81	258.5	22.2
6	UAN	250	185.1	11.02	237.4	25.3
		AVG	**171.3 a**	**10.30 a**	**217.6 a**	**21.0 a**
7	UAN - MU	50	148.4	8.80	190.2	16.3
8	UAN - MU	100	164.9	9.30	191.6	20.8
9	UAN - MU	150	177.4	10.67	234.0	22.6
10	UAN - MU	250	210.4	12.50	284.7	23.3
		AVG	**175.3 a**	**10.32 a**	**225.1 a**	**20.7 a**
11	UAN – MU SP	50	154.1	8.60	183.6	17.1
12	UAN – MU SP	100	169.2	9.71	211.7	20.0
13	UAN – MU SP	150	142.7	7.80	174.4	24.4
14	UAN – MU SP	250	182.8	10.20	226.6	25.4
		AVG	**163.5 a**	**9.16 ab**	**200.7 ab**	**21.7 a**
15	PCU	50	155.1	8.78	183.2	23.5
16	PCU	100	179.8	10.28	224.5	24.9
17	PCU	150	190.6	11.20	244.3	18.9
18	PCU	250	184.9	10.07	227.1	26.3
		AVG	**177.6 a**	**10.08 a**	**219.8 a**	**23.4 a**

*** includes stover, cobs, & grain (based on calculated population at harvest)*

Yield and N Recovery

As indicated earlier, the study site was subjected to saturated soil conditions in June which reduced both dry matter and grain yield potential. In addition, significant stand reduction from the wind storm in July reduced yield potential. Areas within plots were selected for hand harvest which were most uniform in stand. Total dry matter yield across plots averaged 9.9 tons/acre. This was considerably more than the average 5.1 tons/ac harvested from the 2007 study in the same field when grain yields averaged just 113 bu/acre. In 2008 grain yields averaged 171 bu/acre, with plot yields ranging from 88 to 242 bu/ac. There were no significant differences in dry matter or grain yield among fertilizer sources. Within each N source, increased N application generally contributed to increased yield.

From the soil sampling conducted in the fall, it was evident that overall residual nitrate was very low. No differences in residual nitrate were present across all treatments. Substantial rainfall in October likely moved any significant residual N below the root zone, though lysimeters had been removed before this rainfall occurred. Therefore, there were no effects of N source on nitrate accumulation in the root zone after harvest. Nitrogen recovery in above-ground biomass was similar among all N sources tested.

Water and Nitrate Flux

Soil pore water samples were collected weekly (biweekly later in the season) and analyzed for nitrate content. Typically a crew visited the site one day to apply a vacuum to the lysimeters, and then returned 24 hrs later to collect water samples. Watermark sensors were placed at 1, 2 and 3 ft depths, with soil matric potential logged every 10 minutes. Water flux was calculated based on the difference in matric potential at each depth, and unsaturated hydraulic conductivity parameters for the soil.

Due to wet conditions in June, and the resulting high water table, there was negative water flux part of the year, in which water moved upward into the root zone (Figure 3). This was especially the case for the unfertilized check. Crop water removal was less for this treatment than for fertilized treatments, so water accumulated in the root zone of the check throughout the season. Due to variability in water flux from plot to plot, an average water flux was calculated within each N rate, across N sources. These N rate average flux values were used to calculate nitrate flux, using treatment-specific pore water nitrate-N concentrations. Watermark sensors were not located in the 150 lb N/acre treatments. Thus, the average flux for 50 and 250 lb N/acre treatments (overall mean in Figure 3) was used to calculate nitrate-N flux for the 150 lb N/acre treatments.

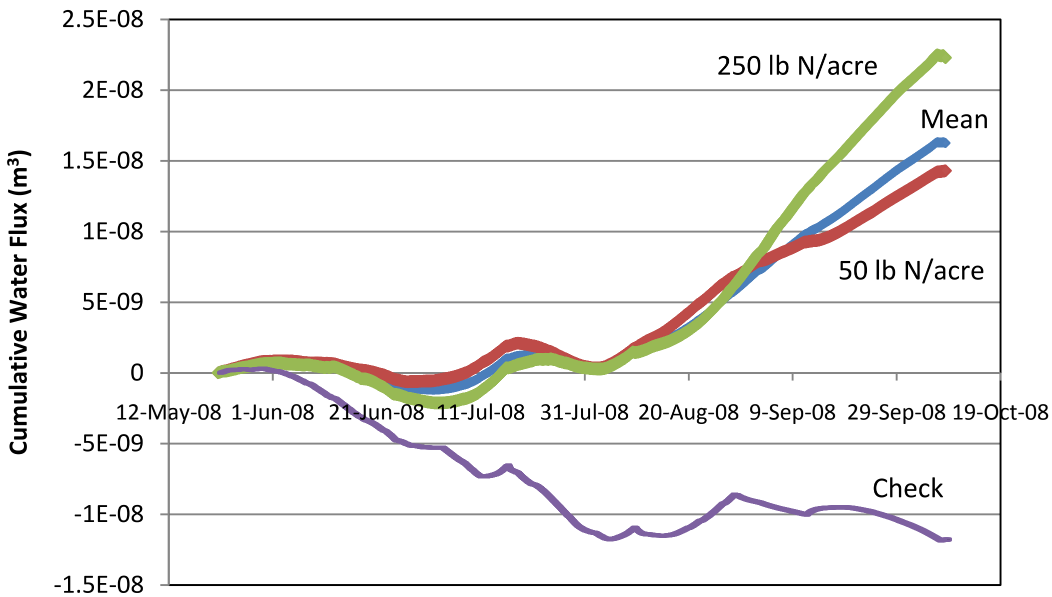

Figure 3. Growing season cumulative water flux 2008. Values are averaged over N sources within N rates. Overall mean is the average of 50 and 250 lb N/acre treatments.

Due to the wet conditions in general, it was possible to collect pore water samples from the bottom of the root zone for most plots throughout the year (Figures 4 and 5). There was a tendency for nitrate concentrations to decline in July as crop N uptake rates peaked. Nitrate concentrations in soil water at the bottom of the root zone then increased later in the growing season.

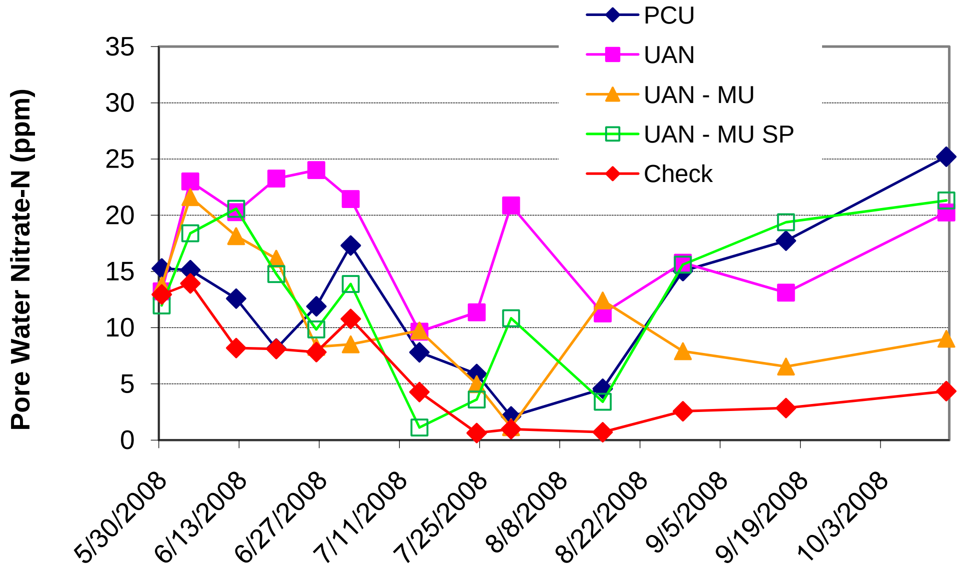

Figure 4. Pore water nitrate-N concentrations during the growing season, averaged over N rate.

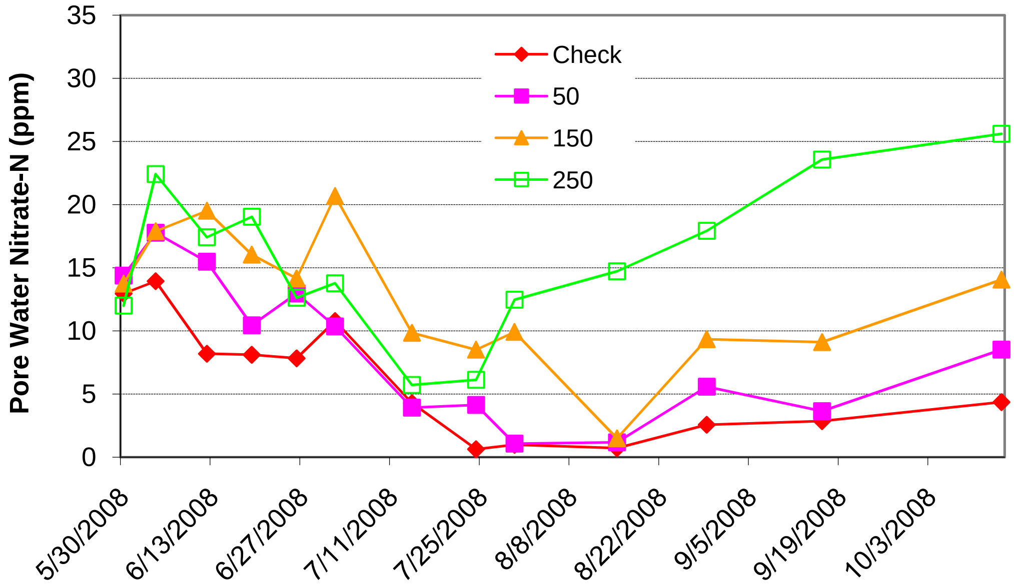

Figure 5. Pore water nitrate-N concentrations during the growing season, averaged over N source.

Due to the negative water flux in the unfertilized check treatment, this treatment actually accumulated 27 lb N/acre through the course of the growing season. Cumulative nitrate-N leached for the other treatments ranged from 9 to 182 lb N/acre (data not shown). Through the early and middle parts of the growing season, very little N leaching was measured. In fact, due to upward movement of water into the root zone from the high water table, there was slight N accumulation in several treatments into late July. Most leaching loss occurred late in the season, from late August through October. By late August, N uptake by the crop was mostly complete. Late-season N uptake was lower than in a normal growing season due to the loss of plant stand with wind damage in mid-July.

Cumulative nitrate-N leached for the 150 lb N/acre treatments is shown in Figure 6. This also includes leaching data for the UNL recommended rate treatment, which was 177 lb N/acre, split-applied as UAN solution. Thus, the recommended N rate for this site was not much different from the 150 lb N/acre treatment. However, nitrate leaching loss was much higher for the UNL REC treatment (85 lb N/acre) than the UAN 150 lb/acre treatment (19 lb N/acre). This disparity in leaching loss, with only 27 lb N/acre difference in application rate, may be related to difference in time of application as much as rate, but also indicates there is a high degree of variability in this leaching data, perhaps related to wet conditions and crop stress throughout the season.

Figure 7 provides the mean cumulative nitrate-N leached at the end of the growing season for each treatment. Nitrate leached increased with fertilizer N application rate as would be expected. In general, slow and controlled release N formulations did not reduce total nitrate leaching, compared to the standard UAN formulation. This finding is contrary to expectations at the start of the study, but may be related to the conditions of the study for this year. The loss of crop stand, particularly in the higher N rate treatments, likely caused crop N uptake to be quite low from mid-July on. If N was gradually released from slow and controlled-release formulations in late June and early July, it is likely that this N was not used effectively by the crop. This is likely evident in the UAN-MU SP treatments, which included a sidedress application of 70% of total N as slow release methyl urea along with UAN, in addition to 30% of total N applied as UAN solution at planting. Nitrate-N leaching loss is higher for this treatment across all application rates (Figure 7), while grain yield and N uptake tended to be lower (Table 3).

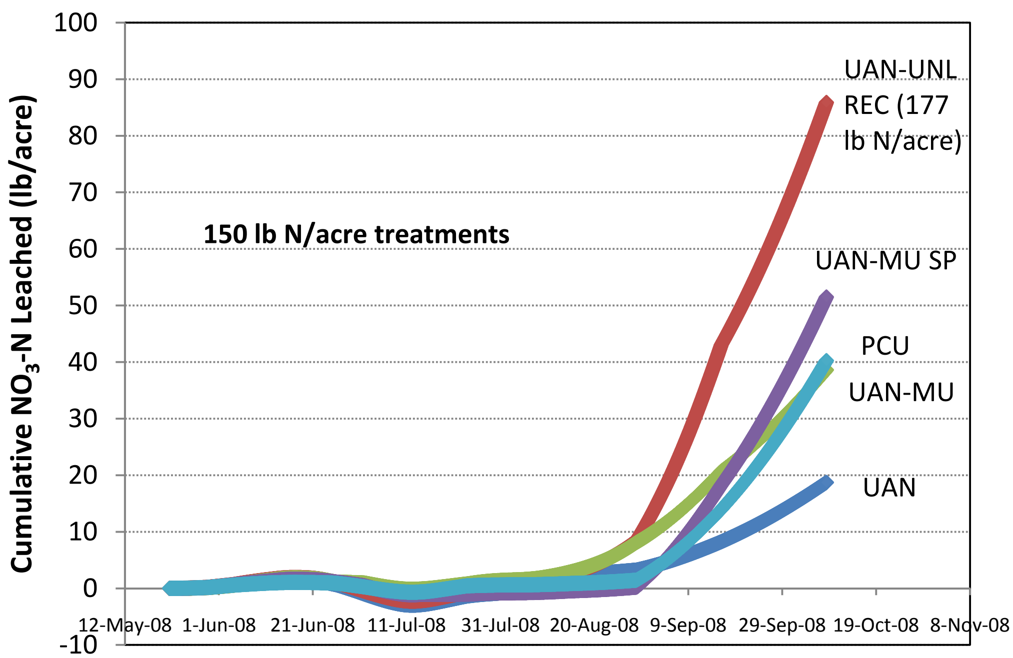

Figure 6. Cumulative nitrate-N leached, 150 lb N/acre and UNL-REC (177 lb N/acre) treatments.

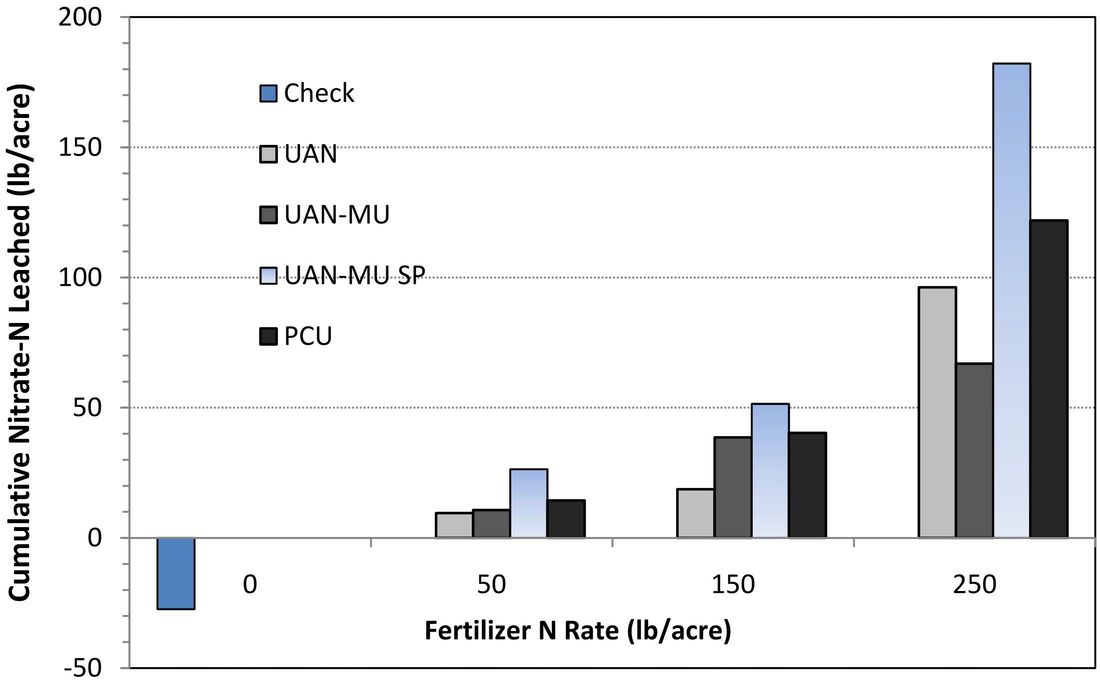

Figure 7. Total nitrate-N leached by N source and N rate.

Summary

Unfortunately the growing conditions for this study in 2008 did not allow a representative evaluation of the effects of slow and controlled release N formulations on leaching potential in a normal growing season. There were no statistically significant effects of N source on grain yield, N uptake, or soil residual nitrate-N. Nitrate leaching levels were quite low, or even negative, throughout most of the growing season – most leaching loss occurred at the end of the growing season, or after physiological maturity. There was no evident benefit to slow or controlled-release formulation on nitrate leaching compared to the standard practice of UAN application at planting.

This study will be repeated in 2009, at a different location, with the same sources and N rates.

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