IMPACT OF N FERTILIZER SOURCE AND DRAINAGE ON SPATIAL VARIATION IN NITROGEN USE EFFICIENCY AND ENVIRONMENTAL N LOSS

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Summary:
Research was conducted in 2006 and 2007 to compare the relative corn growth response and environmental N losses after application of different N fertilizer sources under a range of soil moisture conditions imposed by drainage and irrigation, to examine spatial differences in soil N transformations and N losses during the growing season between drainage tile and subirrigation lines, and to evaluate the relative cost-effectiveness of use of several N fertilizer sources and drainage and irrigation systems to control soil moisture conditions that may reduce N use efficiency.

Among the findings of the study were:

∉ The use of overhead irrigation, subirrigation, and tile drainage systems and N fertilizer applications consistently increased corn grain yields and gross returns compared to non-irrigated and non-drained plots over the two years of this study. The gross economic returns ranged from an average increase of $35/acre in the tile drained plots with an application of anhydrous ammonia to an increase of $354/acre in the overhead irrigated plots with an application of polymer-coated urea (PCU). In general, application of UAN solution did not appear to be as effective as other N sources, especially under conditions when the soil was not drained or irrigated.

∉ The effects of the tile drainage system on the soil profile distribution of soil water content over and above the tile lines compared to the non-drained plots were not consistent during the growing season. In contrast, the subirrigation lines did increase soil water content in the 0 to 6 and 6 to 12 inch depth, but this increase occurred primarily directly above the irrigation line. The subirrigation system with 20 foot spacing between the irrigation lines was not effective in wetting the entire soil profile between the lines resulting in higher grain yields above the lines but not between the lines. Modification of the subirrigation system would need to be made to make it more effective given the relatively low rate of soil water movement in claypan soils.

∉ Preliminary results for N uptake in the 2006 season indicated that N recovery efficiency varied widely among the treatments (0 to 47 % recovery of applied N) and did not explain the observed differences in grain yields among the treatments.

Materials and Methods:
A field trial was conducted in 2006 and 2007 at the University of Missouri Drainage and Subirrigation (MUDS) trial. The MUDS trial was initiated in 2001 at the MU Ross Jones Farm in Northeast Missouri to evaluate the use of subsurface tile drainage at different drain tile spacings with or without subsurface irrigation to improve soybean and corn production. For this study, 150 ft long plots planted to corn (Roundup Ready and Bt resistant variety DKC61-68) containing treatments of: i) no drainage or subirrigation (NIN), ii) drainage with tile drains spaced 20 ft apart and no subirrigation (NID), iii) drainage with tile drains spaced 20 ft apart and subirrigation (SUB), and iv) no drainage and overhead sprinkler irrigation (OND)was split into a control and N fertilizer treatments of either spring-applied pre-plant injected anhydrous ammonia, or broadcast-applied urea-ammonium nitrate (UAN) solution, urea, or polymer-coated urea (PCU) (ESN⊇, Agrium) applied at a rate of 150 lbs N/acre. Each treatment combination had 3 replications. All plots were chisel plowed in the fall and N treatments incorporated in the spring with a field cultivator. Based on preliminary soil test results, no additional P and K fertilizer or lime were applied prior to planting.

Changes in soil inorganic N (NH_4^+-N and NO_3^--N) content and soil gravimetric water content due to the irrigation/ drainage treatments were monitored by periodic soil sampling using a Gator-mounted Giddings hydraulic soil core sampler at depths of 0-6, 6-12, 12-18, and 18-24 inches. In the NID and SUB treatments, samples were collected by compositing 3 subsamples taken at a distance of 0, 5, and 10 ft from the drainage or subirrigation lines. For the anhydrous ammonia treatment, the subsamples were taken in the injection band and two distances towards the next band. All samples were collected in coolers and stored in a cold room before processing.

Silage yields were determined by harvesting 15 to 25 ft of corn plants at physiological maturity in one row either above the tile line or 10 ft from the tile line. All harvested plants were weighed and a subsample taken to determine moisture content and analyze for tissue N. Both the silage yield and N content will be used to calculate crop N uptake. Grain yields and grain moisture were determined on approximately 25 ft of row with a two row plot combine. The relative gross returns of the different N fertilizer and irrigation/drainage treatments were determined by calculating the difference between grain yields in the plots with the different irrigation/drainage treatments and the plots with no irrigation or drainage treatments and then taking the yield difference and multiplying it by an estimated price of corn ($3.50/bu).

Results:

∉ Based on preliminary analysis of measurements of soil water content during the 2006 growing season, no consistent differences in soil water content were observed due to use of drainage tile either immediately above or between the tile lines compared to non-drained plots (Table 1). However, some increase in soil water content was observed above the subirrigation lines primarily in the 0 to 6 and 6 to 12 inch depths. In general, the highest water content in the claypan soil profile was observed in the 12 to 18 and 18 to 24 inch depths. Analysis of the inorganic N in the soil has not been completed but these data will be used to determine the effects of the N treatments, the irrigation/drainage system and the distance away from the tile line on soil N distribution in the soil profile.

- ∉ Grain yields were consistently higher in 2006 and 2007 with use of overhead sprinkler irrigation, subirrigation and tile drainage alone compared to a non-irrigated and non-drained control (Table 2). The highest yield response to subirrigation was directly above the subirrigation lines (spaced 20 feet apart) which by visual observation was probably due to the slow diffusion of water from the lines into the surrounding soil. Use of drainage tile spaced 20 feet apart generally increased grain yields both directly above and between the drainage tile.

- ∉ Some differences in grain yield response were observed among the different N fertilizer sources in interaction with the drainage/irrigation treatments (Table 2). In the plots with no irrigation and no installed drainage systems, all the N fertilizer treatments increased grain yields above the control in 2006 and 2007. However, in 2007, PCU had significantly higher yields compared to urea in those plots. In 2007 under overhead irrigation, PCU and anhydrous ammonia applications had higher yields compared to UAN solution. Directly above the subirrigation lines, PCU and urea outyielded UAN solution in both 2006 and 2007.

- ∉ Preliminary analysis of plant aboveground N uptake does show the expected increase in plant N uptake with N fertilizer addition, but it does not completely explain the observed differences in yields under the different N fertilizer treatments and irrigation/drainage systems (Table 3). Estimates of the N recovery efficiency of the applied N fertilizer vary widely among the treatments from between 0 to 47% plant N recovery of the applied fertilizer N (data not shown).

- ∉ Economic analysis of the use of the different irrigation/drainage systems and N fertilizers indicates that the combination of overhead irrigation and N fertilization resulted in the highest average gross economic returns (Table 4). Gross returns were ranked OND > SUB > NID over the non-drained, non-irrigated control. With overhead irrigation, the PCU application averaged $18/acre greater return than the urea treatment. Based on a price differential of 6¢/lb N between urea and PCU, the net return would be approximately $9/acre using PCU over urea under overhead irrigation. In contrast, under tile drainage and subirrigation systems, no additional gross return was observed using PCU compared to urea. This may be due to reduced N loss due to denitrification in the presence of subsurface drainage. In general, the results indicate that use of irrigation and drainage systems in combination with N fertilization can increase gross returns in claypan soils. However, due to the varying costs of installation and maintenance of these systems, further calculations would have to be made to determine if they would be economically profitable for a specific location.

Table 1. Soil water content on June 28th, 2006 at the Ross Jones Farm due to differences in N fertilizer sources, drainage and irrigation systems and the distance between tile lines.

		NID‡				SUB¶			
N treatment	NIN†	0*	5	10	$LSD_{(0.05)}$**	0	5	10	$LSD_{(0.05)}$
	---------- % by dry weight ----------								
					0 – 6 inch depth				
Control	14.05	17.82	14.90	16.46	1.73	17.61	16.08	15.37	NS
Anhydrous	11.48	17.33	14.75	16.33	1.20	16.08	14.96	14.64	NS
Urea	12.93	18.39	14.18	14.00	4.18	17.84	13.29	15.67	3.20
PCU	13.69	15.94	13.95	15.74	NS	15.87	13.74	13.57	NS
$LSD_{(0.05)}$	2.34	NS	NS	NS		NS	2.57	NS	
					6 – 12 inch depth				
Control	16.36	18.21	17.22	21.02	NS	24.08	16.15	17.72	NS
Anhydrous	12.83	16.01	15.09	16.70	NS	16.75	17.01	17.28	NS
Urea	14.97	24.46	16.00	15.10	NS	25.59	17.27	18.13	NS
PCU	15.29	23.81	15.47	20.77	NS	20.61	16.74	23.47	NS
$LSD_{(0.05)}$	NS	NS	NS	NS		NS	NS	NS	
					12 – 18 inch depth				
Control	32.02	29.72	28.12	28.18	NS	33.35	34.47	35.24	NS
Anhydrous	31.71	27.57	27.15	27.15	NS	28.77	31.15	32.57	NS
Urea	32.72	26.77	26.95	26.82	NS	34.13	32.71	36.32	NS
PCU	33.90	26.46	24.64	27.04	NS	34.62	31.91	33.24	NS
$LSD_{(0.05)}$	1.41	NS	3.33	NS		NS	NS	2.88	
					18 – 24 inch depth				
Control	29.14	25.41	24.74	27.34	NS	31.53	29.10	29.26	NS
Anhydrous	27.08	24.59	25.15	24.33	NS	31.84	26.86	28.58	NS
Urea	31.07	23.96	26.68	25.69	NS	29.75	37.48	26.69	NS
PCU	32.40	24.03	23.25	24.08	NS	30.53	27.66	28.60	NS
$LSD_{(0.05)}$	2.76	NS	2.49	NS		NS	NS	NS	

* Distance in feet from the tile or subirrigation lines.

** $LSD_{(0.05)}$ = Least Significant Difference at $p < 0.05$; NS = Not statistically significant

† NIN = No irrigation, no drainage

‡ NID = No irrigation, drainage

¶ SUB = Subirrigation, drainage

Table 2. Grain yields in 2006 and 2007 at the Ross Jones Farm due to differences in N fertilizer sources, drainage and irrigation systems and the distance between tile lines. "Over" refers to harvest rows over the tile line and "Between" refers to harvest rows between the tile lines

			NID‡			SUB¶		
N treatment	NIN†	OND§	Over	Between	$LSD_{(0.05)}$*	Over	Between	$LSD_{(0.05)}$
	bu/acre							
				2006				
Control	81.3	113.8	96.1	97.5	NS	104.9	99.9	NS
Anhydrous	135.3	240.0	135.3	137.5	NS	202.8	157.9	NS
Urea	130.7	237.9	145.1	141.9	NS	239.0	160.8	12.6
PCU	126.9	240.5	149.1	138.3	NS	253.5	152.6	16.6
UAN	121.8	231.5	141.3	145.9	NS	208.8	148.6	30.0
$LSD_{(0.05)}$	27.0	17.6	28.2	18.8		22.9	10.0	
				2007				
Control	78.3	111.0	101.9	120.2	NS	106.7	118.6	8.1
Anhydrous	124.0	215.6	139.2	146.5	NS	188.9	143.6	NS
Urea	113.6	198.4	139.0	154.2	8.4	194.9	148.9	33.8
PCU	130.1	218.3	139.5	133.5	NS	199.2	148.4	NS
UAN	106.2	169.6	131.9	147.3	NS	168.9	137.9	NS
$LSD_{(0.05)}$	15.8	33.0	24.3	NS		22.3	NS	

* $LSD_{(0.05)}$ = Least Significant Difference at $p < 0.05$; NS = Not statistically significant
† NIN = No irrigation, no drainage
§ OND = Overhead irrigation, no drainage
‡ NID = No irrigation, drainage
¶ SUB = Subirrigation, drainage

Table 3. Nitrogen uptake in 2006 at the Ross Jones Farm due to differences in N fertilizer sources, drainage and irrigation systems and the distance between tile lines. "Over" refers to harvest rows over the tile line and "Between" refers to harvest rows between the tile lines

			NID‡			SUB¶		
N treatment	NIN†	OND§	Over	Between	$LSD_{(0.05)}$*	Over	Between	$LSD_{(0.05)}$
	lb N/acre							
Control	39.2	52.4	60.1	63.2	NS	52.8	50.9	NS
Anhydrous	79.2	114.8	60.8	71.5	6.9	81.0	113.3	NS
Urea	95.2	92.2	93.5	62.1	29.1	118.0	87.1	NS
PCU	81.9	121.5	93.1	86.4	NS	123.2	101.8	NS
UAN	90.9	92.5	74.6	74.3	NS	82.2	76.3	NS
$LSD_{(0.05)}$	40.2	66.4	NS	NS		35.3	30.4	

* $LSD_{(0.05)}$ = Least Significant Difference at $p < 0.05$; NS = Not statistically significant
† NIN = No irrigation, no drainage
§ OND = Overhead irrigation, no drainage
‡ NID = No irrigation, drainage
¶ SUB = Subirrigation, drainage

Table 4. Increase in gross returns over the non-drained, non-irrigated control[†] with use of different N fertilizer sources and drainage and irrigation systems at the Ross Jones Farm in 2006 and 2007.

	OND[§]			NID[‡]			SUB[¶]		
N treatment	2006	2007	Average	2006	2007	Average	2006	2007	Average
	$/acre								
Control	114	114	114	54	114	84	74	120	97
Anhydrous	366	321	344	4	66	35	158	148	153
Urea	375	297	336	45	116	80	242	204	223
PCU	398	309	354	59	22	40	266	153	210
UAN	384	222	303	76	117	96	199	165	182

[†] Gross returns for difference in yield between unirrigated and undrained plots (NIN) and irrigation/drainage treatments were based on a corn price of $3.50/bu. Approximate costs for fertilizers would be urea = $0.58/lb N, anhydrous ammonia = $0.42/lb N, PCU = $0.64/lb N and UAN = $0.42/lb N. Costs for irrigation and drainage systems will vary by location.

[§] OND = Overhead irrigation, no drainage

[‡] NID = No irrigation, drainage

[¶] SUB = Subirrigation, drainage