NITRATE LOSSES TO TILE DRAINAGE AS AFFECTED BY NITROGEN FERTILIZATION OF CORN IN A CORN-SOYBEAN ROTATION[†]

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ABSTRACT: A study, initiated in 2000 and continued in 2003, was conducted to determine the influence of rate and time of N application and the nitrification inhibitor, N-Serve, on the yield and uptake of N by corn and the loss of NO_3 to tile drainage. Anhydrous ammonia (AA) was applied on October 27, 2002 at rates of 0, 80, 120, and 160 lb N/A and on April 15, 2003 at 120 lb N/A. These fourth-year results show a highly significant corn production response to fertilizer N rate but not to time of application (fall vs spring) or to N-Serve. Dry weather throughout the growing season coupled with the absence of any short-term leaching or denitrification events explains the lack of significant differences among much of the plant and water data. Grain yield, N concentration and uptake in the grain, and total N uptake for the 160-lb fall treatment plus N-Serve were not different from the 120-lb rate applied in the spring. Tile flowed intermittently for 25 days from April 18 to June 15. Drainage averaged 3.15" for the corn plots and 2.27" for the soybean plots. Nitrate-N concentrations in the drainage water increased slightly with increasing fertilizer N rate but were not affected by N-Serve. Annual flow-weighted NO_3-N concentrations averaged 11.5, 12.8, and 13.2 mg/L for the 80, 120, and 160-lb N rates, respectively. Nitrate-N losses from the corn plots were small and ranged between 6 and 12 lb/A for the year. Nitrate-N concentrations and losses from the soybean plots were also small, ranging from 5 to 9 mg/L and 2 to 5 lb/A, and were not closely related to N rate applied for corn in the previous year. Nitrate-N losses normalized to the amount of tile flow and combined for the corn and soybean plots were ranked as follows: 80 lb N/A < 120 lb N/A + N-Serve < 120 lb N/A without N-Serve < 160 lb N/A. Nitrate-N concentrations and losses from the fertilized grass plots averaged 3.7 mg/L and 1.8 lb/A, respectively. Soil NO_3 and NH_4 data from the AA bands indicated that nitrification of the fall-applied AA was essentially complete by June 2 and spring-applied AA by June 16, with little effect of N-Serve.

Nitrogen (N) losses to tile drainage water have been directly linked to N additions, crop grown, and soil organic matter level. Research has been conducted on NO_3 losses to tile drainage in Minnesota since 1972. This research has focused primarily on the effects of rate and time of fertilizer N application and tillage in a continuous corn system. The purpose of this study is to determine the influence of rate and time of N application and the use of a nitrification inhibitor on NO_3 movement and accumulation in the soil, NO_3 losses via tile drainage, and yield and N uptake by corn grown in a rotation with soybean.

EXPERIMENTAL PROCEDURES

Thirty-six individual tile line plots were installed on a poorly drained Webster clay loam soil at the Southern Research and Outreach Center in 1976. Each 20 by 30 ft. plot is completely surrounded by plastic sheeting to a depth of 6 ft. to prevent lateral flow and contains a tile line (4 ft. deep) 5 ft. from one

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end. All tiles drain to collection pits where flow rates can be measured and water samples collected for analyses. After completing a research project in 1983 using this tile facility, the plots were cropped to corn with a blanket N rate in 1984 and 1985 to establish uniformity.

A corn-soybean rotation was begun in 1986 with corn planted on one-half of the experimental site while soybean is planted on the other half. Thirty-two plots (16 with corn and 16 with soybean) with the most uniform drainage were selected from the 36 for the primary study. A randomized, complete-block design was used with restricted randomization based on previous annual tile drainage from each plot in 1977-1983. The four primary N treatments (see Table 1) are applied to the corn phase each year with the residual effects measured in the soybean phase. Three additional N treatments were replicated four times around the edge of the core 16-tile-plot area and were planted to corn. These three treatments were analyzed along with the other four as a completely randomized design.

Anhydrous ammonia was applied at rates of 80, 120, and 160 lb N/A on October 27, 2002 and at 120 lb N/A on April 15, 2003. N-Serve, a nitrification inhibitor, was applied to selected treatments at 0.5 lb/A. Average soil temperature at the 4-in. depth on October 27 was 40°F with an average of 38°F during the following 10-day period.

The corn area (2002 soybean area) was field cultivated once before planting, while the soybean area (2002 corn area) was fall chiseled and field cultivated once prior to planting.

Corn (Dekalb DKC44-46RRYG) was planted at 33,000 seeds/A on April 25 with a JD Max-Emerge planter. Corn rootworm insecticide was not used. Weeds were chemically controlled with a preemergence application of Harness (2.5 pt/A) and Hornet (4 oz./A) on April 30 and a post emergence application of Roundup WeatherMax (24 oz/A) + AMS on June 19. Soybeans (Latham 388 RRN) were planted in 30 in. rows at 10 beans per ft. of row on May 8. Weeds were chemically controlled with 28 oz./A of Roundup WeatherMax plus AMS on June 19 and July 17.

Two plots that showed greatest water flow variability (1977-83) within each of the corn and soybean areas were fallowed from 1987-1999. A grass mixture of bluegrass and fescue (50:50) was planted in early August 1999 and was grown and clipped periodically in 2002. The purposes of these plots were to monitor the NO_3-N concentrations in tile water in a grass sod system and to utilize all 36 of the tiled plots, even though these four historically showed the greatest flow variability. Nitrogen fertilizer, 44 lb N/A as urea with Agrotain, was applied to the grass plots on April 25 and June 20, 2003.

Stand counts were taken at the V-3 stage (June 10) and plots were thinned to a uniform population. Chlorophyll content in the ear leaf was measured with a Minolta SPAD meter on July 23 (R1). Stover and grain samples were taken at physiological maturity (September 16) by hand harvesting 15 ft. of row for stover yield and 30 ft. of row for grain yield and moisture. Combine harvest was performed on two 27 ft. rows on September 25. The combine and hand harvest yields were combined and corrected for 15.5% moisture. Tile line flow rates were determined daily and were recorded when flow exceeded 10 ml/minute (0.01 in./day). Samples were collected for NO_3-N analysis on an every-other-day basis. The Research Analytical Laboratory, University of Minnesota performed chemical analyses of plant, water, and soil.

RESULTS AND DISCUSSION

Plant

Stover N concentration and N uptake and relative chlorophyll content of the earleaf at the R1 stage were increased (P=10% level) above the control (0-lb N) by all of the N treatments (Table 1). A linear response to fall-applied N rate (0 through 160 lb/A) was observed for N concentration and N uptake in the stover. However, none of the parameters in Table 1 were affected by time of application (fall vs. spring) and N-Serve (without vs. with), and there was no interaction between time of application and N-Serve. Final plant population averaged 31,000 plants/A and was not affected by any of the N treatments.

Table 1. Influence of rate of N application and N-Serve on stover N concentration, stover yield, N uptake in stover, leaf chlorophyll, and final population of corn in 2003.

Nitrogen Application			Stover			Relative	Final Plant
Time	Rate	N-Serve	N Conc.	Yield	N Uptake	Chlorophyll	Population
	lb N/A		%	T DM/A	lb/A	%	pl/A*1000
Primary Treatments							
Fall (10/27)	80	Yes	0.40	2.59	20.8	89.9	31.2
Fall (10/27)	120	Yes	0.48	2.62	25.5	96.0	31.1
Fall (10/27)	160	Yes	0.57	2.90	33.5	98.4	30.9
Fall (10/27)	120	No	0.52	2.67	28.0	98.3	30.6
Secondary Treatments							
Spr. (4/15)	120	No	0.51	2.87	28.9	98.0	30.9
Spr. (4/15)	120	Yes	0.53	2.63	27.6	98.0	31.1
Check	0	- -	0.33	2.45	16.2	74.0	30.9
Contrasts (P > *F*)							
N-Serve (trt 2 vs 4)			0.304	0.826	0.5283	0.270	0.066
Statistical Analysis for 2-Factor Factorial (Treatments 2, 4, 5 & 6)							
Time of Application							
Fall (10/27/02)			0.50	2.64	26.7	97.1	30.9
Spr. PP (4/15/03)			0.52	2.75	28.3	98.0	31.0
P > *F*:			0.597	0.508	0.499	0.495	0.368
N-Serve							
Without			0.51	2.77	28.5	98.1	30.8
With N-Serve			0.51	2.62	26.5	97.0	31.1
P > *F*:			0.823	0.366	0.409	0.383	0.111
Interaction							
N-Serve * Time (P>F):			0.340	0.569	0.809	0.363	0.580
CV (%):			12.2	11.5	16.2	2.5	1.2
Statistical Analysis for RCB (Trts.1-4 and 7)							
P > *F*:			<0.001	0.4806	0.006	<0.001	0.176
LSD (0.10):			0.06	NS	6.7	3.5	NS
CV (%):			10.8	13.1	21.5	3.1	1.0

Grain and silage yield, grain N concentration, and N uptake in the grain and silage (total uptake) were significantly greater for the six N treatments compared to the 0-lb N control (Table 2). Grain and silage yield were optimized at the 120-lb N rate when applied in the fall. Nitrogen concentration and uptake in the grain and total N uptake were optimized at the 160-lb N rate applied in the fall. Grain yield and N concentration, silage yield, and total N uptake were not influenced by time of application (fall vs. spring). Grain yield, N concentration, N uptake, and total N uptake for the 160-lb fall N treatment plus N-Serve were not different from the 120-lb N rate applied in the spring, regardless of N-Serve. Averaged across fall and spring applications, N-Serve did not affect any of the corn production parameters. No interaction was found between N-Serve and application time

The grass plots were clipped to about a 3-inch height only three times during the year because of the dry conditions. Grass yields were taken from an 18-inch wide strip x 20' long. Subsamples were weighed, dried, ground, and analyzed for total N. All remaining clippings were returned to the plots. Total harvested dry matter for the season totaled only 0.272 T/A (Table 3). Nitrogen concentration for each of the cuttings ranged between 2.6 and 4.1%. Total N uptake in the clipped tissue was 17.5 lb/A or the equivalent of 20% of the applied fertilizer N. Substantial N was apparently incorporated into the above-ground unharvested portion and the root system.

Water

Weather conditions during the 2003 growing season (April through September) were unusually dry and tile drainage was limited. Rainfall during the April-September growing season totaled 15.8” (7.8” below normal) and was below normal each month. Dry conditions in August and September caused some plant stress but apparently did not significantly harm corn yield. Growing degree units for the May 1 - Sept. 25 growing season were normal. Tile flow began on April 18 and averaged across the corn and soybean plots flowed 7 days in April, 14 days in May, and 4 days in June, for a total of 25 days. Drainage volumes were greatest during the May 11-14 period.

Annual drainage from the 16 corn plots averaged 3.15" with a range of 1.55” among the four primary treatments (Table 4). Drainage from the 16 soybean plots was less (2.27") and was less variable with a range of 0.39" among the four primary treatments. Drainage from the corn plots was considerably more variable than from the soybean plots. In the corn, plots 11, 12, 15 & 16 demonstrated higher-than-normal drain flow compared to the other corn plots. These four plots contained the 80, 120, and 160-lb fall N treatments, and greater flow can be observed in Table 4 for these plots, especially in May. The flow rates were 2.4x, 1.8x, 1.6x, and 2.0x higher than the average of the other plots. The standard error (shown in parentheses) in May is highest for the 80-lb treatment due primarily to the high flow from plot 11.

Table 2. Corn grain and silage production as influenced by rate of application and N-Serve in 2003.

Nitrogen Application			Grain			Silage	Total
Time	Rate	N-Serve	Yield	N Conc.	N Uptake	Yield	N Uptake
	lb N/A		bu/A	%	lb/A	T DM/A	lb/A
Primary Treatments							
Fall (10/27)	80	Yes	172	1.08	87	6.65	108
Fall (10/27)	120	Yes	186	1.23	107	7.03	132
Fall (10/27)	160	Yes	182	1.31	114	7.22	148
Fall (10/27)	120	No	189	1.23	111	7.15	139
Secondary Treatments							
Spr. (4/15)	120	No	192	1.27	118	7.40	146
Spr. (4/15)	120	Yes	190	1.26	112	7.11	140
Check (No N)	0	- -	126	0.92	57	5.42	74
Contrast (P > *F*)							
N-Serve (trt. 2 vs 4)			0.594	1.000	0.355	0.638	0.377
Statistical Analysis for 2-Factor Factorial (Treatments 2, 4, 5, & 6)							
Time of Application							
Fall (10/27/02)			188	1.23	109	7.09	136
Spr. (4/15/03)			191	1.26	115	7.26	143
P > *F*:			0.678	0.205	0.074	0.513	0.127
N-Serve							
Without			190	1.25	114	7.27	143
With N-Serve			188	1.24	110	7.07	136
P > *F*:			0.714	0.708	0.174	0.431	0.195
Interaction							
N-Serve * Time (P > *F*):			0.926	0.708	0.829	0.744	0.981
CV (%):			6.7	4.2	5.6	7.0	6.7
Statistical Analysis for RCB (Trts. 1-4 and 7)							
P > *F*:			<0.001	<0.001	<0.001	<0.001	<0.001
LSD (0.10):			10	0.09	7	0.44	12
CV (%):			4.5	6.2	5.9	5.3	8.1

Monthly and annual flow-weighted NO_3-N concentrations in the drainage water from the corn plots exhibited low variability, increased from April to June, generally increased with increasing N rate, and were not reduced by N-Serve (Table 5). The influence of rate of N application was already apparent in the April drainage. This was most likely due to background levels of nitrate caused by the 80, 120, and 160-lb N rates applied to these plots for corn in 2001. It is unlikely that the slightly elevated levels of nitrate-N for the higher N rates could have come from the fall-applied AA because only about 0.6” of drainage occurred in April. Previous studies indicated about 4” of drainage water is needed in the spring to leach late fall-applied N to the tile lines that are 3.5 feet deep. Compared to the recommended rate of 120 lb N/A, flow-weighted NO_3-N concentrations for the season were reduced 1.3 mg/L (10%) by reducing N rate to 80 lb/A but were increased 0.4 mg/L (3%) by the 40-lb "over-application" rate of 160 lb N/A. In summary, the 3.15" of drainage in 2003 was insufficient to detect significant “water quality” effects due to N management.

The NO_3-N concentrations in the drainage from the soybean plots did not change consistently from April through June (Table 5). For the season, NO_3-N concentrations averaged 5.5, 5.0, and 8.7 mg/L for the 80, 120, and 160-lb N treatments, respectively, with N-Serve and 9.4 mg/L for the 120-lb N treatment without N-Serve. Reducing the N rate for corn by 40 lb/A from the recommended 120-lb rate did not reduce NO_3-N concentration, whereas increasing the N rate by 40 lb/A to 160 lb/A resulted in a 74% increase in NO_3-N concentration. Monthly nitrate-N concentrations in the drainage from the fertilized grass plots ranged from 3.1 to 13.1 (only 0.05“ drainage) mg/L and averaged 3.7 mg/L for the season.

Nitrate-N losses in the drainage water from corn in 2003 were variable primarily due to variability in flow rates (described earlier). In addition, nitrate-N losses were small and ranged from 6.4 lb/A (120 lb N/A without N-Serve) to 11.3 lb/A when 120 lb N/A was applied with N-Serve. This does not make sense and is likely due to insufficient water percolating through the soil profile, resulting in little drainage. Loss of residual N in the soybean phase was less than 5 lb NO_3-N/A and was not closely related to N rate applied for corn in 2002 (Table 6). Nitrate-N losses in the tile drainage for the season averaged across all treatments were 8.7, 3.8, and 1.8 lb/A for corn, soybean, and grass, respectively.

Table 3. Dry matter yield, N concentration, and total N uptake in the grass plots in 2003.

Clipping date	Dry matter yield	N concentration	Total N uptake
	T DM/A	%	lb N/A
May 8	0.078	4.11	6.4
May 28	0.097	3.04	6.0
June 20	0.097	2.63	5.1
Total / Avg. Conc.	0.272	3.26	17.5

Table 4. Tile water discharge from the corn, soybean, and grass plots in 2003.

Nitrogen Application			Month			
Time	Rate	N-Serve	April	May	June	Year Total
	lb/A		inches (S.E.)[1/]			
			Corn			
10/27/02	80	Yes	0.58 (0.35)	2.20 (0.92)	0.31 (0.28)	3.09 (1.55)
10/27/02	120	Yes	0.76 (0.26)	2.66 (0.60)	0.53 (0.21)	3.95 (1.06)
10/27/02	160	Yes	0.48 (0.26)	2.33 (0.60)	0.36 (0.28)	3.17 (1.10)
10/27/02	120	No	0.40 (0.14)	1.87 (0.43)	0.12 (0.07)	2.40 (0.64)
N Trts for 2002 corn						
			Soybean			
10/31/01	80	Yes	0.31 (0.25)	1.74 (0.72)	0.27 (0.27)	2.31 (1.24)
10/31/01	120	Yes	0.26 (0.15)	1.88 (0.42)	0.29 (0.14)	2.43 (0.62)
10/31/01	160	Yes	0.28 (0.19)	1.77 (0.37)	0.24 (0.21)	2.29 (0.76)
10/31/01	120	No	0.20 (0.13)	1.75 (0.38)	0.09 (0.09)	2.04 (0.60)
			Grass			
2 appl'ns of 44		-	0.19 (0.15)	1.42 (0.80)	0.05 (0.05)	1.65 (1.00)

[1/] Standard error of the mean (SE).

Table 5. Flow-weighted NO_3-N concentrations for each month from the corn, soybean, and grass plots in 2003.

Nitrogen Application			Month			
Time	Rate	N-Serve	April	May	June	Year Avg.
	Lb/A		mg NO_3-N/L (S.E.)			
			Corn			
10/27/02	80	Yes	9.9 (1.4)	11.5 (1.0)	11.7 (0.9)	11.5 (1.1)
10/27/02	120	Yes	10.2 (0.3)	13.1 (0.4)	14.7 (0.3)	12.8 (0.4)
10/27/02	160	Yes	12.7 (0.6)	13.1 (0.7)	15.7 (0.7)	13.2 (0.7)
10/27/02	120	No	11.4 (1.1)	11.9 (0.8)	14.8 (1.5)	11.9 (0.8)
N Trts for 2002 corn						
			Soybean			
10/31/01	80	Yes	6.7 (1.4)	5.4 (1.1)	7.5 (--)[2/]	5.5 (1.2)
10/31/01	120	Yes	5.6 (0.4)	4.8 (0.4)	4.8 (0.3)	5.0 (0.4)
10/31/01	160	Yes	10.9 (0.9)	8.6 (1.6)	9.1 (0.9)	8.7 (1.6)
10/31/01	120	No	9.9 (1.0)	9.4 (0.6)	9.7 (--)	9.4 (0.6)
			Grass			
2 appl'ns of 44		-	3.1 (1.0)	3.7 (0.7)	13.1 (--)	3.7 (0.8)

[1/] Standard error of the mean (SE).
[2/] Insufficient number of drain tile flowing to calculate SE.

Table 6. Nitrate-N loss for each month from the corn, soybean, and grass plots in 2003.

Nitrogen Application			Month			
Time	Rate	N-Serve	April	May	June	Year Total
	lb/A		lb NO_3-N/A (S.E.)			
			Corn			
10/27/02	80	Yes	1.2 (0.7)	5.3 (1.9)	0.8 (0.7)	7.3 (3.3)
10/27/02	120	Yes	1.7 (0.6)	7.8 (1.7)	1.8 (0.7)	11.3 (2.9)
10/27/02	160	Yes	1.4 (0.8)	7.1 (2.2)	1.3 (1.0)	9.8 (3.9)
10/27/02	120	No	1.0 (0.3)	5.0 (1.3)	0.4 (0.2)	6.4 (1.9)
N Trts for 2002 corn			Soybean			
10/31/01	80	Yes	0.6 (0.5)	2.5 (1.3)	0.5 (0.5)	3.6 (2.3)
10/31/01	120	Yes	0.3 (0.2)	2.0 (0.4)	0.3 (0.1)	2.6 (0.6)
10/31/01	160	Yes	0.6 (0.4)	3.4 (0.7)	0.5 (0.4)	4.4 (1.4)
10/31/01	120	No	0.5 (0.3)	3.8 (1.0)	0.2 (0.2)	4.4 (1.5)
			Grass			
2 appl'ns of 44		-	0.2 (0.2)	1.5 (1.1)	0.1 (0.1)	1.8 (1.4)

[1/] Standard error of the mean (SE).

Nitrate-N losses to tile drainage water were normalized to tile water flow to minimize the influence of water flow volume and to aid interpretation of the data (Table 7). Normalized values for corn were greatly influenced by rate of N application but not by N-Serve in 2003. Averaged across both the corn and soybean systems, the normalized NO_3-N losses per inch of drainage water were 2.02, 2.18, and 2.60 lb for the 80, 120, and 160-lb N rates with N-Serve and 2.43 lb for the 120-lb rate without N-Serve. Normalized NO_3-N losses from the grass plots averaged 1.12 lb/inch of drainage or about one-half of that from the corn-soybean rotation.

Table 7. "Flow-normalized" NO_3-N losses to tile drainage in a corn-soybean sequence in 2003.

	Rate of N Application (lb/A)/N-Serve			
Crop System†	80 + N-Serve	120 + N-Serve	160 + N-Serve	120 + No N-Serve
	NO_3-N lost (lb/inch of drainage)			
Corn	2.35	2.86	3.09	2.67
Soybean	1.54	1.07	1.94	2.17
Corn-Soy System	2.02	2.18	2.60	2.43

† Grass = 1.12 lb/inch.

Soil

Soil samples were taken vertically through the AA bands of selected treatments periodically from April 10 through June 16, 2003. Each sample consisted of 10 cores from the 0 to 10" depth. Soil NO_3-N and NH_4-N concentrations and ratios for each treatment sampled are shown in Table 8. Plots receiving anhydrous ammonia on October 27, 2002 contained relatively high concentrations of nitrate-N and ammonium-N on April 10 and 28 with little difference between the two sampling dates and with no consistent effect of N-Serve. Substantial nitrification of the fall-applied AA occurred by May 16, regardless of N-Serve and some nitrate-N had leached out of the top 10" during the brief wet period around May 11-14. By June, the fall AA was almost completely nitrified with no effect of N-Serve. Data collected June 16 indicate complete nitrification of the fall-applied AA. For those plots receiving AA on April 15, 2003, high concentrations of ammonium-N and much lower nitrate-N concentrations were found on April 28, indicating slight nitrification during this 13-day period. By May 16, significant nitrification had occurred, but ammonium levels were still high. Substantial nitrification occurred by June 2 with slightly more NO_3-N and less NH_4-N where N-Serve had not been used. Samples taken on June 16 indicated spring-applied AA had not completely nitrified in the 60 days since application.

Soybean yields were influenced by the residual effects of the N treatments applied for corn in 2002 (Table 9). This is not consistent with results from previous years, and the reasons are not clear at this time. Perhaps the dry late-season conditions coupled with aphid pressure (plots were sprayed with Warrior) was responsible for the 14 bu/A range of yields among the treatments.

Table 8. Soil nitrate-N and ammonium-N concentrations and NO_3-N:NH_4-N ratios in the 0-10" depth through the fertilizer bands as affected by time and rate of N application and N-Serve.

Sampling	N Treatment			Nitrate-N		Ammonium-N		NO_3-N[†]
Date	Time	Rate	N-Serve	Avg.	SE	Avg.	SE	NH_4-N Ratio
		lb N/A		- - - - - - - - - - - - ppm	- - - -	- - - -	- - - - - - -	
Apr. 10	Fall	120	Yes	42.1	3.8	32.9	8.8	1.07
"	"	120	No	33.4	1.1	28.9	8.2	0.90
"	Control	0	"	9.9	0.3	2.9	0.2	
Apr. 28	Fall	120	Yes	42.6	3.7	23.7	7.4	1.67
"	"	120	No	35.0	2.0	31.7	6.1	0.94
"	Spring	120	"	16.6	1.1	67.3	12.1	0.13
"	"	120	Yes	16.0	1.3	61.7	7.5	0.14
"	Control	0	No	8.0	0.4	3.0	0.1	
May 16	Fall	120	Yes	16.6	2.3	12.7	3.2	0.99
"	"	120	No	13.9	1.8	13.9	3.3	0.63
"	Spring	120	"	27.8	3.6	34.3	9.5	0.66
"	"	120	Yes	20.6	1.9	37.9	5.9	0.38
"	Control	0	No	7.3	0.4	3.3	0.3	
June 2	Fall	120	Yes	40.0	2.3	8.2	1.4	6.32
"	"	120	No	35.7	6.9	8.7	1.6	4.86
"	Spring	120	"	102.3	22.3	16.8	4.4	6.94
"	"	120	Yes	77.9	9.9	19.6	5.0	4.20
"	Control	0	No	10.6	0.6	3.6	0.3	
June 16	Fall	120	Yes	16.0	3.4	4.1	0.4	94.33
"	"	120	No	22.1	1.3	4.8	0.8	16.97
"	Spring	120	"	67.8	11.9	7.6	1.9	16.81
"	"	120	Yes	41.3	6.2	7.8	2.2	8.76
"	Control	0	No	8.9	0.5	4.1	0.5	

† Avg. NO_3-N and NH_4-N concentrations in the control plots were subtracted from the NO_3-N and NH_4-N concentrations in the AA treatments before calculating the NO_3-N:NH_4-N ratios.

Table 9. Soybean yields in 2003 as affected by N treatments for corn in 2002.

Date N was Applied to Corn	N Rate	N-Serve	Soybean Yield
	lb/A		bu/A
10/31/01	80	Yes	36.4
"	120	Yes	34.1
"	160	Yes	42.0
"	120	No	40.9
4/19/02	120	No	46.3
"	120	Yes	48.3
Check	0	-	44.1
Statistical analysis for completely randomized design			
LSD (0.10):			6.6
CV (%):			6.5