Residual NO_3-N in the soil profile (Table 4) at the end of the 1994 growing season showed little difference between the two nitrogen sources.

Table 4. Influence of nitrogen source on residual NO_3-N in the soil profile in November, 1994.

Profile Depth	Nitrogen Source	
	Urea	Dairy manure
ft	---------- NO_3-N (lb/A) ----------	
0-1	15.5 (2.8)†	17.5 (2.0)
1-2	11.0 (2.8)	8.9 (0.8)
2-3	9.1 (2.0)	6.3 (0.8)
3-4	9.7 (1.2)	8.2 (1.2)
4-5	11.0 (1.2)	11.2 (1.2)
5-6	11.8 (1.2)	11.8 (1.2)
6-7	12.0 (0.8)	11.4 (1.2)
7-8	12.1 (0.8)	11.5 (1.2)
Total (0-8')	92.2	86.8

† Numbers in parentheses represent the standard error around the mean

Ortho phosphorus was not detected in any of the 51 water samples from dairy manure applied plots and 55 from urea fertilized plots (Table 5) indicating that manure application did not contribute to inorganic phosphorus losses in tile lines. However, 20% of the water samples from manured plots and 11% from urea fertilized plots had detectable amounts of total phosphorus, averaging only 0.08 and 0.05 mg P/L.

Table 5. Ortho-phosphorus and total phosphorus detects in tile water samples in 1994.

	Ortho-P		Total-P	
	Manure	Urea	Manure	Urea
Number of samples analyzed	51	55	51	55
Number of detects[1/]	0	0	10	6
% of samples with detects	0	0	20	11
Concentration range of detects (mg/L)	-	-	0.03-0.33	0.03-0.09
Average concentration among detects (mg/L)	0	0	0.08	0.05

[1/] Detection level is 0.04 mg/L for ortho-P and 0.02 mg/L for total P.

Nitrate-N concentrations in the PSC samplers at 4 and 6 ft depths were consistently greater at all four sampling dates in the plots that received urea compared to those that received dairy manure (Fig 1). Nitrate-N concentrations at the 4-foot depth increased from August to October with both treatments, but was most dramatic with urea. At the 6-foot depth, NO_3-N concentrations were highly variable and did not show this increase with time in the urea plots. Concentrations of NO_3-N at the 8-foot depth were very low (< 2 mg/L) for both treatments. Water samples were only collected twice from the piezometers in 1994. Water was found in 62% of the piezometers on the first sampling date (September 22) and in 96% of the piezometers on the second sampling date (October 7). During the two sampling dates, all the samples from 4-ft depth piezometers had detectable amounts of NO_3-N while about one-half of piezometers from both 6- and 8-ft depths had less than detectable amounts of NO_3-N.

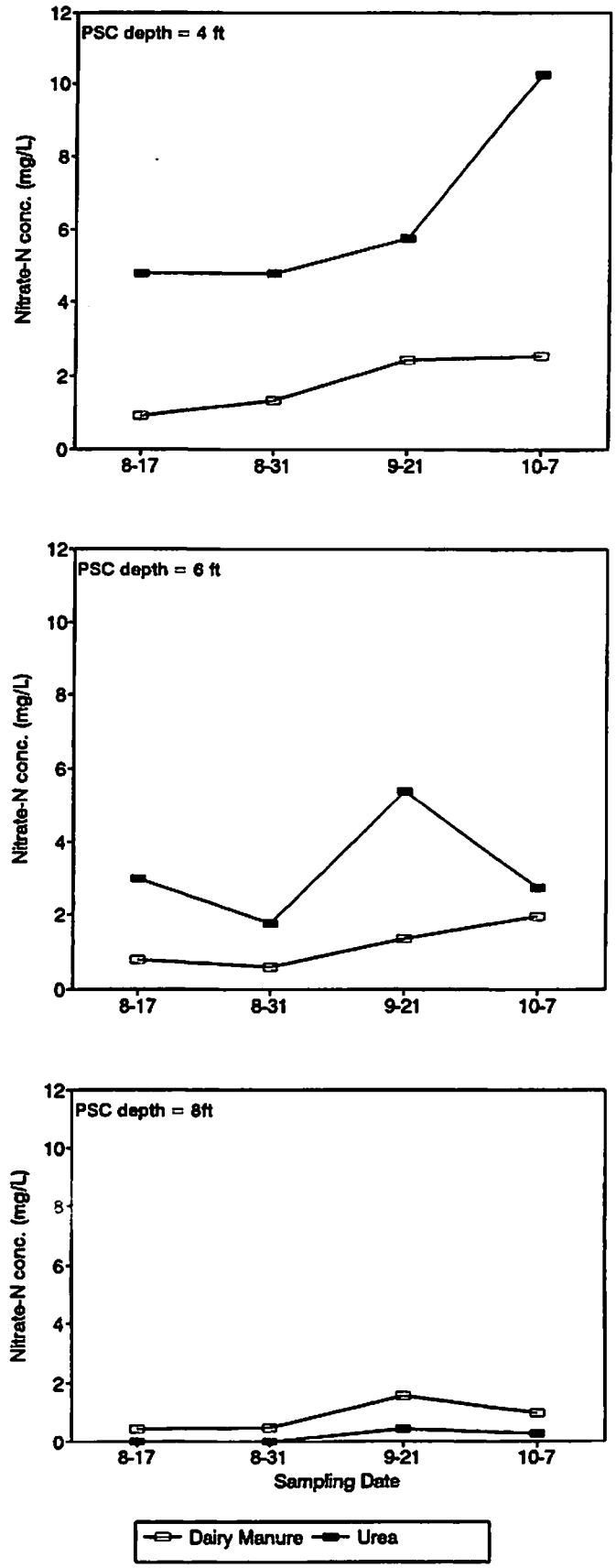

Fig 1.Nitrate-N concentrations in porous suction cup samplers in 1994.

NITRATE LOSSES TO TILE DRAINAGE AS AFFECTED BY NITROGEN FERTILIZATION OF CORN IN A CORN-SOYBEAN ROTATION[1/]

Waseca, 1994

G. W. Randall, J. A. Vetsch and G. L. Malzer[2/]

ABSTRACT: A study was conducted in 1994 to determine the influence of time of N application, N source, and nitrification inhibitor (NI) on the uptake of N by corn and the loss of NO_3 to tile drainage. Results from this first year showed significant yield improvement over the control with all N treatments. Fall application of N without NI gave the lowest yields and N use efficiency of the N treatments. Yields and N use efficiency were not different among the fall + NI, spring anhydrous ammonia (AA), and spring AA + N-Serve treatments. Highest yield was obtained with the preplant urea treatment. Tile lines flowed from mid-April through mid-May, intermittently in August and in October. Tile flow averaged 5.89" for corn and 4.82" for soybeans. Highest NO_3-N concentration and losses in the corn plots occurred with the fall application of N without NI, while the highest concentration and losses under soybean occurred with fall-applied AA + N-Serve applied to the previous corn crop. Nitrate-N concentrations and losses from continuous fallow plots that did not receive fertilizer N or a planted crop for eight years were 70% higher than from the fertilized corn. This was due to soil mineralization and no crop uptake over this period.

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 water in Minnesota since 1972. This research has focused primarily on the effects of rates and timing of fertilizer N application and tillage in a continuous corn system. The purpose of this study is to determine the influence of 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 an 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 at the Southern Experiment Station in 1976. Each 20 x 30' plot is completely surrounded by plastic sheeting to a depth of 6' to prevent lateral flow and contains a tile line (4' deep) 5 feet from one 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.

Beginning in 1986 corn was planted on one-half of the experimental site while soybean was 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. The experimental design consists of a 4 x 4 Latin square where the rows and columns were based on the previous (1977-83) tile flow rates from each plot. 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 a rate of 120 lb/A for all N treatments. The nitrification inhibitor (XDE-474 in the fall and N-Serve in the spring) was applied at 0.5 lb/A. Fall treatments were applied on October 25, 1993. Average soil temperature at the 4" depth on that date was 52°F with an average of 44°F over the following 10-day period. Spring preplant treatments were applied on May 11. The sidedress treatment was applied at the V4 stage on June 16.

The corn area (1993 soybean area) was field cultivated once before planting, while the soybean area (1993 corn area) was fall chiseled and field cultivated once prior to planting. Because of high soil P and K tests, no broadcast nor starter fertilizer was used.

Corn (Pioneer 3769) was planted at 24,000 seeds/acre (sprocket combination error) on May 11 with a JD Max-Emerge planter equipped with waffle coulters. Corn rootworm insecticide was not used. Weeds were chemically controlled with a preemergence application of Lasso (3.5 lb/A) plus Bladex (3 lb/A) on May 18. Soybeans (Sturdy) were planted in 30" rows at 9 beans per foot of row on May 17. Weeds were chemically controlled with 3.0 lb/A Lasso preemergence (May 23) plus a post emergence application of Pursuit (4 oz/A) at the 1st trifoliate stage (June 22).

Two plots within each of the corn and soybean areas were not planted and were fallowed all summer. These four fallow plot areas were located on those tile plots that showed greatest water flow variability (1977-83). The purposes of these plots were to check the NO_3-N concentrations in the tile water in a fallow system and to utilize all 36 of the tiled plots, even though these four historically showed the highest flow variability.

Stand counts were taken at the V-5 stage and plots were not thinned. Stover and grain samples were taken at physiological maturity by hand harvesting 40' of row for stover yields and 60' of row for grain yields and moisture. Tile line flow rates were determined daily and were recorded when flow exceeded 10 ml/minute (0.01"/day). Samples were collected for NO_3-N analysis on an every-other-day basis. Soil samples for NO_3-N analysis were taken in 1-foot increments to a depth of 8 feet from the fallow plots on May 6 and from all plots on November 4. Chemical analyses of plant, water, and soil were performed by the Research Analytical Laboratory, University of Minnesota.

1/ Partial funding provided by Dow Chemical U.S.A., Minnesota Agric. Exp. Stn., and Center for Agric. Impacts on Water Quality.

2/ Professor and Assistant Scientist, So. Exp. Stn., Waseca; Professor, Dept. of Soil Science, St. Paul.

RESULTS AND DISCUSSION

Plant

Stover N concentration at physiological maturity was significantly affected by fertilizer N but not by time of application (Table 1). Stover N was increased over the control by all N treatments with no difference among the N treatments. Stover yield was increased over the control by all of the fertilizer N treatments (Table 1). Highest stover yields were obtained with the spring preplant applications of urea and AA + N-Serve. Stover yield was not influenced by fall vs spring application of AA. Similar to stover yield, N uptake in the stover was increased above the control by all fertilizer N treatments (Table 1). Among the N treatments lowest N uptake in the stover occurred with the fall and preplant AA treatments without a NI and the sidedress AA treatment. Final plant population was much lower than desired due to an error in sprocket selection but was not significantly different among the treatments (Table 1).

Table 1. Influence of time of N application, N source and nitrification inhibitor on whole plant N, stover yield, N uptake, and final population of corn following soybeans.

N Application		Stover			Final
Time	Inhibitor	N	Yield	N uptake	Population
		%	T DM/A	lb/A	ppA x 10^3
Primary trts					
AA Fall	No	0.51	2.45	24.7	22.2
AA Fall (10/25)	Yes	0.51	2.53	25.6	22.1
AA PP (5/11)	No	0.52	2.32	23.9	21.4
AA PP (5/11)	Yes	0.54	2.69	28.7	22.7
Additional trts					
Urea PP (5/11)	No	0.56	2.73	30.4	22.4
AA SD (6/16)	No	0.51	2.40	24.5	22.3
Check (No N)	- -	0.32	1.80	11.5	22.1
			Statistical Analysis		
Latin square (Primary trts)					
Significance Level (%)		21	90	97	55
LSD (.05)		-	-	2.8	-
CV (%)		10.0	6.8	6.4	5.0
Completely randomized (7 trts)					
Significance Level (%)		99	99	99	40
LSD (.05)		0.10	0.40	6.0	-
CV (%)		13.3	11.3	16.9	4.3

Grain and silage yields were increased significantly over the control by all of the N treatments (Table 2). Fall application of N without NI gave consistently lower grain and silage yields than the three other primary treatments. Yields among the fall with NI and spring N treatments were not different. Lowest grain moisture occurred with the check treatment, which is in contrast to previous years.

Grain N concentration was higher for all fertilizer N treatments compared to the control (Table 2). Among the four primary treatments, significantly higher grain N was found with the preplant AA + N-Serve treatment while the lowest grain N concentration occurred with the fall AA treatment without a NI. Grain N concentrations tended to be higher with the spring AA + N-Serve and the urea treatments compared to the fall and spring treatments without a NI. Nitrogen uptake in the harvested grain was lowest with the fall-applied N treatment without NI and highest for the spring urea treatment (Table 2). Total N uptake was increased over the control by 53.6 lb/A (89%) for fall without a NI, 66.8 lb/A (110%) for the fall + NI, 68.5 lb/A (113%) for the spring preplant AA without NI, 78.1 lb/A (129%) for the preplant AA + N-Serve, 88.0 lb/A (146%) for the preplant urea treatment, and 70.7 lb/A (117%) for the sidedress AA treatment. Among the four primarily treatments, total N uptake was significantly lower for the fall AA without a NI treatment and significantly higher for the spring preplant AA + N-Serve treatment.

The General Linear Model procedure in SAS® was used to "contrast" the four primary treatments and determine if significant differences existed. The significance levels in Table 3 show an improvement in grain N concentration, grain yield, silage yield, grain N uptake, and silage N uptake (P = 90% level) with an inhibitor added to the fall-applied N. Spring application of N showed significant advantages over fall-applied N for grain N concentration, grain yield, silage yield, grain N uptake and silage N uptake. Adding N-Serve to spring preplant AA improved the grain N concentration, stover and silage yield, and total N uptake in the silage.

Water

Weather conditions during the 1994 growing season were very close to normal. Greatest tile flow occurred in April and October with much less flow in May and August (Table 4). Drainage from the 16 corn plots averaged 5.89" with 2.27" range among the four time/method treatments. Soybeans showed slightly less tile drainage compared to corn with an average of 4.82" from the 16 plots and a range of 0.64" among the four time/methods. Ideally, drainage should be uniform among the time/method treatments, however, normal soil and drainage variability exists in these plots and results in these unfortunate differences.

Table 2. Corn grain and silage production as influenced by time of application, N source, and nitrification inhibitor.

N application		Grain				Silage	Total N
Time	Inhibitor	Yield	H_2O	N	N Uptake	Yield	uptake
		bu/A	%	%	lb/A	T DM/A	lb/A
Primary trts							
AA Fall (10/25)	No	161.5	25.9	1.17	89.3	6.27	114.0
AA Fall (10/25)	Yes	170.4	27.4	1.26	101.6	6.56	127.2
AA PP (5/11)	No	174.6	27.6	1.27	105.0	6.45	128.9
AA PP (5/11)	Yes	174.6	26.1	1.33	109.7	6.82	138.5
Additional trts							
Urea PP (5/11)	No	183.6	29.5	1.36	118.0	7.07	148.4
AA SD (6/16)	No	173.3	27.9	1.30	106.7	6.50	131.1
Check (No N)	--	117.1	24.7	0.89	48.9	4.57	60.4
Latin square (Primary trts)			Statistical Analysis				
Significance Level (%)		99	74	99	99	97	99
LSD (.05)		7.4	–	0.05	6.9	0.33	7.7
CV (%)		2.5	5.0	2.3	3.9	3.0	3.5
Completely randomized (7 trts)							
Significance Level (%)		99	99	99	99	99	99
LSD (.05)		15.9	2.1	0.07	12.0	0.69	15.2
CV (%)		6.6	5.4	4.1	8.4	7.4	8.5

Table 3. Significance levels for differences among the four primary treatments as determined by contrast statistics.

	Contrast		
Parameter	Fall w/o Inhibitor vs Fall w/ Inhibitor	Fall vs Spring	Spring w/o Inhibitor vs Spring w/ Inhibitor
	---------- Significance Level (%) ----------		
Stover N Concentration	0	56	44
Grain N Concentration	99	99	97
Grain Moisture	84	17	83
Grain Yield	97	99	1
Stover Yield	47	11	98
Silage Yield	92	93	97
Final Population	14	17	86
Stover N Uptake	52	78	99
Grain N Uptake	99	99	86
Silage N Uptake	99	99	98

Monthly flow-weighted NO_3-N concentrations in the corn plots showed little temporal variation throughout the year (Table 5). Nitrate-N concentrations remained high throughout the drainage season for both the fall AA without NI and spring preplant AA + N-Serve treatments. The only possible explanation for the high NO_3-N concentrations in April from the spring preplant AA + N-Serve treatment applied in May is carryover and accumulation of NO_3 in the 3 to 5' soil profile from the split-applied N treatment applied in 1992. Higher NO_3-N concentrations from these plots also were found in 1993 when soybeans were grown, and the soybeans may not have scavenged all of the NO_3 from this depth in the profile. Nitrate-N concentrations were quite uniform among all four replications. Flow-weighted NO_3-N concentrations for the year were highest for the fall treatment, lowest for the fall + NI and spring AA treatments, and intermediate for the spring AA + N-Serve treatment. These concentrations were similar to those found in 1993, but lower than in previous years. This was probably due to the high rainfall that occurred from 1991 through 1993. These data clearly show the susceptibility of fall-applied N without a NI to loss of NO_3 in tile drainage water even under normal growing season rainfall conditions.

In the soybean plots, where N had been applied either in the fall of 1992 or spring of 1993, NO_3-N concentrations were consistently lower throughout the season and never averaged greater than 10 mg/L (Table 5). Highest flow-weighted NO_3-N concentrations were found with the fall AA + N-Serve treatment, especially early in the season. Nitrate-N concentration under an 8-year continuous fallow system (no fertilizer N applied) were approximately 2 to 3 times higher than from the fertilized corn and soybean plots.

Table 4. Tile water discharge from the corn, soybean, and fallow plots in 1994.

N application		Month				Year
Time	Inhibitor	April	May	August	Oct.	Total
		---------- acre-inches ----------				
		Corn				
Fall (10/25)	No	2.75	0.22	0.19	2.85	6.01
Fall (10/25)	Yes	3.27	0.35	0.29	3.19	7.10
Spring (5/11)	No	2.57	0.33	0.26	2.46	5.62
Spring (5/11)	Yes	2.22	0.08	0.29	2.24	4.83
		Soybean				
Fall (Oct.)[1]	No	2.75	0.27	—	2.12	5.14
Fall (Oct.)[1]	Yes	2.63	0.26	—	2.20	5.10
Spring (April)[1]	No	2.20	0.27	—	1.96	4.50
Split[1]	No	2.28	0.29	—	1.97	4.54
		Fallow				
NONE		2.28	0.22	0.17	2.04	4.71

[1] N applied for the 1993 corn crop at 135 lb N/A (See 1993 report for treatment descriptions).

Table 5. Flow-weighted NO_3-N concentrations for each month from the corn, soybean, and fallow plots in 1994.

N application		Month				Year
Time	Inhibitor	April	May	August	Oct.	Total
		---------- mg NO_3-N / L ----------				
		Corn				
Fall (10/25)	No	12.7	10.3	13.1	11.8	12.3
Fall (10/25)	Yes	7.9	8.2	9.3	7.6	7.9
Spring (5/11)	No	7.5	6.9	7.7	8.0	7.8
Spring (5/11)	Yes	11.7	13.1	12.1	10.6	11.2
		Soybean				
Fall (Oct.)[1]	No	6.2	5.5	—	6.3	6.3
Fall (Oct.)[1]	Yes	8.8	6.8	—	6.7	7.9
Spring (April)[1]	No	5.5	5.5	—	6.5	6.0
Split[1]	No	6.7	6.5	—	7.0	6.8
		Fallow				
NONE		21.1	19.8	21.3	19.0	20.2

[1] N applied for the 1993 corn crop at 135 lb N/A (See 1993 report for treatment descriptions).

Nitrate-N losses in the drainage water were twice as high for corn as for soybeans (Table 6). Under corn greatest loss of NO_3 occurred with the fall application when NI was not applied. Losses were least with the spring applications of N without N-Serve. Nitrate-N losses under soybean were not greatly different among the treatments but did tend to be higher with the fall-applied treatment + N-Serve, which showed the highest NO_3-N concentration in April. Nitrate-N losses in the fallow system, when mineralization of the soil organic matter was the NO_3 source, was 40 to 220% higher than from the fertilized corn-soybean rotation. This emphasizes the importance of growing a crop to absorb N released from these high organic matter soils.

Nitrate-N losses to the tile drainage water were normalized to tile water flow to minimize the influence of water flow volume among the N treatments on the interpretation of the data (Table 7). Normalized values for corn were highest for the fall without a NI and the spring preplant application of AA + N-Serve. Much lower values were found with the fall application of AA + NI and the spring application without NI. In the year following corn and its associated treatments, normalized losses ranked in the order fall without NI < fall + NI = spring without NI = split application. Apparently, sufficient N was not utilized by the corn and remained in the soil profile following the latter three treatments, thus, higher NO_3 losses in the succeeding year. Normalized NO_3-N losses for the corn-soybean system were highest for the spring + N-Serve (1994) / split application (1993), intermediate for the fall application without a NI, and lowest for the fall application + NI, and spring preplant AA without a NI. Additional years with adequate drainage losses are necessary to determine if these findings are consistent over time.

Table 6. Nitrate-N loss for each month from the corn, soybean, and fallow plots in 1994.

N application		Month				Year
Time	Inhibitor	April	May	August	Oct.	Total
		---------- lb NO_3-N / A ----------				
		Corn				
Fall (10/25)	No	7.2	0.5	0.5	7.2	15.5
Fall (10/25)	Yes	5.6	0.6	0.5	5.1	11.8
Spring (5/11)	No	4.3	0.5	0.4	4.2	9.4
Spring (5/11)	Yes	6.0	0.2	0.8	5.6	12.7
		Soybean				
Fall (Oct.)[1]	No	3.7	0.4	—	2.7	6.7
Fall (Oct.)[1]	Yes	5.1	0.4	—	3.1	8.6
Spring (April)[1]	No	3.1	0.4	—	3.5	7.2
Split[1]	No	3.7	0.5	—	3.2	7.3
		Fallow				
NONE		10.8	1.0	0.8	8.8	21.4

[1] N applied for the 1993 corn crop at 135 lb N/A (See 1993 report for treatment descriptions).

Table 7. "Flow-normalized" NO_3-N losses to tile drainage in a corn-soybean sequence in 1994.

Crop System[1]	Time/Method of N Application			
	Fall No Inhibitor	Fall Inhibitor	Spring No Inhibitor	Spring Inhibitor / Split
	---------- NO_3-N lost (lb/A/inch of drainage) ----------			
Corn	2.58	1.66	1.67	2.63
Soybean[2]	1.30	1.69	1.60	1.61
Corn Soybean System	1.94	1.68	1.64	2.12

[1] Continuous fallow (8 years without fertilizer N) = 4.54

[2] N applied for the 1993 corn crop at 135 lb N/A (See 1993 report for treatment descriptions).

Soil

Nitrate-N remaining in the 0-8' soil profile of the fallow system in late-April was about 65% higher compared to the spring of 1993 when NO_3-N accumulations were very low (Table 8). In November, NO_3-N levels above the tile lines were similar to those in April, however, slightly higher NO_3-N accumulations were found below the tile lines. Although NO_3-N remaining in the 8-ft soil profile after harvest for all of the N treatments was slightly above the check, very little difference existed among the six N treatments. Highest NO_3-N levels were found in the surface foot, while levels throughout the rest of the profile were very low.

Table 8. Nitrate-N in the soil profile of the fallow plots and all corn plots as influenced by N treatment.

Profile depth	Fallow NO_3-N		N Treatment for Corn						
	Spring	Fall	Fall AA	Fall AA + NI	PP AA	PP AA + NI	Urea	SD AA	Check (No N)
feet	--- lb/A ---		---------- lb/A ----------						
0 - 1	17	21	28	22	25	23	24	21	25
1 - 2	18	12	14	11	15	12	10	11	11
2 - 3	17	11	10	8	10	11	8	11	8
3 - 4	12	14	8	9	7	9	7	9	5
4 - 5	14	23	12	11	7	10	10	10	5
5 - 6	18	25	13	11	8	12	8	9	7
6 - 7	16	17	12	10	9	12	10	8	9
7 - 8	15	20	14	11	11	14	9	9	9
Total in									
0 - 5' profile	79	81	72	61	64	65	59	62	54
0 - 8' profile	129	143	111	93	92	103	86	88	79

NITROGEN FERTILIZATION OF ESTABLISHED REED CANARYGRASS

G. W. Randall, J. A. Vetsch, and M. P. Russelle[1/]

ABSTRACT: Recently developed low-alkaloid varieties of reed canarygrass are being considered as an alternative forage for dairy enterprises. The objectives of this 3-year study were to determine the effect of single early-season and split applications of fertilizer N on the yield and quality of reed canarygrass. Forage yields in 1994 were 1.2 T DM/A less than in previous years and yield was optimized at 200 lb N/A compared to 250 to 300 lb N/A in 1992 and 1993, respectively. Single applications of N were as effective as split applications for forage yield. Increasing fertilizer N rate significantly increased total N and NO_3-N concentrations in the forage. Forage NO_3-N concentration reached toxic levels with fertilizer rates greater than 350 lb N/A for the second harvest and 500 lb N/A for the third harvest. Apparent N recovery declined sharply when fertilizer N rate exceeded 200 lb N/A. The effects of split application on N recovery were inconsistent. Recoveries were less than previous years. Residual soil NO_3-N (RSN) in November accumulated in the top 2 ft with rates less than or equal to 300 lb N/A, while at rates greater than 400 lb N/A RSN was found below 3 ft. The residual effects of nitrogen application to reed canarygrass were measured from last year's site. Nitrogen treatments, applied in 1993, significantly affected forage yield, total N, plant NO_3-N, and N uptake in 1994. Nearly 20% of 600 lb N/A applied in 1993 was recovered in forage in 1994. This suggests that not all residual N will be lost to ground and surface water when optimum N rates are exceeded.

EXPERIMENTAL PROCEDURES

Twenty plots, measuring 20 ft by 40 ft, were laid out on established reed canarygrass (variety Palaton) in April 1994 on a Webster clay loam soil. Plots were fertilized with varying rates of N as ammonium nitrate on April 11. After the first cutting the main plots were split into subplots and again were fertilized with varying rates of N as ammonium nitrate on June 20 (Table 1). A randomized complete block design with four replicates was used in the analysis of the first harvest (June 2). An unbalanced split-plot design was used for the second (July 18) and third (Sept. 14) harvests. Yields were taken by harvesting a 3 ft by 38 ft swath (first cut) and a 3 ft by 19 ft swath (second and third cuts) from each plot. Forage subsamples were taken and analyzed for moisture content, total Kjeldahl N, and plant NO_3-N concentration. The total N analyses were conducted by the Research Analytical Laboratory (RAL) and the NO_3-N analyses by Dr. Russelle's Laboratory in St. Paul. Soil samples, three cores per plot to a depth of 5 ft in 1 ft increments, were taken from selected treatments on November 9. All soil samples were immediately forced-air dried at 125° F, then ground and analyzed for NO_3-N by the RAL.

Yields were taken from selected plots (0, 200, 300, 400, 600 lb N/A) from the 1993 research area to determine residual N effects. The harvest methods, harvest dates, and sample procedures were the same as those used in the 1994 study.

RESULTS AND DISCUSSION

Yield

First harvest dry matter yields increased significantly from the early (April 11) application of N fertilizer compared to the control (zero N plots). Yields were not increased by rates > 150 lb N/A (Table 1). Second and third harvest yields were not affected solely by the April application of N. Second and third harvest yields increased significantly up to 100 lb N/A for the June application. A significant (April x June) interaction was found for both the second and third harvest. This interaction is explained by a 0.71 and 0.60 T DM/A yield increase for the second and third harvests, respectively, when 150 lb N/A was applied in June and no N was applied in April compared to a 0.20 T DM/A yield decrease for both second and third harvests with the same June rate applied to plots receiving 200 lb N/A in April. Moreover, the highest second cut yield (1.48 T DM/A) occurred with the 0 + 150 lb N/A (April + June) application rate, compared to 1.19 T DM/A when 150 lb N/A was applied in both April and June. The 0 + 150 (April + June), 50 + 150, and 100 + 150 lb N/A treatments produced equally high yields for the third harvest.

Total dry matter yield was optimized with a total of 200 lb N/A. An April application of 200 lb N/A produced yields equal to the split application of 100 + 100 and 50 + 150 lb N/A. The significant interaction for total dry matter yield is shown by the 1.31 T DM/A yield increase when 150 lb N/A was applied in June to plots that received no N in April, compared to only a 0.61 T DM/A increase when the same June rate was applied to plots receiving 150 lb N/A in April. Also, yield decreased when 200 lb N/A was applied in June to plots receiving 200 lb N/A in April. Less fertilizer N (200 lb N/A compared to 250 lb N/A in 1992 and 300 lb N/A in 1993) was required to obtain optimum yield of reed canarygrass in 1994. Total dry matter yields were significantly less (1.2 T DM/A), compared to 1992 and 1993. Decreased fertilizer N needs for 1994 were attributed partly to the lower yields.

N Concentration

Total N concentration in the forage increased significantly with N application (both April and June) for all three harvests (Table 2). In the first harvest forage N concentration increased significantly with April rates up through 200 lb N/A. Also, nitrogen concentration in the forage from second and third harvests increased significantly with June rates up to 200 lb N/A. Nitrogen concentration in the forage from the second harvest was very high for the 0 + 150 lb N/A application, suggesting rapid uptake of N in the 28-day period between application and harvest. Generally, June N affected N concentration more than April N for the second and third harvests. The treatment effects on N concentration are consistent with the observed significant yield interaction between April and June applications.

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Table 1. Dry matter yield of Reed Canarygrass as influenced by N fertilization at Waseca in 1994.

Rate/Time of Application		Harvest Number and (Date)			
April 11	June 20	1st (June 2)	2nd (July 18)	3rd (Sept. 14)	Total
------ lb N/A ------		---------- TDM/A ----------			
0	0	1.09	0.77	0.43	2.30
0	50		1.26	0.74	3.09
0	100		1.41	0.94	3.43
0	150		1.48	1.03	3.61
50	0	1.46	0.84	0.50	2.80
50	50		1.23	0.73	3.42
50	100		1.30	0.93	3.69
50	150		1.34	1.07	3.87
100	0	1.46	0.90	0.64	2.94
100	50		1.17	0.74	3.31
100	100		1.42	0.94	3.77
100	150		1.30	1.08	3.78
150	0	1.60	0.86	0.63	3.05
150	50		1.15	0.76	3.51
150	100		1.15	0.83	3.57
150	150		1.19	0.88	3.66
200	0	1.81	1.13	0.99	3.92
200	50		1.04	0.88	3.74
200	150		0.93	0.79	3.52
200	200		1.03	0.64	3.48
300	0	1.83	1.04	0.89	3.75
300	150		0.96	0.70	3.49
300	200		0.90	0.77	3.51
300	300		1.07	0.72	3.61
Individual Factors					
April N Rate					
0		1.09	1.23	0.78	3.11
50		1.46	1.18	0.80	3.45
100		1.46	1.19	0.85	3.51
150		1.60	1.09	0.77	3.46
200		1.80	1.03	0.82	3.66
300		1.80	0.99	0.77	3.59
Significance level (%):		99	85	39	99
BLSD (0.05):		0.32			0.26
June N Rate					
0			0.92	0.68	3.14
50			1.17	0.77	3.42
100			1.32	0.91	3.63
150			1.20	0.92	3.67
200			0.97	0.70	3.49
300			1.07	0.72	3.61
Significance level (%):			99	99	99
BLSD (0.05):			0.11	0.11	0.17
Interaction 'April x June'					
Significance level (%):			99	99	99
C.V. (%):		7.4	12.0	17.0	6.1

NO_3-N Concentration

Fertilizer nitrogen application significantly affected plant NO_3-N concentration (Table 2). Nitrate concentration in the forage increased with increasing N rate for all harvests at all rates for both April and June applications. A significant interaction was found for both the second and third harvests. This interaction is shown by a 1400% increase in NO_3-N concentration for the 150 + 150 lb N/A plots compared to 150 + 0 lb N/A plots and only a 60% increase for the 300 + 150 lb N/A plots compared to the 300 + 0 lb N/A plots (second harvest). Forage NO_3-N reached toxic levels (> 3500 ppm) when total N applied was ≥ 400 (second harvest) and = 600 lb N/A (third harvest).

Table 2. Total N and NO_3-N concentration in and N uptake by Reed Canarygrass as influenced by N fertilization in 1994.

Rate/Time of N Application		Total N Concentration			NO_3-N Concentration			Total N Uptake		
April 11	June 20	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
------ lb N/A ------		------- % -------			------ ppm ------			------ lb N/A ------		
0	0	1.94	1.61	1.94	194	86	83	42.6	24.8	16.9
0	50		2.27	2.00		497	81		57.3	29.7
0	100		2.78	2.32		1617	256		78.3	43.8
0	150		3.36	2.75		2338	704		98.3	56.4
50	0	2.26	1.76	1.81	232	151	76	66.4	29.4	17.9
50	50		2.31	2.12		636	99		56.5	31.0
50	100		2.79	2.54		1489	438		72.0	46.6
50	150		3.24	2.71		2537	811		86.3	57.3
100	0	2.23	1.75	2.14	356	214	97	65.4	31.1	27.3
100	50		2.53	2.32		791	98		59.1	33.9
100	100		2.79	2.24		1544	145		78.8	42.4
100	150		3.06	2.66		2208	553		79.2	56.9
150	0	2.39	1.97	2.07	539	199	97	76.1	33.9	26.1
150	50		2.62	2.22		1184	333		60.1	34.1
150	100		3.30	2.63		2056	442		75.3	43.7
150	150		3.54	3.22		3055	1354		83.9	56.4
200	0	2.81	2.64	2.31	1954	1296	225	101.8	58.5	45.8
200	50		3.03	2.92		2388	837		62.4	50.9
200	150		3.56	3.94		3150	2707		66.3	62.0
200	200		3.84	4.00		4024	3191		78.2	50.2
300	0	2.98	3.39	3.02	2496	2417	1078	109.1	69.2	53.2
300	150		4.02	4.00		3795	2980		77.2	55.7
300	200		3.93	3.91		3868	3185		70.9	60.6
300	300		3.77	3.99		4230	3891		80.0	56.7
Individual Factors										
April N Rate										
0		1.94	2.51	2.25	194	1134	281	42.6	64.7	36.7
50		2.26	2.52	2.29	232	1203	356	66.4	61.1	38.2
100		2.23	2.54	2.34	356	1189	223	65.4	62.0	40.1
150		2.39	2.86	2.54	539	1624	557	76.2	63.3	40.0
200		2.81	3.27	3.29	1954	2714	1740	101.8	66.4	52.2
300		2.96	3.78	3.73	2496	3577	2784	106.3	74.3	56.6
Significance level (%):		99	99	99	99	99	99	99	98	99
BLSD (0.05):		0.26	0.24	0.09	305	427	288	17.7	6.5	9.1
June N Rate										
0			2.19	2.21		727	276		41.2	31.2
50			2.56	2.32		1099	290		59.1	35.9
100			2.92	2.43		1676	320		76.1	44.1
150			3.46	3.21		2847	1518		81.9	57.4
200			3.89	3.95		3946	3188		74.6	55.4
300			3.77	3.99		4230	3891		80.0	56.6
Significance level (%):			99	99		99	99		99	99
BLSD (0.05):			0.26	0.19		314	294		6.9	6.3
Interaction 'April x June'										
Significance level (%):			93	99		99	99		99	99
C.V. (%):		7.4	11.2	8.8	23.0	21.2	38.1	16.2	13.6	18.1

Total N Uptake

April and June N application significantly affected total N uptake in the forage (Table 2). Nitrogen applied in April significantly increased N uptake up to 200 (first and third harvest) and 300 lb N/A (second harvest). While June rates of 100 and 150 lb N/A produced equally high total N uptake for the second and third harvests, respectively. The significant interactions for N uptake are consistent with the interactions for dry matter yield and N concentration.

Annual Uptake of Total N and NO_3-N and Apparent N Recovery

Generally, annual (sum of three harvests) total N uptake and annual NO_3-N uptake increased with increasing total N rate up to 300 to 350 lb N/A (Table 3). Annual total N and NO_3-N uptake was highest with the 300 lb N/A rate for both April and June applications (statistical analysis not shown). Nitrogen applied in June increased annual total N, NO_3-N uptake, and N recovery more than N applied in April. Apparent N recovery in 1994 was substantially less than in previous years. Much of this was due to the higher yield and N concentration in the first harvest in the control plots compared to past years. As a result, recovery of N applied in April above that in the control ranged from only 35 to 59% when no additional N was applied in June. On the other hand, recovery of N ranged from 75 to 91% when no N was applied in April. This interaction between application dates led to very inconsistent effects of split application of N on apparent N recovery. When averaged over both application dates, recovery of N exceeded 50% at total N rates ≤ 200 lb N/A and ranged from 48 to 27% at rates above 200 lb N/A.

Table 3. Annual uptake of total N and NO_3-N, and recovery of fertilizer N by Reed Canarygrass as affected by N treatment.

Rate/Time of N Application		Annual Total N Uptake	Annual NO_3-N Uptake	Apparent N Recovery[1/]
April 11	June 20			
------ lb N/A ------		-- lb N/A --	-- lb NO_3-N/A --	-- percent --
0	0	84.3	0.6	—
0	50	129.6	1.8	91
0	100	164.6	5.5	80
0	150	197.3	8.6	75
50	0	113.7	1.0	59
50	50	153.9	2.4	70
50	100	185.0	5.2	67
50	150	210.1	9.2	63
100	0	123.8	1.6	39
100	50	158.4	3.1	49
100	100	186.6	5.8	51
100	150	201.6	8.0	47
150	0	136.1	2.2	35
150	50	170.3	5.0	43
150	100	195.1	7.1	44
150	150	216.3	11.2	44
200	0	206.1	10.4	61
200	50	215.1	13.4	52
200	150	230.1	17.2	42
200	200	230.2	19.3	36
300	0	231.6	15.8	49
300	150	242.0	20.5	35
300	200	240.7	21.0	31
300	300	245.7	23.7	27

[1/] (Total N uptake - N uptake from control) ÷ Total N applied

Soil Nitrate-N

Soil samples were taken in November to determine if substantial quantities of RSN remained in the 0-5 ft profile and if the fertilizer N had moved down through the soil profile. Residual soil NO_3-N in November accumulated in the top 2 ft with rates ≤ 300 lb N/A, while at rates > 400 lb N/A, RSN was found below 3 ft (Table 4). Movement of soil NO_3-N to depths below 3 ft suggests the potential for leaching losses to ground and surface drainage waters.

Table 4. Nitrate-N remaining in the 0-5 ft profile on November 9 as influenced by N rates applied to Reed Canarygrass.

Rate/Time of N Application		Soil Profile Depth					
April 11	June 20	0 - 1'	1 - 2'	2 - 3'	3 - 4'	4 - 5'	0 - 5'
------ lb N/A ------		---------- lb NO_3-N/A ----------					
0	0	3	3	2	2	3	13
100	100	7	4	2	3	3	19
100	150	7	5	4	4	6	26
150	150	18	10	4	3	4	40
200	150	21	21	16	8	5	70
200	200	57	41	28	8	5	140
300	200	43	46	39	30	8	168
300	300	107	108	70	26	13	323

Residual Effects from 1993 Reed Canarygrass N Study

Yield data, obtained in 1994 from selected treatments of the 1993 study, were taken to address the potential for plant recovery of residual N. Nitrogen fertilizer applied in 1993 significantly affected dry matter yields, total N, plant NO_3-N concentration, total N uptake, and plant NO_3-N uptake in 1994 (Table 5). First harvest yields were increased significantly above the control by 1993 rates > 200 lb N/A. Only the 600 lb N/A rate resulted in a yield increase above the control in the second and third harvests. Total N and NO_3-N concentration were significantly increased by 1993 N rates, but only in the first cutting and only by the 600 lb N/A rate. Total N and NO_3-N uptake in the forage were consistent with the response in the first harvest. Nitrogen recovered in the 1994 forage from plots that received 600 lb N/A in 1993 totaled 117 lb N/A. Soil samples, taken in November to a depth of 5 ft, contained < 15 lb NO_3-N/A among all 1993 N rates (data not shown). This suggests that excess nitrogen applied to reed canarygrass may not be lost to the environment, but can be recovered in subsequent cropping years. The residual effects of the 1994 study will be studied in 1995 to provide support to this hypothesis.

Table 5. Residual effects of N applied in 1993 on dry matter yield, total N and NO_3-N concentration, and total N uptake of Reed Canarygrass in 1994.

1993 N Rate	Dry Matter Yield				Total N Concentration			NO_3-N Concentration			Annual Uptake	
	1st cut	2nd cut	3rd cut	Total	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut	Total N	NO_3-N
lb N/A	----- TDM/A -----				----- % -----			----- ppm -----			lb N/A	lb NO_3-N/A
0	0.48	0.64	0.57	1.68	1.93	1.64	1.85	135	121	93	60.4	0.4
200	0.67	0.67	0.45	1.79	1.96	1.62	1.89	182	117	86	65.7	0.5
300	0.96	0.88	0.56	2.40	1.93	1.76	1.86	247	152	90	90.9	1.0
400	1.28	0.84	0.54	2.65	1.93	1.64	1.83	186	109	89	96.6	0.8
600	1.47	1.59	0.94	4.00	2.61	1.90	2.06	953	300	192	177.3	4.2
Stat. Analysis												
Signif. level (%):	99	99	99	99	99	85	58	99	84	60	99	99
BLSD (0.05):	0.32	0.34	0.24	0.74	0.29			283			39.4	1.5
C.V. (%):	22	25	25	20	9	10	9	56	72	80	27	72

FERTILIZER AND MANURE NITROGEN MANAGEMENT IN SOUTHEASTERN MINNESOTA[1]

G. W. Randall and J. A. Vetsch[2]

1994

ABSTRACT: A 3-yr study has been conducted on a Port Byron sil in Olmsted Co. to develop best management practices (BMPs) for fertilizer N and manure for corn in southeastern Minnesota. Three-year results indicate corn yields and profitability to be optimized at the 120-lb N rate applied in the spring prior to planting. Split and sidedress N applications did not consistently increase yield or profitability above that from preplant applications. Nitrate-N concentrations in the soil and the soil water increased markedly with increasing fertilizer N rate and clearly indicate the environmental impact of over-application of both fertilizer N and manure. Although the high rate of manure applied every-other-year resulted in highest yields in the year of application, residual effects on yield in the year after application were minimal while NO_3-N concentrations in the soil water at 7.5' were markedly higher compared to the annual applications. Additional years will be needed to more clearly distinguish the long-term differences among treatments for the establishment of more precise BMPs.

Management of nitrogen from both fertilizer and manure is vitally important to the economic profitability of southeastern Minnesota crop producers and the environmental quality of this region's resources. The overall purpose of this study is to develop best management practices (BMPs) for fertilizer N and manure for corn grown on well-drained, silt loam soils of southeastern Minnesota. Sub-objectives include determining: a) the optimum profitability associated with various rates and times of N application and b) the downward movement and distribution of nitrates through the soil profile as influenced by rates and times of N application and annual vs every-other-year application of dairy manure.

MATERIALS AND METHODS

A 5-year study (1987-91) at this site (Richard Lawler & Sons Farm) showed the optimum rate of fertilizer N to be between 75 and 150 lb N/A applied in the spring prior to planting. Thus, this study was started in 1992 to determine more precisely the optimum rate of fertilizer N for continuous corn and whether split or sidedress applications would be advantageous. The fertilizer treatments were applied as urea and were compared to liquid dairy manure treatments. The spring preplant fertilizer treatments were broadcast-applied and field cultivated in while the sidedress treatments were knifed in about 4" deep. The nutrient analyses of the liquid dairy manure used each year are given in Table 1 while the nutrient amounts added each year are given in Table 2. The manure was sweep-injected about 4" deep prior to planting. All plots were chisel plowed each fall.

Corn (Pioneer 3751 in 1992 and 1993 and Pioneer 3861 in 1994) was planted at 32000 plants per acre without starter fertilizer. Force was used to control corn rootworm. Yields were taken by combine harvesting the center two rows in 1992 and 1994 and by hand-harvesting in 1993.

Soil water samples were obtained periodically throughout the season (May - Nov.) from porous cup samplers installed at the 5 and 7.5' depths. Soil samples were taken to an 8-foot depth from each plot each fall.

RESULTS

Yields

Grain yields shown in Table 3 were rather low in 1992 and 1993 but were quite respectable in 1994. Optimum yield each year and the greatest economic return to the fertilizer was obtained with the 120-lb preplant N rate. Splitting the N applications into preplant and sidedress application at the 7 to 8-leaf stage (corn 12 - 15" tall) did not consistently improve the 3-yr yield or profit; although the split-applied 90-lb rate was 4 bu/A and $6/A better than the single preplant 90-lb rate. Applying all of the N at the 8-leaf stage resulted in slightly poorer yields and about $5/A less profit compared to the same N rate applied preplant. This emphasizes the point that sidedress N needs to be applied before the V4 stage (6-leaf) in continuous corn if yields and fertilizer efficiency are to be optimized.

In 1992, grain yield was 23 bu/A higher with the 8650-gal manure treatment (no. 10) compared to the 3700-gal treatment (Table 3) However, the residual effect of the high manure rate was minimal in 1993 when yields were 19 bu/A lower than the annual average 4100-gal rate (trt. no. 9). Three annual applications averaging 4400 gal/A (145 lb total N/A/yr) (trt. no. 9) produced 3-year average corn yields which were similar to those from the 90-lb fertilizer N rate. Similar to 1992, the large every-other-year treatment (trt. no. 10) produced a yield in 1994 that was 23 bu/A higher than the annual rate of manure. This yield of 167 bu/A was similar to that obtained with the 120-lb fertilizer N rate, but silage production was 0.7 tons dry matter/A higher with the heavy manure treatment (data not shown).

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[1] Support for this project has been provided by the Center for Agricultural Impacts on Water Quality and the Southern Experiment Station.

[2] Professor and Asst. Scientist, respectively, Southern Experiment Station, Waseca.

Table 1. Nutrient analyses of the liquid dairy manure used in 1992, 1993 and 1994.

Year	Total N	NH_4-N	P_2O_5	K_2O
	lb/1000 gal			
1992	45.0	18.2	14.2	21.2
1993	28.0	18.4	15.9	23.3
1994	28.4	16.0	12.0	30.2

Table 2. Nutrient application rates as liquid dairy manure in 1992, 1993 and 1994.

Year	Trt. No.	Applc'n rate	Total N	NH_4-N	P_2O_5	K_2O
		gal/A	lb/A			
1992	9	3700	166	67	52	78
	10	8650	389	157	123	183
1993	9	4500	126	83	72	105
	10	0	0	0	0	0
1994	9	5000	142	80	60	151
	10	10000	284	160	120	302
1992-93	9	8200	292	150	124	183
Total	10	8650	389	157	123	183
1992-94	9	13200	434	230	184	334
Total	10	18650	673	317	243	485

Table 3. Corn grain yield and economic return to N as influenced by nitrogen and manure treatments.

Treatment			Year			Three-Yr	Return[1/]
No.	N rate	Time of Application	1992	1993	1994	Avg.	to fert.
	lb/A		Yield (bu/A)				$/A
1	0	Spr. preplant (PP)	33	58	63	51	-
2	60	"	82	95	139	105	110
3	90	"	103	96	147	115	128
4	120	"	113	106	165	128	152
5	150	"	112	108	157	126	143
6	60 + 30	Spr. PP + SD (8-leaf)	100	105	153	119	134
7	60 + 60	"	105	105	155	122	136
8	90	SD (8-leaf)	89	100	150	113	123
9[2/]	liquid dairy manure, annually	Spring injected	113	99	144	119	-
10[2/]	liquid dairy manure, every other year	Spring injected	136	80	167	128	-

[1/] Economics based on the following prices: Corn = $2.25/bu, N = $0.15/lb, and $3.00/acre/application.
[2/] See Table 2.

Residual Soil Nitrate

Residual soil nitrate-N (RSN) in the soil profile in November, 1994 was greatly impacted by the N treatments (Fig. 1). RSN ranged from 32 lb/A in the 0-8' profile with the 0-lb N rate to 176 lb/A with the 150-lb treatment. Much of this increase was due to NO_3-N that was found below 5 feet with the 150-lb rate. Accumulation of NO_3 below this depth is significant because of the higher potential for leaching to groundwater. Very little difference in RSN was found between the 90- and 120-lb N rates.

The RSN remaining from the two manure treatments was not excessive and did not result in high levels of NO_3-N in the profile at the end of three years (Fig. 1). Significantly more NO_3 was found in the 0-1' and 1-2' layers with the high every-other-year treatment (no. 10) compared to the annual treatment (no. 9). An intent of this research is to determine whether this "extra" residual NO_3 will carry over and be available for the 1995 crop or whether it will leach downward out of the root zone prior to crop uptake.

Nitrate-N in the Soil Water

Soil water extracted from the 5' and 7.5' depths on Sept. 8, 1994 also showed a significant effect of N rate, source and time of application on the NO_3-N in the water (Fig.'s 2, 3 and 4). Nitrate-N concentration increased at both the 5' and 7.5' depths with increasing fertilizer N rate. At the optimum fertilizer N rate (120 lb/A) soil water contained 14 and 16 mg NO_3-N/L at the 5' and 7.5' depths, respectively (Fig. 2). Reducing the N rate to 90 lb/A resulted in NO_3-N concentrations of 13 and 12 mg/L at the 5 and 7.5' depths, respectively.

Split and sidedress applications of N gave somewhat inconsistent results (Fig. 3). Split applications at the 90- and 120-lb N rates gave similar NO_3-N concentrations as preplant applications at these rates. Surprisingly, the 90-lb sidedress treatment resulted in significantly lower NO_3-N concentrations compared to the preplant application. This is not consistent with previous studies in SE Minnesota.

Nitrate-N concentrations at the 5' depth in the manure treatments were less than from the 60-lb fertilizer N treatment at the end of three years (Fig. 4). The every-other-year treatment applied in 1992 did result in higher NO_3-N concentrations at the 7.5' depth compared to the annual manure treatment. It is very doubtful that the April, 1994 treatment would have contributed to NO_3 at this depth by early September. This suggests that high rates applied every-other-year have a higher potential for NO_3 leaching in years of above-normal rainfall compared to lower rates applied annually.

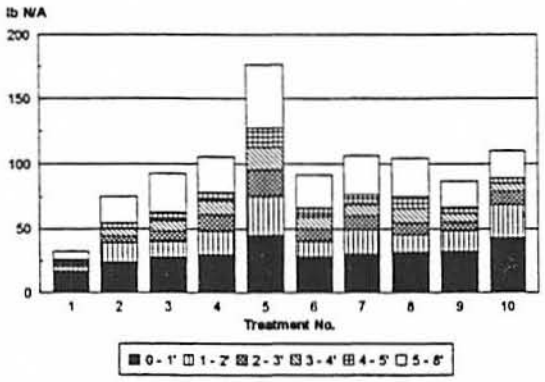

Fig. 1. Soil NO_3-N content as influenced by three years of fertilizer and manure treatments.

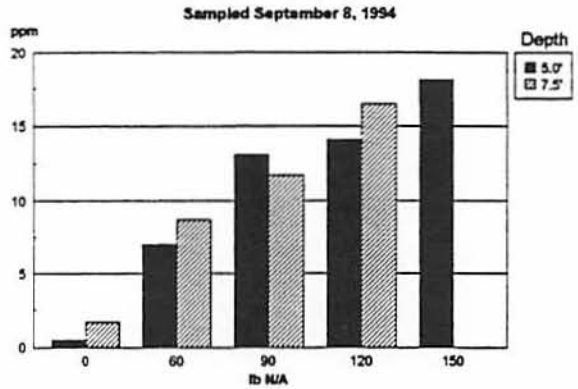

Fig. 2. Nitrate-N concentration in the soil water as influenced by fertilizer N rate.

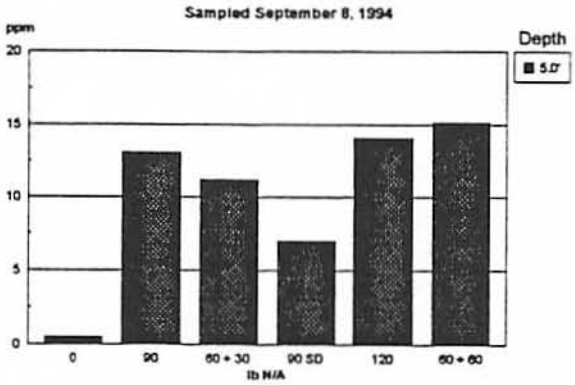

Fig. 3. Nitrate-N concentration in the soil water as influenced by rate and time of fertilizer N application.

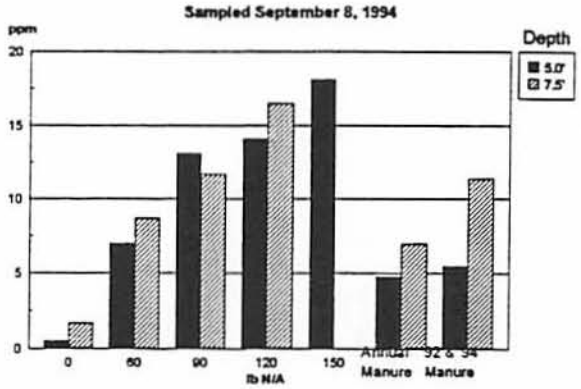

Fig. 4 Nitrate-N concentration in the soil water as influenced by rate and source of N.

NITROGEN AND MANURE MANAGEMENT FOR CORN AFTER ALFALFA IN WINONA COUNTY

G. W. Randall and J. A. Vetsch

1994

ABSTRACT: Semi-solid dairy manure was applied at rates of 0, 10, 20 and 30 T/A (wet basis) to a 3-yr old stand of alfalfa in late October and chisel plowed in. Corn was planted on this Seaton silt loam soil and a sidedress N treatment of 75 lb N/A was applied at the V5 stage. Grain, stover and silage yields and grain N concentration were not affected by the manure or fertilizer treatments. However, N removal by the grain, stover and whole plant (silage) was increased by the manure treatments. Nitrate-N concentration in the soil water at the 5' depth was increased markedly by the manure treatments by July and by both the manure and fertilizer treatments by September. Nitrate-N concentrations in the soil at the V1 and V4 stages, especially the top foot, were increased by the manure treatments. Increased plant uptake lowered the NO_3-N concentrations by the V9 and VT stages, but there was still a slight effect of the manure and fertilizer treatments. These data show no advantage to applying manure or fertilizer N for first year corn after alfalfa.

Surveys of land owners in Winona County indicate a substantial acreage of corn is planted following alfalfa. Previous studies have shown little or no corn yield response to fertilizer N for first-year corn after alfalfa. Yet many farmers often add some fertilizer N and dairy farmers without an adequate land base for manure often apply manure following alfalfa for corn. The result of these fertilizer and manure additions is an abundant supply of N, which is in excess of plant use and which can contribute significantly to nitrates in the ground water. Surveys of private wells within the county document that nitrate-N concentrations are frequently found to exceed the maximum contaminant level (MCL) for drinking water.

The purposes of this study were to determine: (1) the effect of dairy manure and fertilizer N applied following alfalfa on corn production, nitrate-N in the soil profile, and nitrate-N in the soil water at the 5' and 7.5' depths and (2) the "available" N to corn in an animal-based cropping system by evaluating various soil N tests from samples taken periodically during the season.

MATERIALS AND METHODS

The site is located on a Seaton silt loam at the Robert and Eugene Kalmes farm in Winona County. Alfalfa was companion seeded with oats in May 1991 following five years of continuous corn. After removing three cuttings of alfalfa in 1993, semi-solid dairy manure was applied on Oct. 27 at rates of 10, 20, and 30 T/A (wet) to plots that were replicated four times. Three manure samples were taken and analyzed. Average values were: 18.7% dry matter, 10.8 lb total N/ton, 4.0 lb NH_4-N/ton, 10.9 lb P_2O_5/ton, and 14.4 lb K_2O/ton. All plots were chisel plowed to an 8 - 9" depth within 6 hours.

Corn (Pioneer 3861) was planted on May 6 after field cultivation. Weeds were controlled well with herbicides. No mechanical cultivation was practiced. Urea was knifed in 4" deep midway between the rows at a rate of 75 lb N/A on June 14 to four additional plots. The corn was about 12" tall (V5 stage). Soil water samples were taken periodically during the season from porous cup samplers installed at a depth of 5'. Grain and silage yields were taken by hand-harvesting 60' of row from each plot on Sept. 20.

RESULTS AND DISCUSSION

Grain yield, grain N content, and silage yield were not significantly different ($P \leq 10\%$ level) among the five treatments (Table 1). As a group, however, yields and N removal tended to be slightly higher with the manure treatments compared to the fertilizer treatment.

The negative impact of these manure and fertilizer N treatments can readily be seen in Table 2. Nitrate-N concentrations in the soil solution water at a 5' depth in July were increased by all three manure treatments with no effect of the June-applied fertilizer treatment. By September, nitrate-N concentrations were 2X to 3X higher with all of the fertilizer and manure treatments compared to the control.

Nitrate-N concentrations in the 0-2' layer of all plots were considerably higher than in October '93 prior to chisel plowing and reflected mineralization which occurred from the alfalfa system (Table 3). Concentrations of NO_3-N were slightly higher for the manure treatments than for the control throughout the season. At the V1 stage, NO_3-N concentration did not exceed 15 ppm, which is below the sufficiency level of 19 ppm where no yield response is expected according to Minnesota's new soil N test. Because no yield response was obtained, these data suggest that plant available N released from the alfalfa and manure is not being adequately identified and interpreted by the new soil nitrate test at this early sampling time. Under these conditions a 0-1' sample taken at the V4 stage using 21 ppm as the sufficiency level would have been a better test.

SUMMARY

- Although trends toward higher corn yields (<4% grain yield increase) were evident when dairy manure was applied for first year corn after alfalfa, the negative consequences of the manure were readily shown with NO_3-N concentrations in the soil water 2X to 3X above that found in the control.
- Sidedress applying 75 lb N/A to first year corn after alfalfa did not increase corn production but did increase NO_3-N concentration in the soil water by over 3-fold three months after application.
- Based on these data, applying fertilizer or manure for first year corn after good alfalfa is <u>not</u> a recommended BMP.

Table 1. Grain, stover, and silage yields, grain and stover N content, and total N removal in the grain, stover and silage as affected by manure and fertilizer applied for corn following alfalfa.

Treatments		Yield			N Concentration		N Removal		
Manure	Fert N.	Grain	Stover	Silage	Grain	Stover	Grain	Stover	Silage
T/A (wet)	lb/A	bu/A	TDM/A	TDM/A	---- %	------	-------	lb N/A	-------
0	0	178.6	3.972	8.197	1.04	0.53	87.9	42.2	130.0
10	0	185.8	3.941	8.338	1.13	0.69	99.4	54.0	153.4
20	0	183.5	4.235	8.577	1.15	0.67	99.8	56.4	156.2
30	0	187.2	4.382	8.811	1.10	0.70	97.6	61.2	158.8
0	75	176.9	3.988	8.173	1.08	0.67	90.0	53.0	143.0
Treatment Statistical Analysis									
Sign. level (%):		56	82	83	81	97	99	91	99
LSD (0.05):						0.11	7.3		15.4
LSD (0.10):						0.09	6.0	8.8	12.6
C.V. (%):		4.9	7.9	5.3	5.8	10.7	8.9	7.3	6.8
Contrasts 'manure vs fertilizer'									
Sign. level (%):		88	69	85	80	31	85	95	96

Table 2. Nitrate-N concentrations in the soil water at 5' in July and September, 1994 as affected by manure and fertilizer N applied for corn after alfalfa.

Treatments		Nitrate-N Conc. in Soil Water at 5'	
Manure	Fert N.	July	Sept.
T/A (wet)	lb/A	-------- mg/L	--------
0	0	5	4
10	0	9	8
20	0	12	8
30	0	13	11
0	75	7	13

Table 3. Nitrate-N concentrations in the soil as affected by manure and fertilizer N applied for corn after alfalfa.

Treatment			Growth Stage			
Manure	Fert N	Depth	V1	V4	V9	VT
T/A (wet)	lb/A	ft	----------	ppm	----------	
0	0	0-1	13.7	22.3	5.3	3.5
		1-2	7.1	6.8	4.5	1.8
		0-2	10.4	14.6	4.9	2.6
10	0	0-1	16.9	25.6	7.0	3.6
		1-2	8.2	8.7	5.1	2.2
		0-2	12.6	17.2	6.0	2.9
20	0	0-1	20.4	23.8	6.4	5.2
		1-2	8.7	9.7	5.6	3.1
		0-2	14.6	16.8	6.0	4.2
30	0	0-1	19.9	23.9	8.2	6.8
		1-2	9.7	10.3	7.0	5.8
		0-2	14.8	17.1	7.6	6.3
0	75	0-1	-	-	-	8.2
		1-2	-	-	-	5.4
		0-2	-	-	-	6.8

EVALUATING SOIL N TEST METHODS ON FIELDS WITH A MANURE HISTORY[1/]

Gyles Randall, Michael Schmitt, and Jeffrey Vetsch[2/]

ABSTRACT: Nitrogen can become available to the plant from previous applications of manure. The purpose of this study was to evaluate various soil N test methods to see if Minnesota's new soil N test needs to be modified or an additional test needs to be developed to more accurately predict soil N availability to crops in animal-based systems. Corn yields were optimized with N rates of 0, 0, 60 and 120 lb N/A at the four sites and were related to the residual soil NO_3-N (RSN) indicated by the new preplant soil N test. Using the test reduced N recommendations at three of the sites to more economical and environmentally-sound rates of N. Fertilizer N was not under-recommended at any site by the new test. Although further soil N test research appears to be necessary for more accurate prediction of available soil N in these animal-based systems, use of the present N test will provide greater profit while reducing the potential for leaching of excess N to groundwater.

Manure is often applied to the same fields each year by producers because of the proximity of the field to the livestock facility or because of an inadequate land base to facilitate less frequent applications. As a result, manure-N may accumulate over time and can then become available through mineralization to succeeding crops. The amount of N becoming available in any particular field is unknown. Thus, fertilizer N recommendations usually do not take into account these previous applications.

The purpose of this study is to evaluate various soil N tests in animal-based systems to see if our present soil N test needs to be modified or a new test developed to more accurately predict soil N availability to crops. To do this we must obtain experimental sites with a long-term manure history, apply a series of fertilizer N rates, determine the yield response to the fertilizer, and then calibrate this response or lack of response to soil N values obtained by various soil tests.

EXPERIMENTAL PROCEDURES

Four sites were selected for this study in 1994 (Table 1). Two were on fine-textured glacial till soils in south-central Minnesota and two were on medium-textured loess soils in southeastern Minnesota. Three sites had a history of dairy manure and one had hog manure. Manure was not applied after the fall of 1992 at any of the sites. The previous cropping history is also given in Table 1.

Table 1. Cooperator, field history, soil type, and parent material at each of the 1994 sites.

	Site (County)			
	Waseca	Nicollet	Olmsted	Olmsted
Cooperator:	SES, U of M	Leonard Pork Farms	Elmer Borst & Sons	Dan Griffin
History:				
Crop	Corn - 1993 & 1992 Alfalfa - 1989-91	Corn - 1991 & 1993 Soybean - 1992	Continuous Corn	Continuous corn
Manure[1/]	10000 gal/A of liquid dairy manure in Oct. '91 & Oct. '92	9100 gal/A of liquid hog manure in Oct. '92	Dairy manure applied annually	Dairy manure applied annually
Soil type:	Webster cl	LeSueur cl	Mt. Carroll sil	Port Byron sil
Parent Material:	Glacial till	Glacial till	Loess	Loess

[1/] No manure applied after Fall, 1992.

Nitrogen as urea was broadcast-applied and incorporated at rates of 30, 60, 90, 120, 150 and 180 lb N/A just before planting and was compared to an unfertilized check plot at each site. At the two glacial till sites, three split application treatments were compared to the preplant treatments. Urea was knifed-in 4 inches deep mid-way between the rows when corn was 10 to 12" tall at rates of 30, 60 and 90 lb/A on plots that had received a 30-lb preplant N rate. Four replications were used at all sites. Pioneer 3751 was planted and thinned to uniform populations at all sites. Weeds were controlled very well with a combination of herbicides and cultivation.

Soil samples were taken from the control plots in 1-foot increments to a depth of three feet at three times during the season (preplant, emergence, and 10-12" tall corn). After harvest, samples were taken to a 4-foot depth from the 0, 90 and 180-lb treatments. Samples were analyzed for nitrate-N (NO_3-N), ammonium-N (NH_4-N), and two forms of hydrolyzable N.

[1/] Partial funding provided by the Minnesota Legislature from the MN Future Resources Fund as recommended by LCMR. Appreciation is extended to Bruce Montgomery and others at the Minn. Dept. of Agriculture for their role in facilitating this research project.

[2/] Professor, Southern Experiment Station, Waseca; Assoc. Professor, Dept. of Soil Science, St. Paul; and Assistant Scientist, Southern Experiment Station, Waseca.

Grain yields were taken by combine harvesting 114' of row from each plot at the Waseca and Nicollet Co. sites and hand-harvesting 60' of row from each plot at the Olmsted Co. sites. Silage yields were determined from 20' of row in each plot at all sites.

RESULTS AND DISCUSSION

Corn yields were excellent at all sites (Table 2). Statistical analysis showed no significant difference among the yields at both Olmsted Co. sites but a highly significant response to N at the Waseca and Nicollet Co. sites. Yields were optimized at the 120 and 60-lb N rates at these two sites, respectively.

Table 2. Corn yields as influenced by N applied to fields with a manure history in 1994.[1/]

N Treatment		Site			
Preplant	Sidedress	Waseca Co. SES	Nicollet Co. Leonard	Olmsted Co. Borst	Olmsted Co. Griffin
lb N/A		Grain Yield (bu/A)			
0	0	116	161	196	175
30	0	135	177	201	179
60	0	154	187	207	183
90	0	159	179	208	185
120	0	166	181	205	180
150	0	169	182	203	179
180	0	160	184	211	181
30	30	159	190	-	-
30	60	159	178	-	-
30	90	162	178	-	-
Statistical Signif. (%):		99	99	57	57
LSD (.05):		11	13	-	-
CV (%):		4.8	4.9	4.8	3.3

[1/] No manure applied after Fall, 1992.

Soil NO_3-N analyses from samples taken early in the season show virtually no residual soil NO_3 (RSN) at the Waseca Co. site regardless of sampling time (Table 3). At the Nicollet Co. site, modest amounts of RSN were found at all sampling times, especially at the 2 to 3' depth. Modest amounts of RSN were also found at the Borst site in Olmsted Co. with little difference among times or depths of sampling. At the Griffin site in Olmsted Co., somewhat more soil NO_3-N was found, especially in the emergence (V1) and 12" corn (V4 to V5) stages and in the surface 1-foot layer. Rapid mineralization of organic N from prior manure applications with subsequent nitrification occurred at this site when the soil temperatures warmed.

Table 3. Soil NO_3-N as influenced by time and depth of sampling in fields with a manure history in 1994.

Sampling		Site			
Time	Depth (ft)	Waseca SES	Nicollet Leonard	Olmsted Borst	Olmsted Griffin
		ppm			
Preplant[1/]	0-1	4.6	10.7	10.6	12.7
"	1-2	4.7	10.9	10.4	11.1
"	2-3	3.4	14.0	9.8	12.4
"	0-2	4.6	10.8	10.5	11.9
V1 (emergence)	0-1	4.5	10.4	10.3	21.1
"	1-2	4.3	12.8	9.9	14.0
"	2-3	3.8	16.4	8.2	10.7
"	0-2	4.4	11.6	10.1	17.6
V4-5 (12" corn)	0-1	4.6	10.8	12.0	28.4
"	1-2	5.3	12.8	11.7	17.2
"	2-3	4.8	17.8	9.1	8.6
"	0-2	5.0	11.8	11.8	22.8

[1/] Soil NO_3-N in the 0-4' profile totaled 65, 198, 161, and 214 lb/A for the four sites, respectively.

Soil N credits determined by Minnesota's new preplant soil N test indicate a credit of 0, 65, 65, and 65 lb N/A for the Waseca, Nicollet, Olmsted, and Olmsted Co. sites, respectively. Subtracting this credit from our present recommendation of 150 lb N/A for a yield goal of 170 bu/A at these four sites provides N recommendations of 150, 85, 85, and 85 lb N/A, respectively. These

recommendations are closer to the optimum amounts of N needed as shown by the yields in Table 2, but they are not perfect. Even though N recommendations at three of these sites were reduced to more economical rates by our present N test, it appears that further refinement of the test may be needed in cropping systems with long-term manure histories.

Residual soil NO_3-N in the 0-4' profile after harvest was greatly different among the four sites (Table 4). At the Waseca site, where grain yield responded to the 120-lb N rate, RSN did not accumulate above that in the control until the applied N rate clearly exceeded the optimum N rate. In Nicollet Co., where 9100 gal of liquid hog manure had been applied in 1992 and where grain yields only responded to the 60-lb N rate, substantial amounts of RSN were found in all treatments. This was especially true for the 180-lb N rate and in the 3 to 4' depth. Apparently RSN had leached to this depth in the 24 months since application of the manure and much of it had not been taken up by the plants. Some accumulation of excess RSN occurred at the Borst site, especially at the 180-lb N rate. Excess RSN was also found at the Griffin site, where no yield response to N fertilizer was found. These data clearly show how high levels of RSN can accumulate in soils when N from previous manure applications becomes available and fertilizer N is applied, even when very high yields are produced.

Table 4. Residual soil NO_3-N (RSN) after harvest at the four sites.

		Site			
N rate	Depth	Waseca	Nicollet	Borst	Griffin
lb/A	ft	lb NO_3-N/A			
0	0-1	16	57	32	38
	1-2	14	46	18	27
	2-3	10	34	15	22
	3-4	11	61	22	26
	0-4	**51**	**198**	**87**	**113**
90	0-1	16	49	36	50
	1-2	14	60	22	46
	2-3	11	57	20	36
	3-4	12	86	28	35
	0-4	**53**	**252**	**106**	**167**
180	0-1	51	98	44	45
	1-2	38	106	50	66
	2-3	27	88	47	66
	3-4	20	83	42	48
	0-4	**136**	**375**	**183**	225

SUMMARY

- The response to fertilizer N by continuous corn was related to the RSN indicated by the new preplant soil N test in these fields with a long-term manure history.
- The present soil N test recommended a 65-lb credit (reduction in fertilizer N rate) at three of the sites, which was much closer to the optimum economic rate than if one had not used the test in these fields. Thus, the test paid economic dividends even though it was not perfect.
- The potential for NO_3^- leaching to the groundwater is greatly increased by high levels of RSN accumulating in soils when fertilizer N is added without taking into account the release of N from previously applied manure.
- Further soil N test research appears to be necessary to more accurately predict the N availability in fields with a long-term manure history.

IMPACT OF ADDING WHEAT TO A TRADITIONAL CORN-SOYBEAN STRIP SYSTEM ON CROP YIELDS AND EROSION CONTROL[1/]

T. K. Iragavarapu and G. W. Randall[2/]

1994

ABSTRACT: Four single crop production components (ridge tillage; 3-crop wheat-corn-soybean rotation; narrow, alternate strips (15' wide); and legume interseeding) were integrated into a complete cropping system. Studies were started in 1991 at two locations in southern Minnesota on Webster clay loam soil. The rotations compared were: a) continuous corn; b) corn-soybean; c)corn-soybean-wheat with and without interseeded legumes (Nitro alfalfa or hairy vetch). Each corn strip following wheat and soybeans was fertilized at four N rates (0, 40, 80, and 120 lb N/A) to determine N contribution of legumes. Results from the last 4 years indicate that the narrow-alternate strips of corn, soybean, and wheat in a ridge-till system provide excellent surface residue coverage and satisfy erosion control goals. While corn yields were enhanced (1 and 9% in E-W and N-S row orientation, respectively) and soybean yields decreased slightly (5% in both E-W and N-S rows), wheat yields were unaffected in the narrow strips compared to conventional systems. Wheat introduced into the traditional corn-soybean strip system reduced the negative border effects of corn on soybeans. Results from this study suggest that these 3-crop systems be planted in N-S orientation to optimize production.

Narrow, alternate strip cropping systems have been receiving much attention in the farm press the last few years. These aesthetically pleasing cropping systems are touted as sustainable systems that reduce chemical inputs and pest activity while improving net profit and erosion control.

Studies show that in traditional corn-soybean strip crop systems improved corn yields in the border rows are offset by reduced soybean yields. Adding wheat to this 2-crop strip system should reduce border effects on soybeans without sacrificing wheat yields. Wheat planted north of corn and south of soybeans in east-west rows will allow adequate sunlight for soybeans. Wheat, a cool-season crop, will not be shaded as it heads out before corn gets tall enough to shade it. Addition of wheat to the corn-soybean system will not only facilitate interseeding of legumes that provide nitrogen to the following corn, but also will break corn root worm diapause and reduce soybean cyst nematode infestation.

The objective of this study was to evaluate the potential of a 3-crop (wheat-corn-soybean) system on crop yields and erosion control.

PROCEDURE

Studies were started in 1991 at the Southern Experiment Station with east-west rows and on the Lynn Sorenson farm in Freeborn Co. with north-south rows. Soybean strips were located on the south side and wheat strips on the north side of corn in E-W rows. In N-S rows, wheat was located on the east side and soybean on the west side of the corn strips. All crops were planted in 15' wide by 120' long strips on ridges. Corn (Pioneer 3751) was planted in 30" rows at a rate of 30,200 plants/A in rows 2-5 and 36,000 ppA in the outside rows (1&6). Nitrogen as ammonium nitrate was broadcast-applied by hand at rates of 0, 40, 80, and 120 lb N/A to plots measuring 6 rows wide x 30' long in each strip. Weeds were controlled with a 15" band-application of Lasso (3 lb ai/A) and Bladex (2.5 lb ai/A) and ridge till cultivation. Hand-harvest grain yields were obtained from a 25-foot section within each row of each plot.

Soybean (Sturdy) was planted at a rate of 9 to 10 beans/foot of row in 30" rows. Weeds were controlled with a preemergence, 15" band-application of Lasso (3 lb ai/A), and postemergence, 15" band-application of Pursuit (4 oz ai/A), and by ridge cultivation. Each individual row was harvested with a plot combine.

Spring wheat (Grandin) was planted at a rate of 94 lb/A with a minimum-till drill in 8" rows. Broadleaf weeds, when present, were controlled with a broadcast-application of Bromoxynil. Nitrogen as ammonium nitrate was preplant-applied at 50 lb N/A.

RESULTS

The yield advantage of the narrow strips for corn in the 3-crop (wheat-corn-soybean) rotation was 2.0 bu/A (1%) in the E-W system and 12.2 bu/A (9%) in the N-S row orientation compared to the whole-field averages when averaged across the 4 yr period (Table 1). In the E-W rows, the north row (next to wheat) and the south row (next to soybeans) yielded 4 and 15% higher, respectively, compared to the average of the center two rows, which were assumed to represent whole field production. The reason for the south row yielding more than the north is it receives more direct sunlight than the north row.

[1/] Funding provided by USDA-LISA and Minnesota Department of Agriculture.

[2/] Post-doctoral Research Associate and Professor, respectively, Univ. of Minnesota.

When the rows were oriented N-S, both outside corn rows benefitted due to similar amounts of sunlight reaching these outside rows. The yield advantage was 24 and 28% for the east and west outside rows, respectively, compared to the center two rows. Dandelions were a major problem throughout southern Minnesota in the spring of 1994, especially in fields with either no-tillage or reduced tillage. Weed pressure, especially dandelions coupled with previous year's wheat residue posed problems in establishing an uniformly emerging stand of corn and the outside rows showed no yield advantage compared to the center two rows. As a result, the 4 yr average yield advantage for the strips was less than that of the first 3 yr (see Field Research in Soil Science, 1994).

Grain moisture of the strip was 0.2 points greater than the center two rows in E-W rows (Table 2) because of higher moisture content in the north outside row. This is probably due to less sunlight reaching this row than the other rows. On the other hand, grain moisture was lowest in the south row since it receives direct sunlight. In N-S rows, the strip was drier by 0.6 points compared to the center two rows. The west outside row had the lowest grain moisture since it receives more sunlight late in the afternoon when temperatures are high resulting in a faster dry down in this row.

Soybean yields were depressed 7 bu/A (18%) for the north row (next to corn) and 4 bu/A (10%) for the south row next to wheat compared to the center two rows in the E-W row orientation (Table 3). In N-S rows, row 6 (next to wheat) yielded only 1.5 bu/A (4%) less compared to the center two rows while the row bordering corn (row 1) suffered 7.7 bu/A (22%) yield loss. This suggests that including wheat resulted in reduced competition with the adjacent soybean row than the corn row. Root competition for moisture and nutrients between adjacent corn and soybean rows is a possible explanation for yield loss in the north soybean row in E-W rows where shading is not a problem and the east row in N-S rows.

Soybean yields were decreased much more severely in narrow strips alternated with corn (Table 4). Outside rows (rows 1 & 6) bordering corn yielded 23% less (9 bu/A) than the center two rows in the E-W system and 22% less (7.7 bu/A) in the N-S system. The soybean row on the north side of corn (E-W rows) and east side of corn (N-S rows) yielded 34 and 22% less, respectively, than the center two rows. Seed yields for the 6-row alternate strips were decreased by 3.5 bu/A in the E-W rows and 3.6 bu/A in the N-S rows compared to the whole-field averages. Averaged across the 4-yr period, wheat yields were not affected greatly either by the corn or soybean borders (Table 5).

Surface residue coverage before planting was ideal for all crops (Table 6). After planting, residue coverage was still > 30% following corn and wheat. Residue coverage after soybean was only 21%, but this was offset by mid-May with a well-established stand of wheat (soybean is followed by wheat in the 3-crop rotation) capable of providing excellent erosion control.

Table 1. Corn grain yield in a C-Sb-W rotation as influenced by row position and direction[1].

Row Direction	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip[1]
	bu/A					
E-W Rows	154.3	139.9	148.8	142.0	170.8	2.0
N-S Rows	168.8	140.0	136.3	135.4	174.1	12.2

[1] 4-yr (1991-1994) averages at the 120-lb N/A rate.
[1] Yield advantage of 6-row strip compared to the center two rows, which are assumed to represent a whole-field yield.

Table 2. Corn grain moisture at harvest in a C-Sb-W rotation as influenced by row position and direction[1].

Row Direction	Row/Position 1	2	3&4	5	6	Moisture Adv.of 6-row strip[2]
	%					
E-W Rows	33.7	32.5	31.5	31.5	29.5	-0.2
N-S Rows	23.4	23.5	24.2	23.5	22.7	0.6

[1] 4-yr (1991-1994) averages at the 120-lb N/A rate.
[2] Moisture advantage of 6-row strip compared to the center two rows, which are assumed to represent a whole-field.

Table 3. Soybean seed yield in a C-Sb-W rotation as influenced by row position and direction[1].

Row Direction	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip[2]
	bu/A					
E-W Rows	32.1	36.4	39.1	40.0	35.1	-2.1
N-S Rows	27.7	34.5	35.4	35.5	33.9	-1.7

[1] 4-yr (1991-1994) averages
[2] Yield advantage of 6-row strip compared to the center two rows, which are assumed to represent a whole-field yield.

Table 4. Soybean seed yield in a C-Sb rotation as influenced by row position and direction[1].

Row Direction	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip[2]
	bu/A					
E-W Rows	35.2	38.5	39.8	38.0	26.3	-3.5
N-S Rows	27.5	32.2	35.5	32.7	28.0	-3.6

[1] 4-yr (1991-1994) averages
[2] Yield advantage of 6-row strip compared to the center two rows, which are assumed to represent a whole-field yield.

Table 5. Wheat yields in strips as influenced by row direction[1].

Row Direction	N⅓ or E⅓	Center⅓	S⅓ or W⅓	Yield Adv. of 15' strip[2]
	bu/A			
East-West	43.6	42.1	41.1	0.2
North-South	42.1	38.6	35.9	0.3

[1] 4-yr (1991-1994) averages
[2] Relative yield advantage of the 15'strip compared to the center 5', which is assumed to represent a whole-field.

Table 6. Surface residue coverage (3-year average)[1] as influenced by previous crop at Freeborn Co.

Previous crop	Before planting	After planting
	----------%	----------%
Corn	63	37
Soybean	51	21
Wheat	83	35
Wheat + Alf.	88	56
Wheat + Vetch	90	48

[1] 1992-1994 averages

CONCLUSIONS

1. Incorporating a wheat strip between corn and soybean strips resulted in reduced negative border effects on soybean without affecting wheat yields.

2. Corn benefitted more in N-S strips than in E-W strips due to greater yield advantage for the strip and less grain moisture at harvest compared to the whole-field averages.

3. Narrow alternate strips of corn, soybean, and wheat satisfy erosion control goals.

4. Economic analyses of all inputs and outputs from these cropping systems are needed before we can compare the profitability of these narrow strip systems to conventional systems.

NITROGEN SOURCE, ROW CLEANER, AND STARTER FERTILIZER EFFECTS IN NO-TILL CORN PRODUCTION ON A WEBSTER CLAY LOAM SOIL.[1]

J.A. Vetsch and G.W. Randall[2]

ABSTRACT: Previous research has shown decreased corn yields in long-term, continuous no-till corn. This research study was initiated in 1994 to evaluate the effects of N source, row cleaners, and starter fertilizer on corn production in continuous corn and a corn-soybean rotation. Only data from the corn setup area will be presented in this initial year. Anhydrous ammonia (AA) increased grain yield by 4.3 bu/A as compared to urea ammonium-nitrate (UAN) applied with a point-injector. Row cleaner treatments encouraged early plant growth and provided a 3.7 bu/A yield advantage as compared to non row cleaner plots. Starter fertilizer increased early plant growth but resulted in a 5.1 bu/A yield reduction as compared to non starter plots.

INTRODUCTION

Long-term, continuous no-till corn production has decreased grain yields in some years on wet, poorly-drained clay loam soils in southern Minnesota. A research study was initiated in 1994 to evaluate the long-term effects and interactions of N source, (AA vs. UAN), row cleaners (RC), and starter fertilizer (SF) on corn grain production in continuous corn and a corn-soybean rotation.

EXPERIMENTAL PROCEDURES

A research site was established in the spring of 1994 at the Southern Experiment Station on a Webster clay loam soil. The area was cropped to corn in 1993 and was left untilled for 1994. In the spring of 1994 the area was split into three sections. One section will be maintained long-term, contnuous no-till corn. The second was no-till drilled to soybean in 1994 and will be planted to corn in 1995 to establish a corn-soybean rotation. A third section was planted to corn in 1994 and will be planted to soybean in 1995.

Treatments were based on current "on farm" management options for no-till. Individual plots were 10 ft wide by 115 ft long. The treatment combinations were arranged as a complete (2^3) factorial in a randomized complete block design with four replicates. Nitrogen source (AA or UAN), row cleaner (with or without at planting), and starter fertilizer (with or without at planting) were the three treatment main effects (2x2x2=8 treatments). A treatment was added to compare an early-season, broadcast application of UAN to a point-injector banded application at the V1 stage. Anhydrous ammonia was injected 15 in. from the row and 7 in. deep with a 5-knife applicator. UAN was injected 3 in. from the row to a depth of 4 in. with a 4-wheel point-injector. Both AA and UAN treatments were applied at V1. Dawn® row cleaners were used on a John Deere Maxi-merge 7100 planter for the RC treatments. Ten gallons of a 10-34-0 liquid starter were applied with the seed on the SF treatments. All corn plots were planted with the same planter. Anhydrous ammonia and UAN were applied at 150 lb N/A to the corn plots. A 10-lb N/A credit was given to plots that received SF, thus, only 140 lb N/A were applied to SF plots.

Corn (Pioneer 3578) was planted on May 16. Weeds were controlled with a pre-emergence application (May 18) of Lasso (3.0 qt. /A) and Bladex (2.5 qt. /A). The early-season broadcast application of UAN was applied on May 13. The AA and UAN point-injector treatments were applied on June 3. Plant emergence counts were taken on RC and non RC treatments by counting plants emerged in 50 ft of row. Plant heights were measured by taking extended leaf heights of 10 consecutive plants in each plot on June 20. Corn grain was combine harvested from two rows each 112 ft in length on October 26. Grain yield was calculated from plot weight and grain moisture measured in the combine. A subsample of the grain was saved, dried, ground and analyzed for total N content at the University of Minnesota Research Analytical Laboratory (UMRAL).

Soil samples were taken in the spring of 1994 to characterize the P and K fertility of the plot area. Nine soil cores (8 in. deep) were taken and composited from each replication. The samples were analyzed for pH, Bray P, and exchangeable K by the UMRAL. Soil tests for P and K were high to very high in all replications. The continuous corn area for 1994 averaged 28 and 190 ppm for Bray P and K, respectively, and had a pH of 6.7.

RESULTS AND DISCUSSION

Nitrogen source significantly affected grain yield, grain moisture, grain N removal, and final plant population. Grain moisture at harvest was 0.6 percent higher with AA (Table 1). Anhydrous ammonia treatments resulted in 4.3 bu/A greater corn grain yields and 4.9 lb more N in the grain compared to UAN treatments. Slight N deficiencies were evident during the growing season in some UAN plots. Greater N efficiency or less loss of AA could explain the yield advantage to AA.

Row cleaners significantly affected early plant growth and grain yield. Plant emergence reached 80% of total one day earlier in RC plots (Table 2). Plant heights, measured 35 days after planting, averaged 32.1 and 29.6 in. for the RC and non RC plots, respectively (Table 1). Row cleaners produced 3.7 bu/A greater yield as compared to non RC plots. As observed by other researchers in earlier studies, row cleaners hasten emergence and increase early plant growth and grain yield on cool wet soils.

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[1] Funding provided by the University of Minnesota, Southern Experiment Station.

[2] Assistant Scientist and Professor, respectively, University of Minnesota, Southern Experiment Station.

Table 1. The effect of N source, method of application, row cleaner, and starter fertilizer on grain yield, grain moisture, grain N concentration, grain N removal, final plant population and early plant growth.

Treatments			Grain				Final	Plant
N-source	Row Cl.	Starter	H_2O	Yield	N Conc.	N removal	Plant Pop.	Height
			%	bu/A	%	lb N/A	ppAx1000	inch
UAN	No	No	24.1	146.2	1.28	90.9	32.5	27.8
AA	No	No	25.2	150.0	1.32	95.8	32.3	26.5
UAN	No	Yes	24.3	139.7	1.32	90.0	32.6	33.2
AA	No	Yes	24.2	144.8	1.36	94.5	31.7	31.3
UAN	Yes	No	24.3	147.3	1.29	93.0	32.3	31.0
AA	Yes	No	24.8	154.8	1.30	99.0	31.7	29.6
UAN	Yes	Yes	23.4	146.4	1.30	93.6	32.8	34.2
AA	Yes	Yes	24.0	147.2	1.37	98.2	32.1	33.9
UAN Bdct	Yes	No	24.2	146.8	1.26	90.6	32.1	34.2
Statistical analysis of main effects for 2^3 factorial design (8 treatments).								
N source								
AA			24.6	149.2	1.34	96.8	31.9	30.3
UAN			24.0	144.9	1.30	91.9	32.5	31.5
N source Sign. level (%)			99	99	90	95	98	87
Row cleaner								
Yes			24.2	148.9	1.31	96.0	32.2	32.1
No			24.4	145.2	1.32	92.8	32.3	29.6
Row cleaner Sign. level (%)			89	99	26	81	22	99
Starter fertilizer								
Yes			24.0	144.5	1.34	94.1	32.3	33.1
No			24.6	149.6	1.30	94.7	32.2	28.7
Starter Fertilizer Sign. level (%)			99	99	87	20	26	99
Statistical analysis of interaction effects for 2^3 factorial design (8 treatments).								
N-source x Row cl. (%)			15	9	10	9	13	36
N-source x Starter (%)			85	64	44	15	62	13
Row cl. x Starter (%)			78	45	6	17	85	60
N-source x Row cl.*Starter (%)			93	84	54	8	49	40
C.V. (%)			2.6	3.8	5.2	7.0	3.0	7.1
Statistical analysis of treatment effect for randomized complete block design (9 treatments).								
Sign. level (%)			99	99	63	48	67	99
LSD (0.05)			0.6	5.4				3.1
C.V. (%)			2.6	3.7	5.3	7.2	3.0	6.9

Starter fertilizer significantly affected early plant growth (plant height), grain moisture, and grain yield. Plots that received SF averaged 33.1 in. tall 35 days after planting as compared to 28.7 in. for plots without SF (Table 1). Starter fertilizer plots had lower grain moisture but produced 5.1 bu/A less grain than plots without SF.

Table 2. The effect of row cleaners on plant emergence in continuous no-till corn.

	Date Measured							
Row cl.	23-May	24-May	25-May	26-May	27-May	28-May	31-May	3-June
		percent emerged						
No	1	5	26	44	62	79	97	100
Yes	1	13	44	65	78	86	98	100

There were no statistically significant interaction terms among the main effects at the 95% level (Table 1). Analysis of all 9 treatments in a randomized complete block design showed no significant difference between an injected application of UAN at the V1 stage as compared to an early-season broadcast application of UAN.

Impact of Turkey Manure Application on Corn Production and Potential Water Quality Concerns Westport MN 1994.[1]

G.L. Malzer, and T. Graff[2]

Abstract

A field study was continued at Westport, MN (begun in 1991) to study the impact of turkey manure application on irrigated corn and soybean production and nitrate-N movement below an Estherville sandy loam. Treatments included two rates of commercial fertilizer (70 and 140 lb N/a), and two rates of turkey manure (4 and 8 tons/A--wet weight basis) and an untreated check. Manure rates were computed to provide an estimated equivalent amount of available N per acre as fertilizer treatments. Treatments were planted to corn in 1994 following a previous crop of corn. Plant samples were collected at 8 leaf, silking, and physiological maturity. Plant samples obtained at physiological maturity were separated into grain and stover. Total dry matter production, N concentration and total N uptake were determined for each sampling. Water percolation, and movement of nitrate-N below the root zone was monitored utilizing 30 closed bottom non-weighing drainage lysimeters. Excess percolation was to be removed from the bottom of each lysimeter after each leaching event. Lysimeters were drained prior to planting, but since there were no large rainfall events in 1994 at Westport there was no excess water to collect during the growing season. Soil samples were collected from the soil profile prior to planting and at harvest time and analyzed for nitrate and ammonium N. Grain yields were excellent in 1994. Grain yields and N uptake were significantly higher with the higher rate of turkey manure application than with the highest rate of fertilizer. Grain yields and N uptake were increased substantially due to previously applied manure.

Introduction

Turkey production in Minnesota is ranked second in the nation (Minnesota Statistics, 1990). In 1990, Minnesota's turkey farmers boosted their output to a new record of 43.6 million turkeys. A large portion of the turkey production is concentrated in the West Central and Northwest regions of the state, where many turkey producers have limited land areas available to them for manure disposal. As production increases improved manure management skills will be required to meet the agronomic need and minimize groundwater contamination.

Increased emphasis on protection of surface water and ground water, and the farmers desire to reduce fertilizer cost have increased the need to evaluate the use of turkey manure. Turkey manure is rich in several nutrients. A survey conducted by Moncrief et al.(1991 unpublished data at the University of Minnesota) revealed that the nutrient composition of poultry manure on a dry weight basis is 5.1% N, 2.2% P and 2.3% K respectively. The 860,000 tons (dry wt.) of turkey manure produced per year in Minnesota could supply approximately 87.7, 86.7 and 47.5 million pounds of N, P_2O_5 and K_2O respectively for crop production.

The objective of this field study was to compare two rates of turkey manure (4 and 8 T/A on wet weight basis) and two rates of fertilizer N (70 and 140 lb N/A) on dry matter production, N uptake, grain yields, and leaching losses of NO_3-N within a corn-corn-soybean rotation.

Materials and Methods

In 1975, 30 non-weighing lysimeters were installed on the Rosholt farm near Westport, Minnesota. Each lysimeter was 5.75 ft in diameter,and 4 feet deep and constructed of 12-gauge galvanized steel coated with coal tar epoxy enamel. At the bottom of each lysimeter a sintered stainless filter candle was installed and connected to the soil surface by polyethylene tubing. Each lysimeter was placed in the center of 30' x 30' plots. Soil at the experimental site was an Estherville sandy loam (Typic Hapludoll) and the lysimeters were backfilled with that soil by depth. Selected chemical and physical properties of the soil are presented in Table 1.

Prior to 1991 this site did not have a history of manure application. Cropping history was corn following corn in a corn-corn-soybean rotation, and in 1990 corn was grown at this site without any fertilizers. This study was initiated in 1991 and corn was grown with urea fertilizer and manure treatments. In 1992 soybeans were grown with manure treatments only and in 1993 and 1994 corn again was planted into the experimental area with both fertilizer and manure treatments.

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1. Appreciation is expressed to the University of Minnesota Experiment Station, Wes-Min RCD, Pope Co. SWCD, and Pioneer Hi-Bred International for supplying seed.

2. Professor, and Assistant Scientist respectively, Dept. of Soil Science, University of Minnesota.

Table 1. Some chemical and physical properties of the Estherville sandy loam.

Soil Depth	Gravel	Sand	Silt	Clay	Organic Matter	pH
inches	----------	----------	%	----------	----------	
0-6	0.8	57.9	23.8	18.3	4.8	5.7
6-15	8.0	69.0	16.8	14.1	1.1	5.8
15-30	5.4	66.8	16.1	17.1	0.7	6.2

Irrigation was provided to all plots through a drip-type irrigation system. Drippers were 30 inches apart on a 0.5 inch plastic irrigation line. An irrigation line was placed along each row of corn. Water was pumped through the irrigation system at 13.8 kPa pressure. The emission rate for each dripper was 0.35 gal/hr. Each lysimeter contained 4 drippers. Irrigation water was applied when less than 2 inches of water was available in the soil profile. Irrigation water was metered through 3 main irrigation lines.

The experimental design included three replications of nine treatments in a randomized complete block design. Treatments in 1994 consisted of a zero N control, two rates of turkey manure (4 and 8 T/A, wet weight basis) and two rates of commercial fertilizer N (70 and 140 lb N/A as urea) which were applied to the same plots as in 1991 and 1993 (the five original 1991 treatments), two rates of manure (4 and 8 T/A) were added to the 1992 plots, which were residual manure in 1993, and two residual treatments which had manure in 1993. Turkey manure treatments were incorporated, immediately after application. The nutrient composition of the turkey manure is presented in table 2. Estimate of manure N availability was based on the assumption that 80% of the inorganic N and 30% of the organic N will be available during the first year of application. The manure rates applied were expected to provide approximately 70 and 140 lb. of available N/A. The entire study area had a broadcast application of 60 #/A of P_2O_5 and 160 #/A K_2O incorporated with the turkey manure. The area was planted to corn (Pioneer 3751 - 100 day R.M.) on May 3rd at a seeding rate of 29,600 seeds/A. Lorsban at (8 #/A) was banded in the row at planting for insect control. A tank mix of Lasso (1.75 #/A) + Bladex DF (1.5 #/A) was applied on May 20th for weed control.

Table 2.Turkey Manure Composition

Nutrients	lb/T
Total N	49
Inorg. NH_4^+-N	19
NO_3^--N	---
Organic N	30
P_2O	---
K_2O	---
Moisture %	50

+ Nutrient composition presented in wet basis.
--- not available at this time

Dry Matter production and N uptake were determined June 30th (8-leaf), July 25th (silking) and October 4th. Grain yields were determined by harvesting two 20 foot rows. Corn grain yields were reported at 15.5% moisture.

Soil water percolate was collected prior to planting in 1994. There were no major leaching events in 1994 and hence no water was removed during the 1994 growing season. The amount percolated and the NO_3^--N in the leachate was measured to quantitate concentration, flow rate and total N lost by leaching.

Soil samples collected prior to planting and at harvest (0-6, 6-12 and 12-18 inches), were analyzed for nitrate and ammonium N.

Results and Discussion

The 1994 growing season was excellent and grain yields associated with treatment applications ranged from 75 to 227 bu/a (table 4). Turkey manure applications produced higher yields and resulted in higher N uptake by the crop (more available N) than the anticipated comparable urea fertilizer treatment. Both turkey manure and urea application increased yields up to the highest rate applied. The low rates of turkey manure, however, provided N availability and crop responses similar to the highest rate of urea application. Most of the benefits associated with manure application were associated with the growing season following application. The residual benefits associated with manure application were, however, substantial. The grain yield obtained in 1994 when the high rate of manure was applied in 1993 produced yields comparable to 70 lbs N/A as urea applied in 1994.

The only water drained from the lysimeters in 1994 took place prior to planting. The results presented in Table 5, therefore, would not reflect the impact of 1994 treatments, but rather a reflection of what was present at the end of the 1993 growing season. No treatment effects were detected regarding the amount of water, nitrate concentration, and total loss of nitrate-N in the percolate water. All concentrations of nitrate-N in the percolate water (including the check) exceeded the EPA drinking water standard of 10 mg/L. Nitrate-N concentrations in the soil at planting time indicated that high turkey manure applications made in 1993 resulted in elevated concentrations of residual nitrate-N in the soil profile. This nitrate N could be leached to the shallow surface aquifer if the precipitation is excessive enough to cause leaching.

Table 3. Dry matter production, and N utilization as influenced by turkey manure, fertilizer and residual manure treatments - 1994.

Treatments	Dry Matter		N-Concentration		N Uptake	
	8-leaf	silking	8-leaf	silking	8-leaf	silking
	--------T/A--------		------ % N --------		----lb/A-----	
Control	0.64	2.33	2.05	0.79	26	37
70 lb N/A in '91,'93,'94	1.07	4.60	3.03	1.08	65	99
140 lb N/A in '91,'93,'94	1.02	4.41	3.48	1.72	71	151
TM 4 T/A in'91,'93,'94	1.17	4.76	2.96	1.29	69	122
TM 8 T/A in'91, '93,'94	1.45	5.71	3.27	1.50	94	170
TM 4 T/A TM'92,'94	1.07	4.66	2.88	1.18	61	109
TM 8 T/A TM'92,'94	1.42	5.36	3.07	1.52	87	162
TM 4 T/A in '93,none '94	0.76	3.36	2.05	0.90	31	61
TM 8 T/A in '93,none'94	0.97	3.53	1.99	0.98	38	69
Statistical Analysis						
N-Rate X Management						
N-Rate						
Low Fertility	1.01	4.34	2.73	1.11	56	98
High Fertility	1.21	4.75	2.95	1.43	72	138
P-Valve	99	99	99	99	99	99
Management						
Fertilizer Annually	1.04	4.50	3.25	1.40	67	125
Manure Annually	1.31	5.23	3.11	1.39	82	146
Manure Biannual	1.24	5.01	2.97	1.34	74	136
Manure Residual	0.86	3.44	2.02	0.94	35	65
P-Valve	99	99	99	99	99	99
LSD (0.05)	0.12	0.33	0.16	0.09	5	8
Rate X Management	98	98	96	99	99	99

* TM is turkey manure.

Table 4. Grain and stover yields as influenced by turkey manure, fertilizer and residual manure treatments - 1994.

Treatments	Grain yield	N-Concentration Stover	N-Concentration Grain	Dry Matter Production Stover	Dry Matter Production Grain	Dry Matter Production Total	N-Removal Stover	N-Removal Grain	N-Removal Total
	bu/a	------%------		-------T/A-------			--------lb/a---------		
Control	75	0.45	1.08	4.98	1.78	7.89	55	38	93
70 lb N/A in '91,'93,94	142	0.44	1.21	4.78	3.37	9.30	52	81	133
140 lb N/A in '91,'93,94	174	0.58	1.51	5.43	4.12	10.70	76	124	200
TM 4 T/A in'91,'93,'94	167	0.57	1.28	4.88	3.96	9.97	68	102	170
TM 8 T/A in'91,'93,'94	227	0.93	1.51	4.84	5.38	11.35	111	162	273
TM 4 T/A TM'92,'94	154	0.54	1.11	4.89	3.65	9.69	65	81	146
TM 8 T/A TM'92,'94	206	0.65	1.58	4.98	4.88	11.01	80	154	234
TM 4 T/A in '93 none'94	108	0.41	1.06	4.97	2.56	8.66	51	54	105
TM 8 T/A in '93 none'94	137	0.43	1.06	5.42	3.26	9.80	63	69	132
Statistical Analysis									
N-Rate X Management									
N-Rate									
Low Fertility	143	0.48	1.16	6.02	3.38	9.40	59	80	138
High Fertility	186	0.66	1.41	6.30	4.40	10.72	82	128	210
P-Valve	99	99	99	87	99	99	99	99	99
Management									
Fertilizer Annually	158	0.50	1.36	6.25	3.74	10.00	64	103	167
Manure Annually	197	0.74	1.40	5.99	4.67	10.67	89	132	221
Manure Biannual	180	0.59	1.34	6.08	4.27	10.35	72	117	189
Manure Residual	123	0.44	1.06	6.32	2.91	9.23	56	62	118
P-Valve	99	99	99	43	99	99	99	99	99
LSD (0.05)	12	0.07	0.12		0.27	0.65	12	14	22
Rate X Management	95	99	99	48	95	3	91	99	98

* TM is Turkey Manure

Table 5. Water percolation amount, concentration of NO_3^--N and Nitrate-N leached as influenced by manure, fertilizer and residual manure treatments in 1994.

Planting 1994

Treatments	Inches of H_2O	ppm NO_3^--N	lb/A NO_3^--N
Control	2.8	27.2	12.2
70 lb N/A in '91,'93,'94	3.6	12.8	11.7
140 lb N/A in '91,'93,'94	3.9	18.5	15.9
TM 4 T/A in'91,'93,'94	2.5	24.9	14.5
TM 8 T/A in'91,'93,'94	4.3	16.7	11.5
TM 4 T/A TM'92, '94	2.8	32.8	19.5
TM 8 T/A TM'92, '94	3.8	16.6	13.0
TM 4 T/A in '93 none '94	2.4	28.7	13.4
TM 8 T/A in '93 none '94	3.2	18.2	13.5
P-Value	25	32	18
LSD (0.05)			

* TM is Turkey manure.

Table 6. Soil N levels sampled before planting and at harvest 1994.

Treatments	Depth	Ammonium Planting	Ammonium Harvest	Nitrate Planting	Nitrate Harvest	Total Inorg. Planting	Total Inorg. Harvest
		------ppm------		-----ppm------		------ppm------	
Control	1	3.2	2.5	7.1	5.0	10.3	7.5
	2	2.2	2.7	3.6	2.9	5.8	5.6
	3	0.8	2.7	2.9	2.7	3.7	5.4
70 lb N/A in '91,'93,'94	1	2.3	3.0	11.1	5.9	13.4	8.9
	2	2.7	1.7	5.3	3.7	8.0	9.7
	3	2.3	2.3	2.6	3.2	4.9	7.2
140 lb N/A in '91,'93,'94	1	3.2	3.0	9.2	6.5	12.4	9.5
	2	1.7	1.2	4.2	4.2	5.9	5.4
	3	1.7	1.3	5.0	5.1	6.7	6.4
TM 4 T/A in'91,'93,'94	1	2.5	2.0	10.4	7.6	12.9	9.6
	2	1.7	2.2	5.2	5.2	6.9	8.8
	3	1.4	1.5	4.6	2.3	5.9	3.8
TM 8 T/A in'91,'93,'94	1	3.1	3.6	28.5	12.8	31.6	16.4
	2	2.5	1.4	14.9	6.8	17.3	18.7
	3	2.8	3.5	12.6	7.4	15.4	10.9
TM 4 T/A TM'92,'94	1	1.8	2.5	10.1	4.5	11.8	7.0
	2	1.2	1.8	4.2	2.4	5.5	4.2
	3	1.1	1.5	3.1	1.0	4.2	2.5
TM 8 T/A TM'92,'94	1	2.6	3.3	12.4	4.5	15.0	7.8
	2	1.9	1.0	6.0	3.3	7.9	4.3
	3	2.5	2.9	3.3	3.4	5.8	6.3
TM 4 T/A in '93,none'94	1	3.1	6.8	12.2	1.8	15.3	8.6
	2	2.5	2.8	5.2	8.7	7.7	11.5
	3	2.3	1.8	5.4	2.9	7.7	4.7
TM 8 T/A in '93,none'94	1	2.5	6.3	22.7	7.0	25.2	13.3
	2	2.3	2.3	13.5	2.1	15.8	4.4
	3	2.1	1.6	9.4	1.0	11.5	2.6

* TM is turkey manure. Depth 1 ,2 and 3 (0-6), (6-12), and (12-18) inches.

LAND SPREADING OF YARD WASTE - 1994[1]

Carl Rosen, Thomas Halbach, Dave Birong, and Jennifer Weiszel[2]

ABSTRACT: The third year of a field experiment at the Sand Plain Research Farm in Becker, Minn. was conducted to determine the residual effects of land applied yard waste, primarily tree leaves, on corn production and soil nitrate movement. Four yard waste treatments (0, 20, 40, and 80 dry T/A) were applied during the fall of 1991. In 1994, treatments included the four rates of yard waste that were applied in 1991 with 0, 100, and 200 lbs N/A applied during the growing season. During the first year of the study, 1992, yard waste application initially inhibited growth and depressed tissue nitrogen concentration in the corn plants. The inhibitory effect diminished by the middle of the 1992 growing season and final grain yields were similar to 0 T/A yard waste treatment (with 200 lb N/A) when 200 lb N/A was applied to the yard waste treatments. During the second year of the study, 1993, increases in growth and yield were greater with increasing yard waste application rates than with applied fertilizer N. Results in 1994 were similar to those in 1993. About 2 lbs of N per dry ton were supplied by the yard waste. Highest yields were obtained with the yard waste applications plus 200 lb N/A. Nitrate leaching tended to increase with fertilizer N application than with yard waste application. Residual soil nitrate-N increased with increasing yard waste application but not fertilizer N application. These results suggest: 1) Soil N was initially immobilized during the first year after yard waste application; and 2) Yard waste decomposition increased available N during the second and third year after application. This study needs to be continued to determine nitrogen release rates from residual yard waste in subsequent years.

Until recently, yard wastes (tree leaves and grass clippings) accounted for 15-20% of the bulk in landfills. In 1990 (metro counties) and in 1992 (greater Minnesota), regulations were passed that prohibited dumping of yard wastes in landfills. Because of this legislation, alternatives to landfilling yard waste need immediate attention. Some options for using or recycling the yard waste include: 1) backyard composting and application of the compost to gardens; 2) municipal composting followed by land application of the compost; and 3) direct land application of noncomposted yard waste. While backyard composting is a desirable way to handle yard waste, not all homeowners desire to compost their own yard waste. Several problems with municipal yard waste composting include finding an acceptable site, controlling nutrient runoff, and controlling odors. Direct land application of noncomposted yard waste may be more efficient than composting and does not have the same problems associated with composting. Land application of yard waste may require an adjustment of nitrogen requirements, because of its high carbon to nitrogen ratio. The effects of nitrogen application on crop production also needs to be ascertained. Therefore, the objectives of this study were to: 1) Determine the residual effects of direct application and incorporation of noncomposted yard waste (primarily tree leaves), with and without fertilizer nitrogen, on the productivity of irrigated field corn, and 2) Characterize nitrogen release from the yard waste during the growing season in terms of availability for crop needs and movement through the soil profile.

PROCEDURES

The experiment was conducted at the Sand Plain Research Farm in Becker, MN on a Hubbard loamy sand soil. This was the third year of the study, to determine the residual effects of applied yard waste. The yard waste was collected and applied to 15' x 35' plots with a front end loader in October of 1991. The yard waste primarily consisted of tree leaves, although some garden plants and grass clippings were also present. Twelve treatments were tested: 0, 20, 40, and 80 dry tons/A yard waste with 0, 100, and 200 lbs N/A. The experimental design was a randomized complete block with 4 replications.

The field was plowed to a depth of 8-10 inches two days prior to planting. In addition, 200 lbs/A 0-0-22 and 210 lbs/A 0-0-60 were broadcast and incorporated prior to planting. Pioneer hybrid 3751 (100 day maturity) was planted on May 9, 1994 at a population of 32,000 seeds/A (2.5 ft. between rows). At planting, starter fertilizer was banded 2 inches to the side and 2 inches below the seed at a rate of 185 lbs/A 0-14-42. The nitrogen treated plots received split N applications as urea with half of the N applied on May 25 and the remainder on June 17, 1994. Irrigation was used to supplement rainfall (Figure 1).

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[1]Funding for this project was provided by the Legislative Commission for Minnesota Resources
[2]Extension Soil Scientist, Extension Waste Management Specialist, Assistant Scientist, and Senior Research Plot Technician respectively, Department of Soil, Water and Climate.

Suction tubes with ceramic cups were installed in the row at a depth of 4 feet in three replications of each treatment. Water samples were collected, after significant irrigation or precipitation events (greater than 0.5 inches), and analyzed for nitrate. Whole plant samples (4 per plot) were collected at the 8-12 leaf stage on June 22 after all fertilizer N was applied. Ear leaf samples were collected on July 20 at 50% silking. Two, 20 foot rows were harvested for grain and stover yield from each plot on September 29 and October 6, respectively. Subsamples of stover and grain plus cob were taken for moisture determinations and nitrogen analyses. Plant tissue samples were dried and then ground through a 30 mesh screen. Dried samples were digested in concentrated sulfuric acid and Kjeldahl nitrogen was determined using conductimetric procedures. After harvest, soil samples were collected from 0-6, 6-12, 12-24 and 24-36 inch depths. Soil nitrate was determined using 2 N KCl extracts.

RESULTS

Corn Growth and Yield: Initial corn growth increased with increasing rates of yard waste (Table 1). The addition of nitrogen also increased initial growth. At the 8 - 12 leaf stage, the greatest growth was found in treatments with the highest yard waste rates and highest nitrogen rates. The addition of yard waste also increased total yield indicating a significant release of nutrients during the second year after incorporation. Corn growth and yield displayed a greater response to yard waste application when nitrogen fertilizer was not applied; although 200 lb N/A plus 40 or 80 T/A yard waste resulted in the highest yields. At all N rates, addition of yard waste significantly increased grain yield. Neither nitrogen application nor yard waste amendment affected the final stand count. Kernel moisture at harvest decreased with the addition of yard waste and nitrogen.

Tissue Nitrogen Concentrations and Total Nitrogen Uptake: At the 8 - 12 leaf stage, yard waste application did not create a significant difference in tissue nitrogen concentration (Table 2). By the silking stage, yard waste amendment increased ear leaf N concentrations with greatest increases occurring at the 0 and 100 lb N/A treatments. Nitrogen uptake increased with increased rates of yard waste. Yard waste application supplied approximately 2 lbs N/dry ton over the growing season to the corn crop. The addition of N fertilizer also increased N uptake although the contribution from yard waste was about the same regardless of N rate. Differences in tissue N concentration were observed at all growth stages with the application of fertilizer nitrogen.

Soil Nitrate-Nitrogen Content: Yard waste application increased residual nitrate-N in the soil (Table 3). The 80 T/A yard waste amendment, with or without fertilizer N, resulted in the highest residual nitrate-N content in the upper 3 ft of the soil. Fertilizer N application had minimal effects on residual nitrate-N content in the soil. With leaching rainfall or over-irrigation the higher residual nitrate N content in the yard waste treatments may result in higher nitrate leaching losses.

Soil Water Nitrate Concentrations: Concentrations of nitrate-N in soil water, as affected by treatments, are presented in figures 2 - 13. In all treatments, peak nitrate-N concentrations at the four foot depth occurred at about 7 - 8 weeks after planting. Yard waste application tended to increase nitrate-N concentrations in soil water at the four foot depth when fertilizer N was not applied. Variation in nitrate-N concentration within treatments, became more pronounced as fertilizer application rates increased. Fertilizer application had a greater effect on increasing nitrate-N concentrations than yard waste application. Yard waste applications with 0 or 100 lb N/A applied resulted in less nitrate leaching than no yard waste applied with 200 lb N/A. Nitrate leaching in the treatments receiving yard waste and 200 lb N/A was similar to that in the 200 lb N/A treatment without yard waste. Although residual nitrate-N in the soil was higher with increasing yard waste application, overall nitrate movement was not greatly affected by yard waste application as measured with suction tubes. This lack of movement may have been due to the fact that 1994 was a relatively low leaching year.

Table 1. Effect of yard waste and nitrogen application on whole plant dry matter at the 8-12 leaf stage, final stand count, grain yield, and kernel moisture.

Yard waste rate	Nitrogen application	Whole plant dry matter (8-12 leaf)	Final stand count	Grain yield	Kernel moisture
-tons/A-	--lbs/A--	-grams/plant-	-plants/A-	-bu/A-	- % -
0	0	7.5	32343	50	36
20	0	13.8	32452	90	33
40	0	20.8	31581	117	34
80	0	23.8	31254	159	29
0	100	16.6	31908	129	32
20	100	20.9	31799	166	31
40	100	26.8	32452	187	31
80	100	23.9	31037	208	29
0	200	16.8	31690	182	32
20	200	22.0	31037	220	29
40	200	25.2	31799	233	30
80	200	25.9	31254	238	29
Significance		**	NS	**	**
BLSD (5%)		4.0	--	22	3
Main effects					
	Yard Waste Rate				
	0	13.6	31980	120	34
	20	18.9	31763	159	31
	40	24.3	31944	179	32
	80	24.5	31182	202	29
	Significance	**	NS	**	**
	BLSD (5%)	2.3	--	13	2
	Linear	**	NS	**	**
	Quadratic	**	NS	**	NS
	Nitrogen Application				
	0	16.5	31908	104	33
	100	22.0	31799	172	31
	200	22.5	31445	218	30
	Significance	**	NS	**	**
	BLSD (5%)	2.0	--	11	1
Interaction					
	Yard Waste x Nitrogen	++	NS	++	NS

NS = nonsignificant, ++ = significant at 10%, ** = significant at 1%.

Table 2. Effect of yard waste and nitrogen application on nitrogen concentrations, dry matter accumulation, and nitrogen content.

Yard waste rate	Nitrogen application	Whole plant N 8-12 leaf stage	Ear leaf N silking stage	Nitrogen Concentration			Dry Mass				Nitrogen Content			
				Cob	Stover	Grain	Cob	Stover	Grain	Total	Cob	Stover	Grain	Total
-tons/A-	--lbs/A--	-------- % Nitrogen --------		--- % Nitrogen ---			--------- Ton/A ---------				-------- lb N/A ---------			
0	0	2.20	1.10	0.71	0.44	0.89	0.14	1.33	1.40	2.87	2.0	11.9	24.9	38.8
20	0	2.07	1.19	0.57	0.41	0.91	0.23	1.92	2.52	4.67	2.5	15.8	46.0	64.3
40	0	2.20	1.41	0.55	0.40	0.90	0.31	2.36	3.28	5.95	3.4	18.8	59.4	81.6
80	0	2.36	1.69	0.48	0.45	0.98	0.38	3.24	4.46	8.08	3.6	30.4	87.5	121.5
0	100	3.17	1.83	0.56	0.34	0.88	0.39	2.79	3.61	6.79	4.3	19.0	64.1	87.4
20	100	3.20	2.14	0.47	0.44	0.95	0.45	3.73	4.65	8.83	4.2	32.6	89.3	126.1
40	100	3.00	2.27	0.43	0.45	0.99	0.54	3.97	5.22	9.73	4.7	36.1	103.7	144.5
80	100	3.09	2.47	0.44	0.61	1.12	0.59	3.68	5.82	10.09	5.1	44.4	130.5	180.0
0	200	3.62	2.62	0.39	0.46	1.09	0.54	3.26	5.09	8.89	4.2	30.2	111.3	145.7
20	200	3.32	2.75	0.39	0.55	1.18	0.62	3.89	6.17	10.68	4.9	42.7	145.5	193.1
40	200	3.40	2.76	0.38	0.60	1.20	0.65	4.36	6.54	11.55	5.0	52:1	157.6	214.7
80	200	3.38	2.73	0.40	0.69	1.32	0.72	3.76	6.67	11.15	5.7	52.4	176.2	234.3
Significance		**	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (5%)		0.22	0.21	0.09	0.10	0.06	0.06	0.52	0.61	1.00	0.8	10.6	15.5	21.4
Main effects														
Yard Waste Rate														
0		2.99	1.85	0.56	0.41	0.95	0.36	2.46	3.37	6.19	3.5	20.4	66.8	90.7
20		2.87	2.03	0.48	0.47	1.01	0.44	3.18	4.44	8.06	3.9	30.3	93.6	127.8
40		2.86	2.15	0.46	0.48	1.03	0.50	3.56	5.01	9.07	4.3	35.7	106.9	146.9
80		2.94	2.30	0.44	0.58	1.14	0.56	3.56	5.65	9.77	4.8	42.4	131.4	178.6
Significance		NS	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (5%)		--	0.13	0.05	0.06	0.03	0.04	0.30	0.35	0.58	0.4	6.1	9.0	12.3
Linear		NS	**	**	**	**	**	**	**	**	**	**	**	**
Quadratic		*	NS	*	NS	NS	*	**	**	**	NS	++	*	*
Nitrogen Application														
0		2.21	1.35	0.58	0.43	0.92	0.26	2.21	2.92	5.39	2.9	19.2	54.5	76.6
100		3.12	2.18	0.48	0.46	0.99	0.49	3.54	4.83	8.86	4.6	33.0	96.9	134.5
200		3.43	2.71	0.39	0.57	1.20	0.63	3.81	6.12	10.56	4.9	44.4	147.7	197.0
Significance		**	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (5%)		0.11	0.11	0.04	0.05	0.03	0.03	0.26	0.30	0.49	0.4	5.1	7.7	10.6
Interaction														
Yard Waste x Nitrogen		NS	*	*	*	*	NS	**	++	**	NS	NS	NS	NS

NS = nonsignificant, ++ = significant at 10%, * = significant at 5%, ** = significant at 1%.

Table 3. Effect of yard waste and nitrogen application on soil nitrate-N (lbs/A) in the top three feet at the end of the growing season.

Yard waste rate	Nitrogen application	Sample depth (inches) 0 - 6	6 - 12	12 - 24	24 - 36	Total
-tons/A-	--lbs/A--	lbs nitrate-N/A				
0	0	1.54	3.28	3.18	0.97	8.97
20	0	2.29	3.59	4.23	1.50	11.61
40	0	3.34	5.00	5.81	2.49	16.64
80	0	5.71	6.53	5.87	1.90	20.01
0	100	1.68	2.73	3.41	0.87	8.69
20	100	3.01	4.57	3.02	0.97	11.57
40	100	3.64	4.53	3.22	0.95	12.34
80	100	7.22	8.34	5.01	1.33	21.90
0	200	2.63	3.89	2.95	0.71	10.18
20	200	2.78	5.06	3.93	1.10	12.87
40	200	4.21	5.84	3.59	1.12	14.76
80	200	7.24	8.88	4.92	2.23	23.27
Significance		**	**	++	*	**
BLSD (5%)		2.43	3.55	3.05	1.37	7.54
Main effects						
Yard Waste Rate						
0		1.95	3.30	3.18	0.85	9.28
20		2.69	4.41	3.73	1.19	12.02
40		3.73	5.12	4.20	1.52	14.57
80		6.72	7.92	5.27	1.81	21.72
Significance		**	**	*	*	**
BLSD (5%)		1.29	1.73	1.39	0.68	3.83
Linear		**	**	**	**	**
Quadratic		NS	NS	NS	NS	NS
Nitrogen Application						
0		3.22	4.60	4.77	1.71	14.30
100		3.89	5.04	3.66	1.03	13.62
200		4.21	5.92	3.85	1.29	15.27
Significance		NS	NS	NS	++	NS
BLSD (5%)		--	--	--	0.59	--
Interaction						
Yard Waste x Nitrogen		NS	NS	NS	NS	NS

NS = nonsignificant. ++ = significant at 10%. * = significant at 5%. ** = significant at 1%.

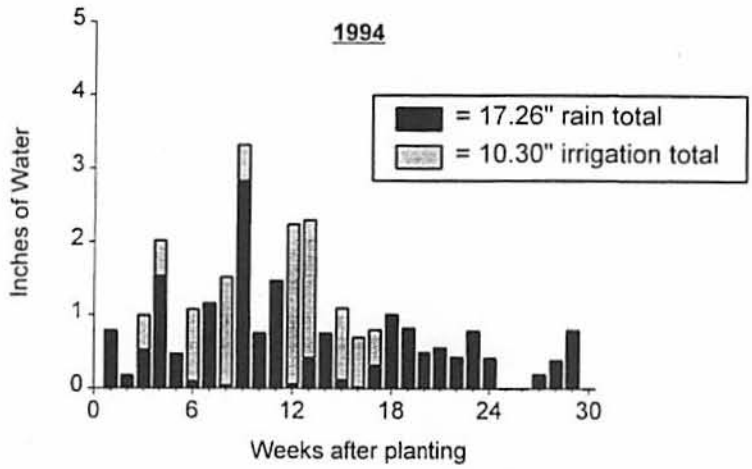

Figure 1. Rainfall and irrigation during the 1994 growing season.

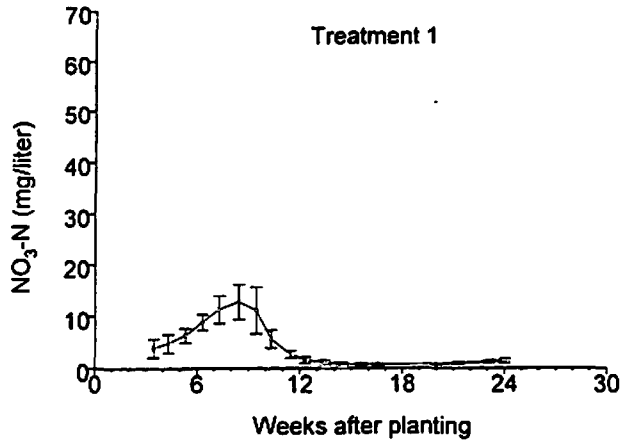

Figure 2. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 1: no leaves, no nitrogen applied. Error bars represent SE of the mean.

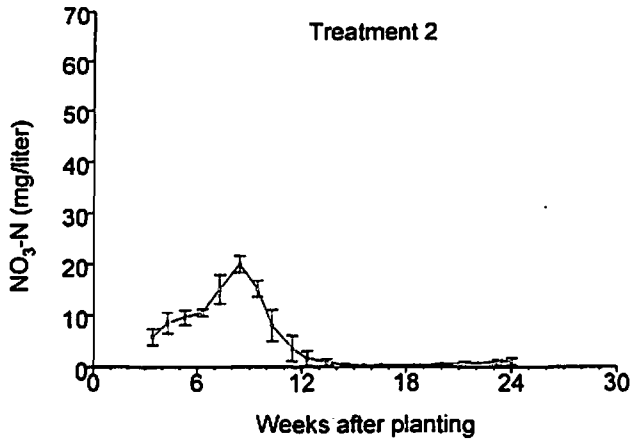

Figure 3. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 2: 20 tons/A leaves, no nitrogen applied. Error bars represent SE of the mean.

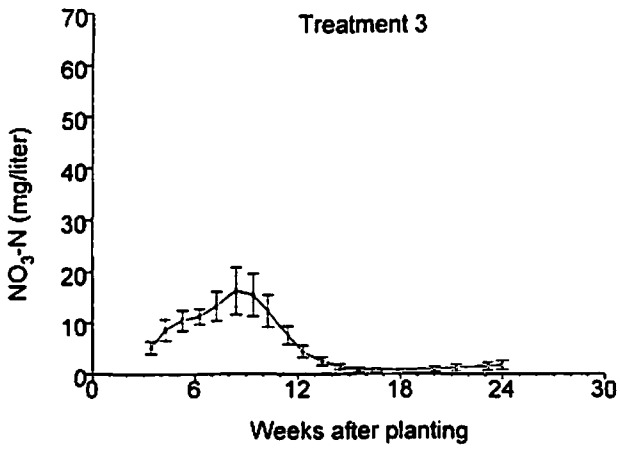

Figure 4. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 3: 40 tons/A leaves, no nitrogen applied. Error bars represent SE of the mean.

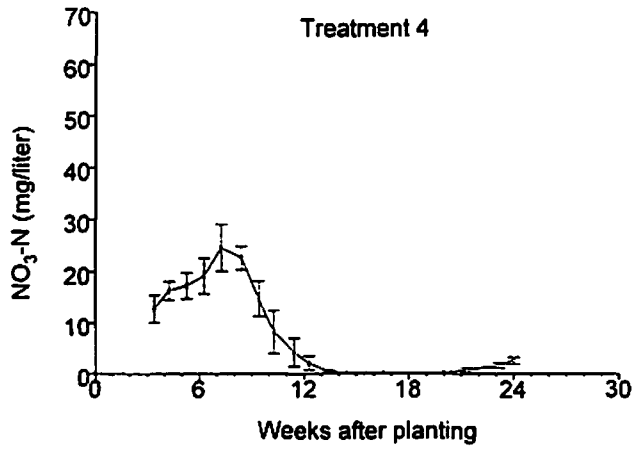

Figure 5. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 4: 80 tons/A leaves, no nitrogen applied. Error bars represent SE of the mean.

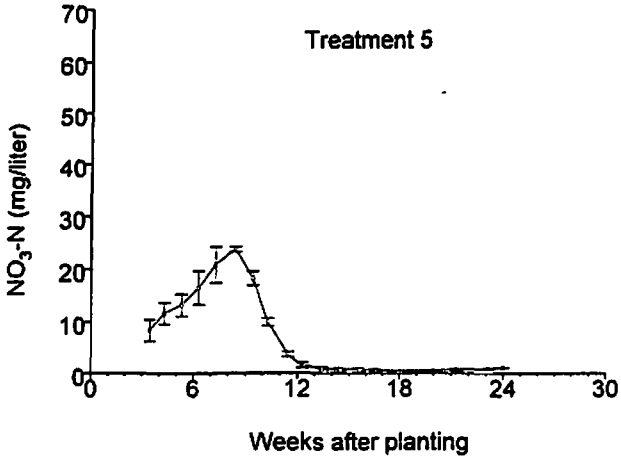

Figure 6. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 5: no leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

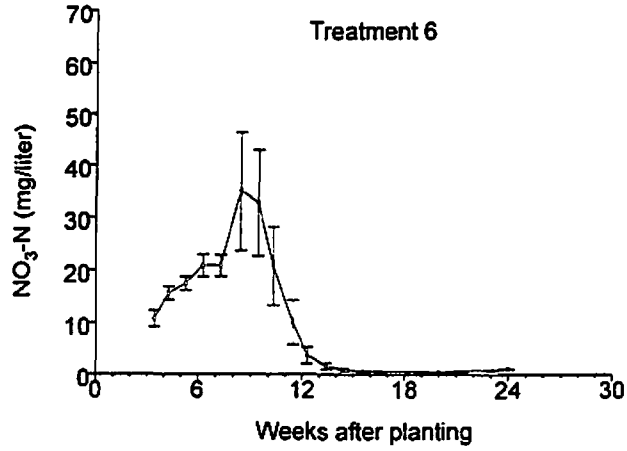

Figure 7. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 6: 20 tons/A leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

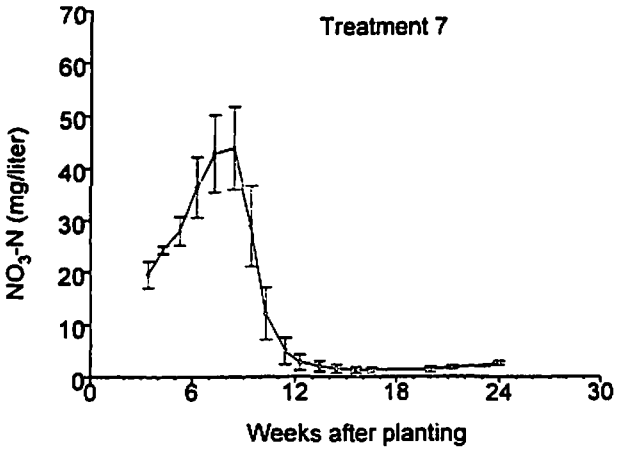

Figure 8. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 7: 40 tons/A leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

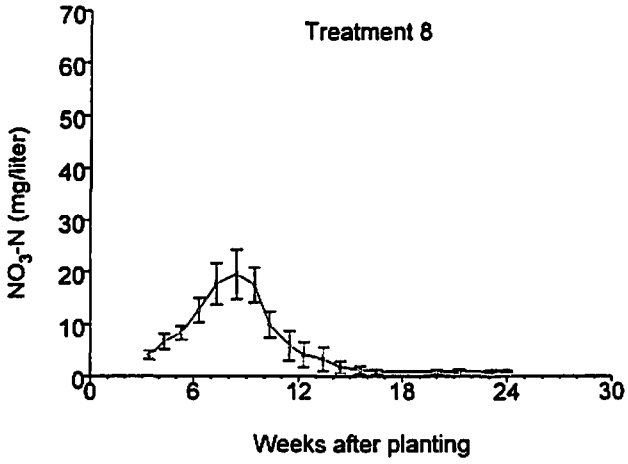

Figure 9. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 8: 80 tons/A leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

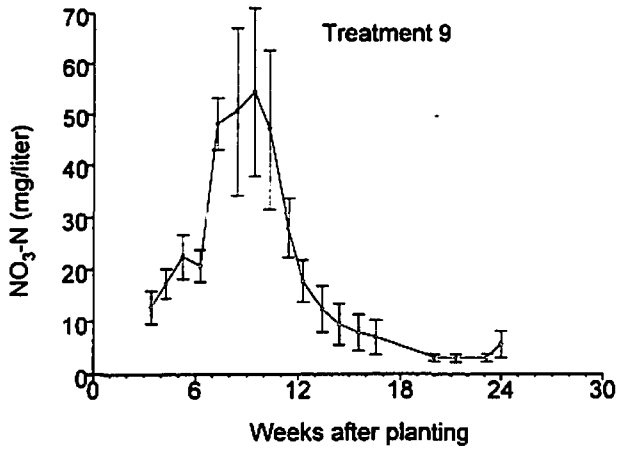

Figure 10. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 9: no leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

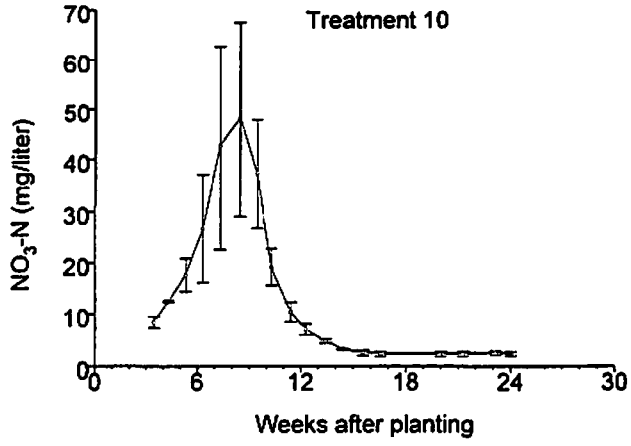

Figure 11. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 10: 20 tons/A leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

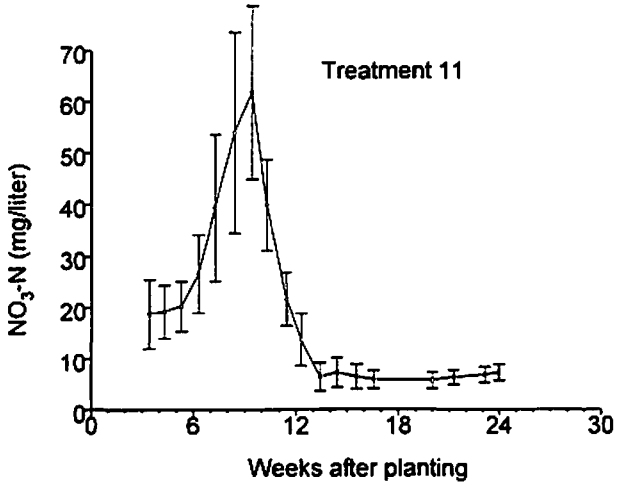

Figure 12. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 11: 40 tons/A leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

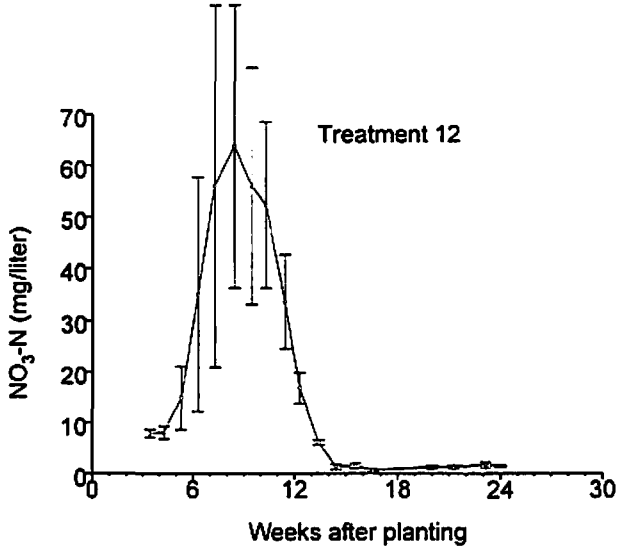

Figure 13. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 12: 80 tons/A leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

AGRICULTURAL UTILIZATION OF NUTRALIME: RESIDUAL EFFECTS ON ALFALFA PRODUCTION[1]

Carl Rosen, Dave Birong, and Jennifer Weiszel[2]

ABSTRACT: The fourth year of a NutraLime demonstration was conducted in Isanti county. NutraLime (spent lime and sewage sludge incinerator ash) was applied in 1991. Residual effects were monitored in 1994 on a second year alfalfa crop. Spent lime without ash was applied on half the control plots in 1993 to determine effects of raising pH without the elements in the ash. Alfalfa yields increased substantially with NutraLime application and to a lesser extent with spent lime application compared to the nonammended treatment. Elevated concentrations of Mo in alfalfa tissue (up to 7 ppm Mo) were associated with NutraLime application. The Cu/Mo ratios (<2) in alfalfa tissue from NutraLime plots were below those considered safe for chronic ingestion by ruminants. If fed to ruminants, close monitoring of the Cu/Mo ratio in feed rations is recommended. Mixing rations with low Mo forage or supplementing rations with Cu would be two methods to overcome the high Mo problem. Higher Mo was also found in alfalfa grown on limed plots, but levels were about 3 to 4 time lower than with NutraLime. Application of NutraLime increased soil water sulfur concentrations at the 2.5 ft depth. Trace metals in soil water were generally below detection limits at the 2.5 ft depth. In cases where NutraLime increased trace elements in soil water (Zn for example), the levels detected were all well below limits set for drinking water. Soil pH and plant available P increased with increasing NutraLime application. DTPA extractable Cd, Pb, Mo, and Cu increased with NutraLime in the top 6 inches, whereas DTPA extractable Fe, Ni, and Mn decreased. NutraLime had no effect on DTPA extractable Zn or Cr. Nitric acid extractable elements increased in the top 6 inches with NutraLime application.

NutraLime is a product made from two waste materials: sewage sludge incinerator ash from the Metropolitan Waste Control Commission in St. Paul and spent lime from municipal water treatment plants. Land application of these waste products has been studied individually in previous research. The sewage sludge ash was found to supply phosphorus and micronutrients for crop production. At realistic application rates, heavy metals were not found to be taken up by plants nor did the metals move significantly in the soil. Spent lime was found to an effective liming amendment. By combining these two waste products, both nutrients and lime could be recycled onto cropland, alleviating the need to rely on landfills for disposal. The objectives of this demonstration plot were to inform growers and the public about NutraLime, monitor alfalfa growth at various rates of applied NutraLime, monitor plant uptake of elements supplied by NutraLime, and follow movement of elements supplied by NutraLime in soil. All results reported here are based on residual effects of NutraLime following a one time application in 1991.

PROCEDURES

One field site, used for commercial crop production, was selected for the demonstration plot. The site was located in Isanti county on a Hayden silt loam. The site had an initial pH of 5.5, Bray P1 of 40 ppm, and ammonium acetate extractable K of 170 ppm. Treatments were applied in 1991 and consisted of a control and three rates (5.1, 10.2 and 20.4 dry tons/A) of NutraLime, replicated three times in strips. The strips were 25 feet wide and 300 feet in length. Prior to NutraLime application, 14" suction tubes were buried so that the ceramic tip was about 2.5' deep. These suction tubes were intended to be used for the duration of the demonstration without having to reinstall them each year. Plastic line from the suction tubes was laid along a 5' trench, so that soil above the suction tube would not be disturbed when water samples were collected, and the line was buried to allow for tillage operations. The NutraLime was applied as a slurry using a terragator set at the 0.5X rate. To obtain the 1X and 2X rate, the terragator travelled 2 and 4 times, respectively, over the plots at the same speed. Preweighed plastic trays (3ft x 2ft) were placed in the middle of each 0.5X strip to catch the applied material. The trays were weighed again after application and a subsample was collected in plastic bottles for moisture determination and elemental content. Elemental content of the NutraLime was determined on concentrated nitric acid/perchloric acid digests and has been presented previously. In addition to the NutraLime applied in 1991, spent lime (without the ash) was applied on half of the control plots at a rate of 20 dry tons/acre on April 24, 1993. Potassium was applied as KCl at the rate of 600 lb K_2O/A. The lime and potassium were disked in to a depth of 6" and the alfalfa (Agate) was planted on April 25, 1993. The site was nonirrigated.

[1]Funding for this project was provided by the Metropolitan Waste Control Commission.
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Soil water samples were collected two times during the growing season at each site. Multiple elements were determined in water samples using ICP procedures. Alfalfa was harvested four times in 1994: June 3, July 13, August 24 and October 17. Harvested area included 6 square feet per replication. Samples were dried at 60 C, and then the samples were ground to pass through a 30 mesh screen. Samples were ashed, dissolved in 1 N HCl and then analyzed for elemental content using ICP procedures. Tissue nitrogen concentrations were determined following Kjeldahl digestion using conductimetric procedures. Soil samples were collected in the spring and fall; within each replication, eight subsamples were combined down to a depth of 6 inches. Samples were air dried and then ground. Multiple elements were determined on 1N nitric acid extracts. Other analyses included soil pH and soluble salts (1:1 soil:water), ammonium acetate extractable cations, and DTPA extractable metals.

RESULTS

Plant growth and yield. Effects of NutraLime on alfalfa growth are presented in Table 1. Except for the first cutting where no differences among treatments were recorded, NutraLime increased alfalfa yield substantially compared to the nonlimed control. Yield with NutraLime also tended to be greater than yield with the limed control. This comparison is somewhat biased toward the NutraLime treatment since the lime application was recently applied and only disked in prior to planting. The yield data from 1994 indicate that when applied at realistic rates, NutraLime can have a beneficial effect on plant growth.

Elemental Concentrations in Soil Water. Concentrations of Al, B, Cd, Cr, Cu, Fe, K, Mo, Ni, P, and Pb in soil water at the 2.5 ft depth were generally below detection limits (Table 2). Concentrations of Ca, Mg, Mn, Na, and Zn were not consistently affected by NutraLime application. Concentrations of S increased with increasing NutraLime at both sampling dates.

Elemental Concentrations in Soil. Soluble salts, soil pH, Bray and Olsen P, ammonium acetate extractable cations and DTPA extractable metals in the spring and fall of 1994 are presented in Tables 3 and 4, respectively. In general, few changes occurred between the spring and fall sampling dates. Soil pH was substantially higher (1 - 2 units) in the top 6 inches with NutraLime application compared to the control. Lime application resulted in similar pH changes as the NutraLime. Soluble salts in the top 6 inches generally increased with NutraLime application rate; however, none of the soluble salt levels were in a range considered to be high enough to cause salt toxicity. Lime application resulted in higher salt levels than the control and similar to those for NutraLime. Bray and Olsen P increased with NutraLime application in the top 6 inches. Lime application resulted in similar extractable P levels as the control. Extractable K decreased with NutraLime application rate. Extractable Ca and Mg increased with NutraLime application in the top 6 inches. DTPA extractable Fe, Mn, and Ni decreased with NutraLime application in the top 6 inches. DTPA extractable Cd, Cu, Pb, and Mo increased in the top 6 inches. DTPA extractable Zn in the top 6 inches was not affected by NutraLime application. DTPA extractable Cr was not affected by NutraLime application, with most concentrations below detection limits of the spectrophotometer. Lime treatment generally decreased availability of Mn, Pb, Ni, Cu and Cd in the top 6".

Nitric acid extractable soil elements are presented in Tables 5 and 6. All elements tested, except K increased with NutraLime application in the top 6 inches. The lime treatment resulted in higher levels of nitric acid extractable Al, B, Ca, Fe, Mg, Mn, and S in the 0-6" depth relative to the nonlimed treatment and lower levels of all elements except for Ca, Mg, Fe, K, and S relative to the NutraLime treatments.

Elemental Concentrations in Plant Tissue. Elemental concentrations in alfalfa tissue at the four harvests are presented in Tables 7-10. In the first harvest, concentrations of N, P, Ca, Mg, Na, Al, Cu, and Mo increased and Mn, Zn, and Ni decreased with increasing NutraLime. Spent lime applications increased Mo compared to the nonlimed treatment. In the other harvests, the most consistent trend was increased levels of P and Mo with NutraLime application. Alfalfa tissue concentrations of Mo relative to tissue Cu in NutraLime amended plots were at a level where molybdenosis could be a problem. The Cu/Mo ratio should be greater than 2 to ensure that molybdenosis does not occur. The Cu/Mo ratios in tissue from the 1X and 2X NutraLime plots were less than 2 at all harvest dates. In contrast to 1993, concentrations of Mo in the alfalfa tissue actually increased over the season. As discussed in previous years when soybean was grown, legumes have a high demand for Mo and seem to accumulate this element in foliage and grain. The amount of Mo applied with the 10 dry ton NutraLime rate was 0.5 lb/A. Based on the yields obtained in this study, the alfalfa crop removes about 0.065 lb Mo per year which means that about 7 to 8 years would be required to remove the Mo applied with NutraLime from alfalfa production. Although the lime treatment also increased Mo concentrations, the level was below that considered a problem for ruminants. For all harvests, Cd, Cr, and Pb were either not affected by NutraLime treatment or were below detection limits.

GENERAL SUMMARY

NutraLime application significantly increased alfalfa yield, but tissue Mo increased to levels where molybdenosis could be a problem if the forage was chronically ingested. The implication for using NutraLime

for alfalfa is that plant tissue Mo content needs to be monitored so that rations can be supplemented with copper or mixed with forage that is much lower in Mo. Improved P and Mo nutrition appeared to be involved with increases in alfalfa yield. Concentrations of Cd, Cr, Ni and Pb in plant tissues were below the levels where animal health problems would be a concern. NutraLime effectively increased soil pH and plant available P. Trace elements detected in soil water at the 2.5 foot depth were below limits set for drinking water. If legumes are grown on NutraLime amended soil, monitoring of the NutraLime and forage for Mo content is recommended to prevent molybdenosis problems.

Table 1. Effect of NutraLime on alfalfa whole plant dry weight at the 1 to 10 percent bloom stage - Isanti County.

NutraLime Treatment	Plant dry weight first cutting	Plant dry weight second cutting	Plant dry weight third cutting	Plant dry weight fourth cutting	Plant dry weight year total
	-tons/A-	-tons/A-	-tons/A-	-tons/A-	-tons/A-
0	1.82	1.31	1.05	0.66	4.84
Lime	2.09	1.61	1.24	0.82	5.76
0.5x	2.17	2.03	1.42	0.71	6.33
1.0x	2.34	1.82	1.29	0.99	6.44
2.0x	2.33	1.65	1.55	0.88	6.41
Significance	NS	*	**	*	*
BLSD (5%)	--	0.37	0.22	0.20	1.20
Linear	NS	NS	**	*	*
Quadratic	NS	**	NS	*	*
Lime vs 2.0x	NS	NS	*	NS	NS

NS = not significant, * = significant at 5%, ** = significant at 1%.

Table 2. Effect of NutraLime on elemental composition of soil water collected from suction tubes - Isanti County.

Date	Trmt	Al	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Zn
April 21, 1994		ppm																
	0	<0.18	<0.02	28	<0.006	<0.01	<0.03	<0.02	<0.7	11	<0.01	<0.01	10	<0.03	<0.04	<0.08	5	0.05
	0.5x	<0.38	<0.02	77	<0.006	<0.01	<0.03	<0.02	<0.7	26	0.05	<0.01	14	0.04	<0.04	<0.08	16	0.06
	1.0x	<0.18	<0.02	46	<0.006	<0.01	<0.03	<0.02	<0.7	16	0.04	<0.01	10	<0.03	<0.04	<0.08	20	0.11
	2.0x	<0.23	<0.02	52	<0.006	<0.01	<0.03	<0.02	<0.7	18	0.05	<0.01	9	<0.04	<0.04	<0.08	34	0.08
Significance		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	*	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	19	--
Contrasts																		
Linear		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	**	NS
Quadratic		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	NS	NS
May 24, 1994																		
	0	<0.18	<0.02	26	<0.006	<0.01	<0.03	<0.02	<0.7	11	<0.01	<0.01	11	<0.02	<0.04	<0.08	3	0.02
	0.5x	<0.20	<0.02	79	<0.006	<0.01	<0.03	<0.02	<0.7	27	0.06	<0.01	14	0.04	<0.04	<0.08	15	0.04
	1.0x	<0.19	<0.02	41	<0.006	<0.01	<0.03	<0.02	<0.8	15	0.03	<0.01	9	<0.03	<0.04	<0.08	18	0.04
	2.0x	<0.28	<0.02	79	<0.006	<0.01	<0.03	<0.02	<0.7	28	0.08	<0.01	13	0.06	<0.04	<0.08	44	0.04
Significance		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	**	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	12	--
Contrasts																		
Linear		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	**	NS
Quadratic		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	NS	NS

NS = not significant, * = significant at 5%, ** = significant at 1%.

Table 3. Effect of NutraLime on soil pH, soluble salts, Bray P, Olsen P, ammonium acetate extractable cations and DTPA extractable metals - April 21, 1994

						NH4OAc Extractable				DTPA Extractable							
Depth	Trmt	pH	Soluble Salts	Bray P	Olsen P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr	Mo
			mmhos/cm	ppm														
0-6"	0	6.9	0.10	26	11	240	751	70	4.1	61	28.9	1.3	0.5	0.8	0.8	0.06	<0.03	<0.02
	Lime	7.9	0.37	24	15	209	3472	225	5.0	44	14.4	1.0	0.6	0.7	0.6	0.06	<0.03	<0.02
	0.5x	8.1	0.20	106	31	212	1856	114	5.0	29	10.1	1.2	2.7	0.9	0.5	0.11	<0.03	0.03
	1.0x	8.2	0.20	127	33	213	2171	125	4.9	28	9.4	1.2	3.1	0.9	0.5	0.11	<0.03	0.04
	2.0x	8.2	0.20	143	37	186	2491	136	5.3	28	9.1	1.3	3.7	1.0	0.5	0.12	<0.03	0.04
Significance		**	**	**	**	NS	**	*	NS	**	**	NS	**	**	*	**	--	*
BLSD	(5%)	0.2	0.10	29	8	--	860	92	--	13	5.7	--	0.9	0.1	0.2	0.02	--	0.01
Contrasts																		
Linear		**	NS	**	**	*	**	NS	*	**	**	NS	**	**	*	**	--	**
Quadratic		**	NS	**	**	NS	NS	NS	NS	**	**	NS	**	NS	*	**	--	NS
Lime vs 2.0x		NS	**	**	**	NS	*	*	NS	*	NS	NS	**	**	NS	**	--	**

NS = not significant, * = significant at 5%, ** = significant at 1%.

Table 4. Effect of NutraLime on soil pH, soluble salts, Bray P1, Olsen P, ammonium acetate extractable cations, and DTPA extractable metals - October 17, 1994

						NH4OAc Extractable				DTPA Extractable							
Depth	Trmt	pH	Soluble Salts	Bray P	Olsen P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
			mmhos/cm	ppm													
0 - 6"	0	6.1	0.10	23	9	155	731	66	4.2	66	17.1	1.1	0.5	0.7	0.7	0.05	0.03
	Lime	8.1	0.27	17	12	144	4112	230	5.2	37	6.9	0.8	0.5	0.4	0.4	0.04	0.03
	0.5x	8.0	0.20	112	29	117	1774	98	5.0	24	5.1	1.1	2.7	0.7	0.6	0.11	0.03
	1.0x	8.1	0.17	135	34	108	2377	110	5.2	23	4.3	1.1	3.3	0.8	0.3	0.12	0.03
	2.0x	8.0	0.17	152	39	106	2603	126	5.5	25	4.2	1.3	3.7	1.0	0.7	0.11	0.03
Significance		**	*	**	**	*	**	**	*	**	**	NS	**	**	NS	**	NS
BLSD	(5%)	0.2	0.09	30	7	40	607	34	0.8	16	3.4	--	0.8	0.2	--	0.02	--
Contrasts																	
Linear		**	NS	**	**	*	**	**	**	**	**	NS	**	*	NS	**	NS
Quadratic		**	NS	**	**	NS	*	NS	NS	**	**	NS	**	NS	*	*	NS
Lime vs 2.0x		NS	*	**	**	*	**	**	NS	NS	NS	*	**	**	*	**	NS

NS = not significant, * = significant at 5%, ** = significant at 1%.

Table 5. Effect of NutraLime on nitric acid extractable elements - April 21, 1994

DEPTH	Treatment	1 N Nitric Acid Extractable																
		Al	B	Cd	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Na	S	Zn
		ppm																
0 - 6 inches	0	617	0.4	0.2	1018	0.5	2	567	4	109	104	0.20	1.6	62	295	7	8	4
	Lime	802	0.7	0.2	8743	0.8	3	833	5	410	167	0.22	1.7	103	286	10	22	4
	0.5x	892	0.8	0.6	3148	1.9	18	848	8	238	175	0.31	2.1	472	280	15	13	9
	1.0x	981	0.9	0.7	3705	2.3	22	907	9	278	191	0.35	2.3	576	279	17	15	11
	2.0x	1081	1.0	0.8	4451	2.8	28	954	10	331	203	0.39	2.4	711	263	20	16	12
Significance		**	**	**	*	**	**	**	**	NS	**	**	**	**	NS	**	*	**
BLSD (5%)		104	0.2	0.2	488	0.7	8	125	2	--	27	0.04	0.4	194	--	4	8	3
Contrasts																		
Linear		**	**	**	NS	**	**	**	**	*	**	**	**	**	NS	**	*	**
Quadratic		**	*	**	NS	**	*	**	**	NS	**	**	*	*	NS	*	NS	*
Lime vs 2.0x		**	*	**	NS	**	**	NS	**	NS	*	**	**	**	NS	**	NS	**

NS = not significant; * = significant at 5%, ** = significant at 1%.

Table 6. Effect of NutraLime on nitric acid extractable elements - Isanti County. October 21, 1994

DEPTH	Treatment	1 N Nitric Acid Extractable																
		Al	B	Cd	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Na	S	Zn
		ppm																
0 - 6 inches	0	599	0.3	0.2	972	0.5	2	510	4	103	81	0.18	1.6	54	232	6	7	3
	Lime	790	0.9	0.3	8513	0.8	3	782	7	382	152	0.28	1.8	94	221	9	18	4
	0.5x	855	0.8	0.7	3088	2.0	20	727	8	228	156	0.32	2.5	475	207	14	11	9
	1.0x	990	0.9	0.9	4240	2.8	28	775	10	295	171	0.37	2.3	691	192	18	14	11
	2.0x	1054	1.0	0.9	4573	3.0	30	853	11	326	178	0.40	3.2	744	190	19	14	12
Significance		**	**	**	**	**	**	*	**	**	**	**	**	**	NS	**	**	**
BLSD (5%)		178	0.2	0.2	2470	0.9	10	178	2	109	31	0.07	0.6	251	--	5	4	3
Contrasts																		
Linear		**	**	**	*	**	**	**	**	**	**	**	**	**	NS	**	**	**
Quadratic		*	**	**	NS	**	**	NS	**	NS	**	**	NS	**	NS	*	NS	*
Lime vs 2.0x		**	NS	**	**	**	**	NS	**	NS	NS	**	**	**	NS	**	NS	**

NS = not significant, * = significant at 5%, ** = significant at 1%.

Table 7. Effect of NutraLime on the elemental composition of alfalfa samples, June 3, 1994 - Isanti county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	2.45	0.21	3.25	1.03	0.17	25	54	53	44	22.4	6.5	17.9	<1.68	1.91	<0.30	<0.12	<0.26
Lime	2.71	0.22	3.39	1.16	0.17	26	58	67	32	20.2	6.8	16.3	<1.68	2.12	<0.30	<0.12	0.78
0.5x	2.85	0.25	3.36	1.25	0.18	32	63	86	23	17.9	7.3	16.2	<1.68	1.75	0.32	<0.12	2.78
1.0x	2.93	0.27	3.49	1.30	0.19	37	68	102	24	18.1	7.3	17.4	<1.68	1.82	0.35	<0.12	4.01
2.0x	3.13	0.27	3.25	1.38	0.20	45	75	108	25	17.9	7.5	19.0	<1.68	1.41	<0.41	<0.12	4.29
Significance	**	**	NS	*	*	NS	NS	*	NS	**	*	NS	--	NS	--	--	**
BLSD (5%)	0.30	0.02	--	0.18	0.02	--	--	38	--	1.6	0.6	--	--	--	--	--	1.36
Contrasts																	
Linear	**	**	NS	**	**	*	*	**	NS	**	*	NS	--	NS	--	--	**
Quadratic	NS	**	NS	NS	NS	NS	NS	NS	*	**	NS	NS	--	NS	--	--	**
Lime vs 2.0x	*	**	NS	*	*	*	*	*	NS	**	*	NS	--	*	--	--	**

NS = nonsignificant, * = significant at 5%, ** = significant at 1%.

Table 8. Effect of NutraLime on the elemental composition of alfalfa samples, July 13, 1994 - Isanti county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	3.08	0.26	2.91	1.10	0.18	36	80	77	54	24.6	9.8	21.0	<1.68	2.82	<0.32	<0.12	<0.22
Lime	2.65	0.26	2.86	1.05	0.16	28	73	74	41	21.5	9.6	15.3	<1.68	3.25	<0.30	<0.12	0.92
0.5x	2.89	0.30	2.76	1.21	0.17	38	77	124	40	19.7	8.9	16.5	<1.68	2.69	0.34	<0.12	3.26
1.0x	2.79	0.30	2.61	1.21	0.18	42	79	152	35	18.7	8.7	17.6	<1.68	2.40	0.35	<0.12	5.57
2.0x	2.80	0.30	2.47	1.19	0.19	45	78	184	32	18.3	8.9	16.9	<1.68	2.60	0.41	<0.12	6.38
Significance	NS	**	**	NS	NS	NS	NS	*	NS	**	**	**	--	NS	--	--	**
BLSD (5%)	--	0.02	0.22	--	--	--	--	84	--	2.5	0.6	2.0	--	--	--	--	1.79
Contrasts																	
Linear	NS	**	**	NS	NS	NS	NS	*	*	**	*	**	--	NS	--	NS	**
Quadratic	NS	**	NS	NS	NS	NS	NS	NS	NS	**	**	*	--	NS	--	NS	**
Lime vs 2.0x	NS	**	**	NS	NS	NS	NS	*	NS	*	*	NS	--	NS	--	NS	**

NS = nonsignificant, * = significant at 5%, ** = significant at 1%.

Table 9. Effect of NutraLime on the elemental composition of alfalfa samples, August 24, 1994 - Isanti county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	3.48	0.25	2.87	1.48	0.20	93	155	115	71	26.1	10.0	22.9	<1.68	4.46	0.63	<0.20	0.27
Lime	3.30	0.28	2.90	1.36	0.19	158	192	121	67	23.8	9.9	19.8	<1.68	5.04	0.77	0.19	0.92
0.5x	3.54	0.32	2.84	1.56	0.20	117	159	156	55	22.3	10.0	18.2	<1.68	3.78	0.72	0.16	3.06
1.0x	3.46	0.32	2.74	1.62	0.21	78	126	157	55	21.6	10.0	20.0	<1.68	3.06	0.63	0.16	5.25
2.0x	3.45	0.32	3.36	1.54	0.21	83	125	229	50	21.2	10.0	25.0	<1.68	3.21	0.64	0.17	5.95
Significance	NS	**	NS	*	NS	NS	NS	NS	*	**	NS	*	--	**	NS	--	**
BLSD (5%)	--	0.01	--	0.16	--	--	--	--	16	2.4	--	2.9	--	0.79	--	--	2.05
Contrasts																	
Linear	NS	**	NS	NS	NS	NS	NS	*	*	**	NS	NS	--	**	NS	--	**
Quadratic	NS	**	NS	NS	NS	NS	NS	NS	NS	*	NS	*	--	*	NS	--	*
Lime vs 2.0x	NS	**	*	*	NS	NS	NS	*	*	*	NS	NS	--	**	NS	--	**

NS = nonsignificant, * = significant at 5%, ** = significant at 1%.

Table 10. Effect of NutraLime on the elemental composition of alfalfa samples, October 17, 1994 - Isanti county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	3.71	0.26	2.93	1.41	0.20	338	339	138	96	24.9	9.1	27.4	<1.68	6.77	2.29	0.16	0.61
Lime	3.45	0.29	3.15	1.41	0.20	449	446	98	91	23.6	9.2	25.1	<1.82	6.34	2.41	0.18	1.60
0.5x	3.57	0.33	2.96	1.54	0.18	431	417	194	77	22.2	10.3	25.6	<1.88	6.00	3.14	0.17	4.60
1.0x	3.50	0.32	2.90	1.49	0.19	432	403	193	84	20.5	10.3	25.5	<2.00	4.41	2.48	0.16	5.97
2.0x	3.58	0.34	2.86	1.59	0.21	357	328	279	69	21.0	10.7	28.3	<1.82	5.04	2.22	0.17	7.12
Significance	NS	**	NS	NS	NS	NS	NS	NS	NS	**	**	NS	NS	NS	NS	NS	**
BLSD (5%)	--	0.03	--	--	--	--	--	--	--	2.0	0.9	--	--	--	--	--	1.57
Contrasts																	
Linear	NS	**	NS	NS	NS	NS	NS	*	NS	**	**	NS	--	NS	NS	NS	**
Quadratic	NS	*	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	--	NS	NS	NS	**
Lime vs 2.0x	NS	**	NS	NS	NS	NS	NS	**	NS	*	**	NS	--	NS	NS	NS	**

NS = nonsignificant, * = significant at 5%, ** = significant at 1%.

EVALUATION OF WOOD ASH AS A LIMING SOURCE[1]

D. L. Rabas and R. D. Mathison[2]

Abstract

Research comparing wood ash from Blandin Paper Company in Grand Rapids to conventional agricultural limestone found the ash to be an effective liming material. An application rate of 10 dry tons/acre (DT/A) of wood ash produced the same increase in soil pH as 4 tons/acre of lime, and application rates above 20 DT/A did not result in further soil pH increases. Five years after treatment application, soil pH of the 10 DT/A ash and lime treatments were 5.7 and and 6.0, respectively (considered too low for alfalfa production), whereas soil pH of the 20, 30 and 40 DT/A ash treatments remained above 6.5. Alfalfa dry matter yield was highest for the 30 and 40 DT/A ash treatments, intermediate for the 10 DT/A ash and lime treatments, and lowest for the control. Ash application did not result in soil or plant tissue heavy metal concentrations higher than the control.

Introduction

Many wood-based industries, such as paper mills, burn waste wood to produce steam or electricity, and many institutions near adequate wood supplies burn wood to heat buildings in winter. The resultant ashes from these activities are high in pH and may have potential as a lime source to neutralize acidic soils for production of pH sensitive crops, such as alfalfa (Medicago sativa). Use of ashes as a lime source would benefit alfalfa producers by providing a low cost alternative to traditional liming materials and would benefit ash producers by providing a disposal alternative to the expensive and environmentally questionable practice of landfilling of large quantities of ash. The objective of this research was to evaluate the agronomic value and environmental aspects associated with farmland utilization of industrially produced wood ashes.

Materials and Methods

The experiment was conducted at Grand Rapids, MN. Soil was a coarse-loamy, mixed, nonacid, frigid Aeric Haplaquepts (Cowhorn very fine sand) with a pH of 5.7. Treatments were hand applied in fall 1986 to 10 x 20 ft plots in a randomized complete block design with four replicates, then immediately incorporated to a depth of 2 in. with a tractor-mounted Howard rotovator. All plots initially received 66, 306, and 54 lb/a of S, K, and MG, respectively and 240 and 4 lb/a of K and B annually to ensure plant responses were to soil pH, not other nutrients contained in the ash. In the spring following treatment application, carbofuran (2,3 dihydro-2, 2-dimethyl-7-benzifuranyl methylcarbamate) was applied at 2 lb a.i./a before alfalfa establishment for nematode control. 'Oneida' alfalfa was seeded at 15 lb/a on May 11, 1987.

Herbage yields were measured by cutting a 54 sq ft area within each plot to a 4 in stubble height. Wet forage yields were adjusted to dry weight by drying a 500 to 800 g subsample from each plot at 135° F to determine dry matter percentage. One harvest was taken during the seeding year, followed by a lenient 3 cut/year schedule in subsequent years to maximize forage yield and favor long-term stand persistence.

Soil samples were collected at the beginning of the study and annually after the second harvest at depths of 0 to 6 in. Samples were sent to the University of Minnesota Research Analytical Laboratory to be analyzed for pH, S, K, Ca, Mg, Na, Cu, B, Zn, Fe, Mn, Cr, Cd, Ni, and Pb according to Recommended Chemical Soil Test Procedures for the North Central Region (North Dakota State University Bulletin 499 [Revised], October, 1988), except that samples, excluding pH samples, were weighed rather than scooped. In the first and last production years of each experiment, all four replicates were sampled to allow statistical analysis of soil test data. In intermediate years, samples from the four individual plots of each treatment were bulked to form two samples to minimize analysis costs. Plant tissue samples consisting of the top one third of one tenth bloom alfalfa were hand cut at the second harvest to allow comparisons with soil test data and to monitor the possible accumulation of toxic compounds in harvested forage.

Results

Soil pH

Ash proved to be an effective liming material. Soil pH changes indicated that approximately 2.5 tons of ash were equivalant to 1 ton of the agricultural limestone used in this study, as the 10 DT/A ash rate produced the same change in soil pH as 4 t/a lime. After 5 years, soil pH of the lime and 10 DT/A ash had declined below 6.5, the level considered necessary for alfalfa production. Maximum soil pH increase was reached with application of 20 DT/A of ash; however the 30 and 40 DT/A application rates maintained the higher soil pH levels longer.

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[1] Support for this project was provided by the Blandin Foundation.

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Forage yield

Forage dry matter yield was increased with the addition of lime, as expected. Ash application also resulted in increased forage dry matter yield, with the 10 and 20 DT/A ash application rates resulting in dry matter yield increases similar to the ag lime treatment, and the 30 and 40 DT/A application rates yielding significantly more. The reason for the dry matter yield increase associated with the two higher ash rates is not readily apparent, as sufficient fertilizer was added annually as part of the experimental procedure to attempt to eliminate soil fertility as a variable in this study. Comparison of soil and plant tissue elemental analysis suggests differences in soil K levels may have been partially responsible for the observed yield differences because treatments with the highest dry matter yield had significantly higher soil and plant tissue K levels. Similarly, differences in S levels may have also been partially responsible for the observed differences in dry matter yield.

Table 1. Effect of treatment application on forage dry matter yield[3] and plant tissue elemental analysis[4]

Treatment	Yield	Plant Tissue							
		SO_4	K	Mg	B	Pb	Ni	Cd	Cr
	TDM/A	%	ppm						
Check	6.32	0.24	17,971	2660	89	<2.16	2.33	<0.32	<0.22
Ag lime, 4T/A	7.87	0.28	16,386	3174	78	<2.16	1.99	<0.33	<0.22
Ash,10 TDM/A	7.78	0.29	18,568	2546	86	<2.16	<2.09	<0.40	<0.24
Ash,20 TDM/A	8.36	0.31	20,207	2440	80	<2.16	<1.81	<0.39	<0.24
Ash,30 TDM/A	8.93	0.33	22,254	2298	81	<2.16	1.62	<0.32	<0.30
Ash,40 TDM/A	8.93	0.35	22,338	2283	89	<2.16	2.25	<0.28	<0.23
LSD (0.05)	0.74	0.04	2335	230	NS	NS	NS	NS	NS

Table 2. Effect of treatment application on soil pH and elemental analysis[5]

Treatment	pH		Soil							
	1987	1990	K	Mg	SO_4	B	Pb	Ni	Cd	Cr
			ppm							
Check	5.7	5.2	81	60	7	1.3	3.06	0.53	0.04	<0.02
Ag lime, 4 T/A	6.5	6.0	61	140	8	1.5	3.56	0.38	0.05	<0.03
Ash,10 TDM/A	6.5	5.7	73	63	6	2.1	3.15	0.43	0.07	<0.02
Ash,20 TDM/A	7.3	6.6	88	64	8	2.4	2.38	0.27	0.06	<0.02
Ash,30 TDM/A	7.3	7.1	112	73	9	2.5	2.95	0.33	0.04	<0.02
Ash,40 TDM/A	7.5	7.2	114	78	10	3.3	3.91	0.26	0.04	<0.02
LSD (0.05)	0.5	0.3	27	20	2	0.7	NS	0.13	NS	<0.004

[3]Total forage dry matter yield for 1988 through 1990.

[4]Top one third of earlhy bloom aflalfa taken at the second harvest.

[5]0 to 6 in. sampling depth, collected after the second harvest.