NITRATE LOSSES TO TILE DRAINAGE AS AFFECTED BY NITROGEN FERTILIZATION OF CORN IN A CORN-SOYBEAN ROTATION[1/]
Waseca, 1995

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

ABSTRACT: A study was conducted in 1995 to determine the influence of time of N application, N source, and nitrification inhibitor (NI) on the yield and uptake of N by corn and the loss of NO_3 to tile drainage. These second-year results showed a significant yield increase over the control from all N treatments. However, yields were not affected by time of N application, N source, or the nitrification inhibitor (N-Serve). Grain N concentration and relative leaf chlorophyll content were higher with spring preplant-applied AA compared to fall-applied AA. Tile lines flowed from mid-April through mid-June, intermittently in August, and in October through early November. Tile flow averaged 4.70" for corn and 3.84" for soybeans. In the corn plots highest NO_3-N concentration and loss occurred with the fall application of N without NI. Under soybean the highest concentrations occurred with fall-applied AA without N-Serve and spring preplant-applied AA with N-Serve (N applied to the previous corn crop). Nitrate-N concentrations and losses from continuous fallow plots that have not received fertilizer N or a planted crop for nine years were 90% higher than from the fertilized corn. This is due to soil mineralization and lack of crop uptake over the 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 drainage in Minnesota since 1972. This research has focused primarily on the effects of rate and time of fertilizer N application and tillage in a continuous corn system. The purpose of this study is to determine the influence of 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 soil 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.

Fertilizer N was applied at a rate of 120 lb/A for all N treatments. The nitrification inhibitor, N-Serve was applied at 0.5 lb/A. Fall treatments were applied on October 28, 1994. Average soil temperature at the 4" depth on that date was 50°F with an average of 47°F over the following 10-day period. The spring preplant anhydrous ammonia treatments were applied on April 25. The preplant urea treatment (5) was applied on May 3. The sidedress AA treatment was applied at the V4 stage on June 15.

The corn area (1994 soybean area) was field cultivated once before planting, while the soybean area (1994 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 32,000 seeds/acre on May 4 with a JD Max-Emerge planter. 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 11. 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 22) plus a post emergence application of Pursuit (4 oz/A) at the 1st trifoliate stage (July 3).

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. Chlorophyll content in the ear leaf was measured with a Minolta SPAD meter on July 31 (R-1). Stover and grain samples were taken at physiological maturity by hand harvesting 30' of row for stover yield and 60' of row for grain yield 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 all plots on November 7. 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. and Minnesota Agric. Exp. Stn.

2/ Professor and Assistant Scientist, So. Exp. Stn., Waseca.

RESULTS AND DISCUSSION

Plant

Stover N concentration, yield, and N uptake at physiological maturity were increased over the control by all of the N treatments with no differences among the six N treatments (Table 1). Chlorophyll content of the ear leaf at R-1 stage was increased significantly above the control by all of the N treatments. The two preplant AA treatments showed slightly higher chlorophyll contents than did the two fall-applied AA treatments, however they were not statistically significant at the $\alpha=0.05$ level. Final plant population was excellent and was not affected by 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, leaf chlorophyll, and final population of corn following soybeans.

N Application		Stover			Relative	Final
Time	Inhibitor	N	Yield	N uptake	Chlorophyll	Population
		%	T DM/A	lb/A	%	ppA x 10^3
Primary trts						
AA Fall (10/25)	No	0.51	2.499	25.5	95.0	29.91
AA Fall (10/25)	Yes	0.53	2.648	28.1	96.6	29.86
AA PP (5/11)	No	0.54	2.549	27.5	100.0	29.74
AA PP (5/11)	Yes	0.54	2.483	26.8	98.5	30.13
Additional trts						
Urea PP (5/11)	No	0.51	2.588	26.4	98.2	30.20
AA SD (6/16)	No	0.55	2.362	26.0	98.5	29.96
Check (No N)	--	0.40	1.715	13.7	69.0	30.01
Statistical Analysis Latin square (Primary trts)						
P > *F*:		0.60	0.85	0.30	0.06	0.40
LSD (0.05):						
CV (%):		7.0	11.3	7.8	2.1	1.0
Statistical Analysis Completely randomized (7 trts)						
P > *F*:		<0.01	<0.01	<0.01	<0.01	0.48
LSD (0.05):		0.07	0.47	6.0	2.9	
CV (%):		8.9	13.2	16.4	2.1	1.1

Grain and silage yields were increased significantly over the control by all of the N treatments (Table 2). However, yields were not different among the six treatments. Grain moisture of the control treatment was significantly higher than all fall and preplant N treatments but was not significantly greater ($\alpha=0.05$) than the sidedress treatment. Grain N concentration was also increased above the control by all six N treatments. In addition, spring preplant-applied AA showed slightly higher grain N ($P > F = 0.10$) compared to the fall-applied AA. Nitrogen uptake in the grain and in the total aboveground portion of the plant was increased by all of the N treatments above the control, but no difference was found among the six N treatments.

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 lower grain moisture at harvest when N-Serve was applied with the fall application. However, grain N concentration and relative chlorophyll content were lower for the fall treatments compared to the spring treatments when averaged across N-Serve. In summary, the plant data show very little difference among times of N application, between sources of N, or between N-Serve applications on corn production in 1995.

Water

Weather conditions during the 1995 growing season were very close to normal except for a wet fall. 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 4.70" with a 1.16" range among the four time/method treatments. Soybeans showed slightly less tile drainage compared to corn with an average of 3.84" from the 16 plots and a range of 2.18" 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	N-Serve	Yield	H_2O	N	N Uptake	Yield	uptake
		bu/A	%	%	lb/A	T DM/A	lb/A
Primary trts							
AA Fall (10/28)	No	157.8	26.1	1.19	88.4	6.232	113.6
AA Fall (10/28)	Yes	151.3	24.9	1.23	88.2	6.228	116.5
AA PP (4/25)	No	144.4	25.0	1.25	85.6	5.966	112.9
AA PP (4/25)	Yes	148.9	25.3	1.29	90.6	6.005	117.6
Additional trts							
Urea PP (5/3)	No	150.7	25.6	1.25	89.0	6.153	115.2
AA SD (6/15)	No	146.0	27.1	1.21	83.3	5.816	109.6
Check (No N)	--	79.4	28.5	0.93	34.8	3.593	48.4
Statistical Analysis Latin square (Primary trts)							
P > *F*:		0.44	0.08	0.10	0.76	0.77	0.71
LSD (0.05):							
CV (%):		7.3	2.3	3.8	7.4	7.5	5.7
Statistical Analysis Completely randomized (7 trts)							
P > *F*:		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD (0.05):		14.2	1.5	0.09	10.2	0.616	11.7
CV (%):		6.9	3.9	5.4	8.6	7.3	7.6

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

Parameter	Contrast		
	Fall without N-Serve vs Fall with N-Serve	Fall vs Spring	Spring without N-Serve vs Spring with N-Serve
	---------- Probability > *F* ----------		
Stover N Concentration	0.38	0.35	0.78
Grain N Concentration	0.20	0.04	0.36
Grain Moisture	0.02	0.32	0.49
Grain Yield	0.44	0.20	0.59
Stover Yield	0.49	0.70	0.76
Silage Yield	0.99	0.32	0.91
Final Population	0.83	0.78	0.12
Stover N Uptake	0.82	0.70	0.82
Grain N Uptake	0.97	0.96	0.32
Silage N Uptake	0.54	0.95	0.36
Relative Chlorophyll	0.32	0.02	0.34

Annual flow-weighted NO_3-N concentrations in the drainage water for the corn plots were 1.6 mg/l higher for the fall-applied N treatment without N-Serve compared to the fall treatment with N-Serve and the spring preplant AA treatments. (Table 5). Monthly flow-weighted NO_3-N concentrations showed slight temporal variation for all treatments except the spring preplant AA + N-Serve treatment. The fall-applied AA without N-Serve treatment had the highest NO_3-N concentration in April, May, and June and then declined to levels similar to the other treatments. Nitrate-N concentrations for the fall AA + N-Serve and spring preplant AA without N-Serve treatments were lower in April and May, increased about 1.5 mg/l in June and August, and then declined to concentrations similar to the fall AA without N-Serve treatment. Although the differences in the NO_3-N concentrations were not large, these data show a clear trend toward increased concentrations of NO_3 in tile drainage water with fall-applied AA (October 28) when a nitrification inhibitor was not used, compared to inhibitor use or spring applications.

In the soybean plots, where N had been applied either in the fall of 1993 or spring of 1994, NO_3-N concentrations were consistently higher, especially late in the season, compared to the corn plots and averaged 11.3 mg/l (Table 5). Highest flow-weighted NO_3-N concentrations were found with the fall without N-Serve and spring preplant AA + N-Serve treatments (both early and late in the season). Nitrate-N concentration under a 9-yr continuous fallow system (no fertilizer N applied) was approximately 2 to 2.5 times greater than for the fertilized corn and soybean plots.

Table 4. Tile water discharge from the corn, soybean, and fallow plots in 1995.

N application		Month						Year
Time	Inhibitor	April	May	June	August	October	November	Total
		acre-inches						
		Corn						
Fall (10/28)	No	2.14	0.56	0.06	0.75	1.36	0.40	5.31
Fall (10/28)	Yes	2.00	0.58	0.09	0.55	1.45	0.47	5.16
Spring (4/25)	No	1.80	0.40	0.08	0.46	1.06	0.36	4.15
Spring (4/25)	Yes	1.77	0.44	0.07	0.28	1.18	0.44	4.18
		Soybean						
Fall (10/25/93)	No	1.18	0.46	0.07	0.76	0.68	0.31	3.48
Fall (10/25/93)	Yes	1.87	0.73	0.09	0.81	0.86	0.52	4.80
Spring (5/11/94)	No	1.42	0.82	0.14	0.75	0.72	0.40	4.28
Spring (5/11/94)	Yes	1.12	0.17	0.00	0.74	0.49	0.20	2.72
		Fallow						
NONE		1.12	0.36	0.08	0.90	0.70	0.32	3.50

Table 5. Flow-weighted NO_3-N concentrations for each month from the corn, soybean, and fallow plots in 1995.

N application		Month						Year
Time	Inhibitor	April	May	June	August	October	November	Average
		NO_3-N (mg/l)						
		Corn						
Fall (10/28)	No	11.4	9.4	10.9	9.3	7.0	7.1	9.6
Fall (10/28)	Yes	8.6	8.5	9.9	9.6	7.0	5.7	8.1
Spring (4/25)	No	8.0	7.8	9.0	10.4	7.1	6.8	7.9
Spring (4/25)	Yes	8.3	7.0	7.3	7.7	7.4	8.3	7.9
		Soybean						
Fall (10/25/93)	No	12.3	9.1	8.6	12.4	13.5	12.6	12.4
Fall (10/25/93)	Yes	8.3	8.2	8.0	9.9	10.2	9.6	9.2
Spring (5/11/94)	No	10.3	9.2	9.1	12.0	11.6	11.3	10.8
Spring (5/11/94)	Yes	12.6	7.8	—	12.7	14.6	14.1	12.9
		Fallow						
NONE		23.8	15.9	17.2	22.3	21.9	17.9	21.7

Nitrate-N losses in the drainage water for 1995 were similar for corn and soybean when averaged across N treatments (Table 6). Greatest loss under corn occurred with the fall AA without N-Serve treatment while the lowest loss occurred with the spring preplant AA + N-Serve treatment. Nitrate-N losses under soybean, although not greatly different among treatments, tended to be slightly lower with these two treatments. Nitrate-N losses in the fallow system, when mineralization of the soil organic matter was the NO_3 source, was 90% 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 both the fall and spring AA treatments that did not include N-Serve. Somewhat lower values were found with the N-Serve treatments with no difference between spring and fall application times. In the year following corn and its associated treatments, normalized losses ranked in the order: fall with N-Serve < spring without N-Serve = fall without N-Serve < spring with N-Serve. Apparently, sufficient N was not utilized by the corn and remained in the soil profile following the spring preplant AA + N-Serve treatment, 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 application, intermediate for the fall and spring applications without N-Serve, and lowest for the fall application + N-Serve. 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 1995.

N application		Month						Year
Time	Inhibitor	April	May	June	August	October	November	Total
		---------- NO_3-N lb/A ----------						
		Corn						
Fall (10/28)	No	4.8	1.2	0.1	1.5	1.9	0.5	10.3
Fall (10/28)	Yes	3.7	1.1	0.2	1.0	2.0	0.6	8.6
Spring (4/25)	No	3.4	0.8	0.2	1.2	2.0	0.6	8.3
Spring (4/25)	Yes	3.1	0.7	0.1	0.4	2.0	0.7	7.1
		Soybean						
Fall (10/25/93)	No	2.8	0.8	0.1	1.9	1.8	0.7	8.2
Fall (10/25/93)	Yes	3.3	1.1	0.1	1.7	1.8	1.0	9.1
Spring (5/11/94)	No	3.0	1.5	0.3	1.9	1.7	0.8	9.2
Spring (5/11/94)	Yes	3.1	0.5	0.0	2.1	1.6	0.6	7.9
		Fallow						
NONE		5.2	1.5	0.3	5.3	3.1	1.3	16.6

Table 7. "Flow-normalized" NO_3-N losses to tile drainage in a corn-soybean sequence in 1995.

	Time/Method of N Application			
Crop System[1]	Fall No Inhibitor	Fall Inhibitor	Spring No Inhibitor	Spring Inhibitor
	---------- NO_3-N lost (lb/A/inch of drainage) ----------			
Corn	1.94	1.67	2.00	1.70
Soybean[2]	2.36	1.86	2.15	2.90
Corn Soybean System	2.10	1.76	2.08	2.17

[1] Continuous fallow (9 years without fertilizer N) = 4.74
[2] N applied for the 1994 corn crop at 120 lb N/A.

Soil

Nitrate-N remaining in the 0-8' soil profile in November was about 2 times greater in the fallow plots compared to the plots that received the six N treatments (Table 8). 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. Residual soil nitrate-N in November 1995 from all fallow and corn plots as influenced by N treatment.

		N Treatment for Corn						
Profile depth	Fallow NO_3-N	Fall AA	Fall AA+NI	PP AA	PP AA+NI	Urea	SD AA	Check (No N)
feet	--- lb/A ---	---------- lb/A ----------						
0 - 1	28	16	17	14	22	18	17	18
1 - 2	13	7	8	7	10	7	8	3
2 - 3	11	6	7	6	8	5	10	2
3 - 4	12	3	6	6	8	4	7	2
4 - 5	14	8	7	6	6	6	6	3
5 - 6	14	7	7	6	6	9	5	3
6 - 7	15	8	7	5	7	6	6	5
7 - 8	15	8	7	6	9	7	6	6
Total in								
0 - 5' profile	78	39	45	39	52	40	48	29
0 - 8' profile	122	62	66	56	74	62	65	43

NUTRIENT LOSSES TO TILE LINES AS INFLUENCED BY SOURCE OF N[1/]

Waseca, 1995

G.W. Randall, T.K. Iragavarapu, and M.A. Schmitt[2/]

ABSTRACT: A study was started in 1994 to compare the effects of liquid dairy manure and urea applied at similar N rates on N movement in the soil and into tile lines and corn production. Corn yields and N uptake were statistically similar between the urea and dairy manure treatments. Nitrogen source had no effect on tile flow, NO_3-N concentration and loss in tile water, and NO_3-N content in the 0-5' profile in the fall. Ortho-phosphate was detected in only one of the 71 samples analyzed while total P was detected in only 9% of the 55 samples. Total P concentrations averaged < .10 mg/L and were not different between manure and urea. Ammonium-N was detected in 54% of the 48 samples and the NH_4-N concentration did not differ between the two N sources. Nitrate-N concentrations in porous suction cup samplers tended to be greater in the urea fertilized plots compared to the dairy manure applied plots at the 4 ft depth whereas at the 6 and 8 ft depths, NO_3-N concentrations were slightly greater in the dairy manure treatment compared to urea. More NO_3-N detects were found in the 4 ft. depth piezometers than in the 6 or 8 ft depths. Nitrate-N concentrations in water taken from the piezometers showed much greater variability than in the tile lines or porous cups.

Nitrogen losses to tile lines have been documented in a number of research studies including some conducted at Lamberton and Waseca, Minnesota. These studies primarily showed that N losses were a function of the N application rate and amount of precipitation. Time of application and crop grown have also been shown to influence NO_3-N loss to tile lines. However, little information is available on N losses to tile lines when different sources of N are applied. The purpose of this study was to determine the effect of liquid dairy manure compared to urea on N movement in the soil and into tile lines and on corn production.

EXPERIMENTAL PROCEDURES

A study was initiated in 1975 on a Webster clay loam at Waseca to monitor the movement of N into tile lines installed in plots measuring 45' x 50'. Each plot is enclosed with plastic sheeting to a 6-ft depth. Corn was grown from 1975-1981 with varying rates of fertilizer N. In the fall of 1981, the plot area was converted to a new study where two tillage treatments (fall moldboard plowing and no-tillage) were replicated four times. Corn was grown from 1982 through 1992 and was fertilized at an annual application rate of 180 lb N/A. In the fall of 1992, all 8 plots were moldboard plowed and corn was grown in the residual year (1993).

In the fall of 1993, the same 8 plots used in the previous study were converted to dairy manure and urea treatments. Liquid dairy manure was broadcast-applied on November 7, 1994 at a rate of 10000 gal per acre and the plots were moldboard plowed immediately. On April 28, 1995, urea was broadcast-applied by hand to 4 plots at a rate of 185 lb N/A before field cultivation. The nitrogen rate was selected to match the amount of N "available" from the manure based on calculations from the manure analysis (Table 1). "Available" N was calculated based on the assumption that 90% of the ammonium-N (128 lb) and 25% of the organic N (115 x 0.25 = 29 lb) plus 15% of the total N of the manure that was applied in the fall of 1993 (203 x 0.15 = 30 lb) was available for a total of 185 lb N/A.

Corn (P3578) was planted on April 28 at a population of 32000 plants/A. Starter fertilizer was not used because of the high soil tests. Force was applied at 1 lb ai/A to control rootworms. Weeds were controlled with a preemergence application of Harness (2.75 lb ai/A) and Bladex (3 lb ai/A) applied May 11. Weed and insect control were excellent.

In August 1994, porous suction cup (PSC) samplers and piezometers were installed at 4, 6, and 8 ft depths in the 8 plots that received either urea or dairy manure. The PSC and piezometers were installed 30-in. apart between the corn rows at a distance of 7 ft from the tile line.

Silage yields were taken at physiological maturity. Grain yields were taken by combine from 2-45' rows. When tile lines were flowing, flow rates were measured daily and samples taken on a daily basis for the first week and then on a M-W-F basis thereafter for NO_3 analysis. Ammonium-N, total-P, and ortho-P were determined on samples taken on selected days when all tile lines were running in April, May, October, and November. Tile water samples were collected for fecal coliform bacteria analysis in May and June. Water samples collected on a twice-monthly basis from PSC samplers and piezometers were also analyzed for NO_3. Chloride concentrations were determined in tile water samples

[1/] Funding provided by the Minnesota Legislature from the MN Future Research Fund as recommended by LCMR.
[2/] Professor and Post-doctoral Research Associate, Southern Experiment Station, Waseca and Assoc. Professor, Dept. of Soil, Water, and Climate, St.Paul, respectively.

collected on two sampling dates in the fall. All analyses were done by the Research Analytical Lab.

Soil NO_3-N in the 0-5' profile was determined from two cores/plot taken in 1-foot increments on November 7, 1995.

RESULTS

Corn grain yield, grain N removal and silage N uptake tended to be greater in the plots that received urea compared to those plots that received liquid dairy manure (Table 2). However, these differences were not statistically significant at the 0.05 P level. The 14 bu/A yield "advantage" for the urea treatment, although not significant at the 95% level, suggests that sufficient N was not provided by the dairy manure treatment. We do not believe this to be the only reason for this yield difference, however. During the season, visual observations indicated a slight color (dark green) and growth/height advantage for the dairy manure treatment. At physiological maturity slightly more stover (data not shown), although statistically insignificant, was harvested from the dairy plots. In a few other studies, we also noted more lush mid-season growth with certain high N treatments but at maturity grain yield was less than from other lower rate N treatments that did not exhibit the same lush growth. Perhaps the very high August temperatures caused a stress that may have affected grain production in these plants with more lush biomass. It should be mentioned, however, that late-season unavailability of N from the manure treatments should not be discounted completely. Although differences were not statistically significant at the 95% level, N concentration in the stover (data not shown) and grain from the manured plots was somewhat less than from the urea plots. Perhaps the assumption that 60% of the total N in the manure applied in Nov. 1994 plus 15% of the total N applied in Nov. 1993 was available to the 1995 crop is an overestimate of N availability from dairy manure. Residual soil NO_3-N was also slightly less with the manured plots. These data indicate that further comparisons between urea and the availability of N from liquid dairy manure need to be made.

Table 1. Nutrient analyses and application rate of liquid dairy manure applied in November, 1994.

Dry matter	Total N	NH_4-N	Organic N	Total P_2O_5	Total K_2O
%	lb/1000 gal				
7.0	25.7	14.2	11.5	13.9	30.8
	lb/acre				
	257	142	115	139	308

Table 2. Influence of nitrogen source on corn production and N utilization at Waseca in 1995.

Nitrogen source	Final Population	Chlorophyll reading	Silage Yield	Silage N uptake	Grain Yield	Grain N	Grain N removal	Grain H_2O
	x10³	SPAD units	T DM/A	lb N/A	bu/A	%	lb N/A	%
Urea	28.6	57.9	9.37	177.7	156.6	1.46	108.5	23.4
Dairy Manure	28.8	57.4	9.18	157.8	142.6	1.40	94.7	22.8
Check[1/]	29.4	37.3	5.20	59.0	64.3	1.07	32.7	24.1
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	3.8	0.8	5.5	7.7	5.0	3.0	7.7	2.9

[1/] The check plots (0 lb N/A) are not randomized within the replications and do not have the same plot history as the 8 main plots. Therefore, data from these plots are not included in the statistical analysis.

Precipitation exceeded normal by 0.8" in April and by 2.5" October - both months with relatively low ET. As a result, highest tile flow occurred in April followed by October (Table 3). Tile flow, flow-weighted NO_3-N concentration and nitrate-N losses did not differ between the two nitrogen sources.

Table 3. Influence of nitrogen source on tile flow, flow-weighted NO_3-N concentration and NO_3-N loss in 1995.

Month	Tile Flow	NO_3-N Concentration	NO_3-N Loss
	acre-in.	mg/L	lb/A
		Urea	
April	2.46	8.1	4.4
May	0.92	8.5	1.8
June	0.26	8.2	0.5
July	-	-	-
August	0.63	8.7	1.2
September	-	-	-
October	1.90	7.7	3.4
Nov	1.21	8.1	2.2
Total	7.38	Avg = 8.1	13.5
		Dairy manure	
April	2.65	8.8	5.3
May	1.03	9.3	2.2
June	0.32	9.8	0.7
July	-	-	-
August	0.54	9.8	1.2
September	-	-	-
October	2.05	8.9	4.1
Nov	1.34	8.8	2.6
Total	7.93	Avg = 9.0	16.1

Residual NO_3-N in the 0-5 ft. soil profile at the end of the 1995 growing season was slightly greater in the plots that received urea compared to those that received liquid dairy manure (Table 4). This was especially true in the soil layer between 1 and 3 feet.

Table 4. Influence of nitrogen source on residual NO_3-N in the soil profile in November, 1995.

Profile Depth	Nitrogen Source: Urea	Nitrogen Source: Dairy manure
ft	NO_3-N (lb/A)	
0-1	13.3 (2.3)†	12.1 (2.4)
1-2	15.2 (3.5)	10.7 (0.5)
2-3	23.3 (8.8)	10.9 (1.4)
3-4	12.7 (2.9)	11.5 (7.2)
4-5	9.9 (0.6)	10.7 (4.4)
Total (0-5')	74.4	55.9

† Numbers in parentheses represent the standard error around the mean

Ortho-P was detected in only one of the 35 water samples from the plots that received dairy manure and in none of the 36 from plots that received urea (Table 5) indicating that manure application did not contribute to inorganic phosphorus losses in tile lines. Eleven percent of the water samples from the manured plots and 7% from the urea fertilized plots had detectable amounts of total phosphorus, averaging only 0.04 mg P/L. Coliform bacteria (E.Coli) was not detected in any of the 14 samples analyzed. Ammonium-N was detected in 54% of the 24 samples analyzed from each of the dairy manure and urea treatments. Ammonium-N concentrations were identical between the dairy manure and urea treatments.

Chloride content was determined in the fall in eight water samples from each of the dairy manure and urea treatments to measure the impact of manure, a source of chlorides, on the chloride levels in the tile water (Table 6). Chloride concentrations were slightly greater in the dairy manure treatment compared to the urea treatment at both sampling dates.

Table 5. Ortho-phosphorus, total phosphorus, and coliform bacteria detects in tile water samples in 1995.

	Ortho-P		Total P		*E.Coli* Bacteria		NH_4-N	
	Manure	Urea	Manure	Urea	Manure	Urea	Manure	Urea
Number of samples analyzed	35	36	27	28	9	5	24	24
Number of detects[1/]	1	0	3	2	0	0	13	13
% of samples with detects	3	0	11	7	0	0	54	54
Concentration range of detects (mg/L)	0.06	-	0.03-0.04	0.03-0.05	-	-	0.02-0.06	0.02-0.06
Average concentration among detects (mg/L)	0.06	0	0.04	0.04	-	-	0.03	0.03

[1/] Detection level is 0.04 mg/L for ortho-P, 0.02 mg/L for total P, and 0.02 mg/L for NH_3-N.

Table 6. Chloride concentrations in tile water samples from dairy manure and urea treatments

Date	Manure	Urea
	---------- mg/L ----------	
10/30	15.1 (1.3)	12.8 (1.2)
11/06	18.5 (1.4)	14.6 (2.6)

Numbers in parentheses indicate the standard error around the mean.

Nitrate-N concentrations in the PSC samplers at the 4 ft depth were consistently greater at all seven sampling dates in the plots that received urea compared to those that received dairy manure (Fig 1). The reverse was true at the 6 and 8 ft. depths. Nitrate-N concentrations at the 4 ft depth increased from August (23) to October (10) with both treatments, but was most dramatic with urea. This increase was also seen at the 6-ft depth in the urea plots. Concentrations of NO_3-N at the 8-foot depth were low (< 4 mg/L) for both treatments. Water samples were collected four times from the piezometers in 1995. Nitrate-N detects in the piezometer water samples are given in Table 7. Across the four sampling dates between August 8 and October 25, water was found in only 14 of a possible 32 piezometers at the 4 ft. depth whereas at the 6 and 8 ft depths 28 and 27, respectively, of the piezometers had water. However, all the samples from the 4 ft depth piezometers had detectable amounts of nitrates. Average nitrate-N concentrations in the 4 ft depth piezometers were less than those in the 4 ft depth PSC samplers at all sampling dates except the last sampling date (10-25). In general, more detects were found in the urea treated plots compared to the dairy manure applied plots. The variation around the mean nitrate-N concentration was greater for the piezometer samples than those from the tile lines or PSC samplers.

Table 7. Nitrate-N detects in the piezometer water samples in 1995.

		8-8		8-23		10-9		10-25	
	Depth	Manure	Urea	Manure	Urea	Manure	Urea	Manure	Urea
# of samples analyzed	4	2	2	0	3	0	1	3	3
	6	4	4	3	4	3	2	4	4
	8	4	4	4	4	3	2	3	3
# of detects[1/]	4	2	2	-	3	-	1	3	3
	6	1	2	1	2	1	2	4	3
	8	1	1	1	0	1	0	2	0
% of samples with detects	4	100	100	-	100	-	100	100	100
	6	25	50	33	50	33	100	100	75
	8	25	25	25	0	33	0	67	-
Conc. range of detects (mg/L)	4	1.4-1.7	4.0-4.5	-	0.5-12.9	-	7.1	6.8-23.2	12.1-31.3
	6	1.3	4.7-15.9	3.3	2.6-3.3	0.7	0.5-27.5	4-13.4	4.5-8.2
	8	6.1	0.6	5.3	-	9.1	-	6.3-6.4	-
Avg. conc. among detects (mg/L)	4	4.7	4.3	-	5.4	-	7.1	14.0	19.8
	6	1.3	10.3	3.3	3.0	0.7	14.0	7.9	6.5
	8	6.1	0.6	5.3	-	9.1	-	6.4	-

[1/] detection limit is 0.5 mg/L.

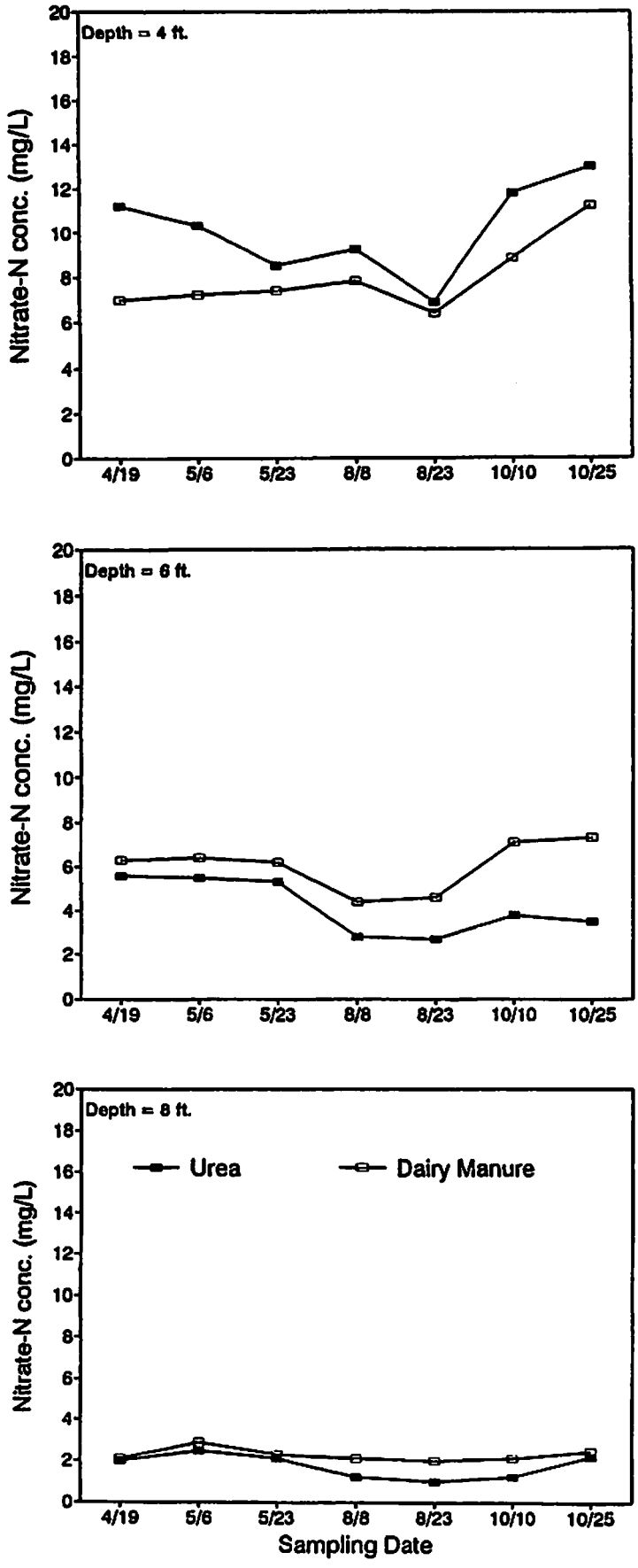

Fig 1. Nitrate-N concentrations in porous suction cup samplers in 1995

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

G. W. Randall, M. A. Schmitt, and J. A. 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 30 and 60 lb N/A at the two sites and were related to the residual soil NO_3-N (RSN) indicated by the preplant soil N test. Using the test reduced N recommendations at both sites to more economical and environmentally-sound rates of N. Fertilizer N was not under-recommended at either site by the 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

Two sites were selected for this study in 1995 (Table 1). One was on a fine-textured glacial till soil in south-central Minnesota and the other was on medium-textured loess soil in southeastern Minnesota. Both sites had a history of dairy manure. The previous cropping history is also given in Table 1.

Table 1. Cooperator, field history, soil type, and parent material at each of the 1995 sites.

	Site (County)	
	Waseca	Olmsted
Cooperator:	SES, U of M	Lawler Farm
History:		
Crop	Corn: 1992-94, Alfalfa: 1989-91	Continuous corn
Manure	10000 gal/A of liquid dairy manure in Oct. 1991 and Oct. 1992	8000 gal/A of liquid dairy manure in April of 1994.
Soil type:	Webster cl	Port Byron sil
Parent Material:	Glacial till	Loess

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 glacial till site, 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 inches 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 3769 and 3861 were planted and thinned to a uniform population at the Waseca and Olmsted sites, respectively. Weeds were controlled very well with a combination of herbicides and cultivation.

Soil samples were taken from the control plots in 1-ft increments to a depth of 3-ft at three times during the season (preplant, emergence, and 10 to 12 inch tall corn). After harvest, samples were taken to a 4-ft depth from the 0, 90 and 180-lb treatments. Samples were analyzed for nitrate-N (NO_3-N) and ammonium-N (NH_4-N).

Grain yields were taken by combine harvesting 89 and 79 ft of row from each plot at the Waseca and Olmsted Co. sites, respectively. Silage yields were determined from 15 ft of row in each plot at all sites.

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, Water, and Climate, St. Paul; and Assistant Scientist, Southern Experiment Station, Waseca.

RESULTS AND DISCUSSION

Corn yields were quite good at the Waseca site but less than expected and more variable in Olmsted Co. (Table 2). The lower yields in Olmsted Co. were probably due to very strong straight-line winds in early August, which caused severe lodging, and the hybrid used. Statistical analyses showed that grain yields were optimized with the 30-lb preplant N rate in Waseca Co. and the 60-lb rate in Olmsted Co. Silage yields also were optimized at the 30-lb rate in Waseca, but 90 lb N/A was required in Olmsted Co. A relative chlorophyll content of ≥ 95%, calculated as a percent of the highest chlorophyll treatment, is usually considered optimum. This occurred at the 60 and 90-lb N rates at the Waseca and Olmsted Co. sites, respectively. Contrast statistics showed slightly lower grain and silage yields when the 60, 90 and 120-lb N rates were split applied at Waseca compared to the single, preplant application.

Table 2. Corn grain yield, silage yield, and relative chlorophyll content (R1 stage) as influenced by N applied to fields with a manure history in 1995.

Nitrogen Treatment		Waseca Co.			Olmsted Co.		
Preplant	Sidedress	Grain Yield	Silage Yield	Chlorophyll[1/]	Grain Yield	Silage Yield	Chlorophyll[1/]
--- lb N/A ---		- bu/A -	- T DM/A -	- % -	- bu/A -	- T DM/A -	- % -
0	0	134	6.06	92.2	109	5.11	85.5
30	0	160	6.88	94.7	126	5.31	89.8
60	0	168	7.25	95.4	138	5.54	93.4
90	0	166	7.24	98.5	129	5.90	97.0
120	0	162	6.87	100.0	144	6.08	97.3
150	0	162	7.00	99.9	149	6.58	100.0
180	0	155	6.52	98.7	142	6.60	97.7
30	30	157	6.72	96.4	-	-	-
30	60	156	6.51	96.4	-	-	-
30	90	163	6.85	99.5	-	-	-
Pr. > *F*:		< 0.01	< 0.01	< 0.01	0.01	0.01	< 0.01
LSD (0.05):		13	0.48	2.5	20	0.88	3.3
CV (%):		5.8	4.9	1.8	10.1	10.1	2.3

[1/] Relative to the treatment with the highest chlorophyll content

Soil NO_3-N analysis (Table 3) indicated carryover of RSN throughout the 0 to 3-ft profile at Waseca. Residual N was slightly less in Olmsted and was confined primarily to the top 2 ft. Residual N values form samples taken at emergence and when the corn was about 10 inches tall were similar to the preplant N concentrations at Waseca. At Olmsted, mineralization of N (most likely from the previous manure applications) resulted in much higher NO_3-N concentrations when samples were taken in 10-inch tall corn after soil temperatures had warmed compared to either the preplant or emergence sampling.

Table 3. Soil NO_3-N as influenced by time and depth of sampling in fields with a manure history in 1995.

Sampling		Sites	
Time	Depth	Waseca	Olmsted
	- ft -	-------- ppm --------	
Preplant[1/]	0-1	10.7	7.5
"	1-2	11.3	9.2
"	2-3	10.8	4.9
"	0-2	11.0	8.4
V1 (emergence)	0-1	10.3	9.0
"	1-2	10.7	8.1
"	2-3	11.4	4.4
"	0-2	10.5	8.6
V4-5 (10 inch corn)	0-1	10.8	15.8
"	1-2	10.6	11.5
"	2-3	11.8	6.7
"	0-2	10.7	13.6

[1/] Soil NO_3-N in the 0 to 4-ft profile totaled 172 and 101 lb/A for the Waseca and Olmsted sites, respectively.

Soil N credits determined by Minnesota's preplant soil N test indicate a credit of 65 and 35 lb N/A for the Waseca and Olmsted Co. sites, respectively. Subtracting this credit from our present recommendation of 150 lb N/A for a yield goal of 160 bu/A at these sites provides N recommendations of 85 and 115 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. At both sites, this reduced rate of N would have lowered fertilizer costs and potential ground water contamination without impacting yield. In fact, about 55 lb N/A in

excess of what the plant really needed was applied at both sites even though the test was used. These data suggest that the present U of M preplant soil N test is helpful for improved N management, but it may need some refinement for fields with a manure history if greater profits are to be realized along with less environmental risk.

Residual soil NO_3-N (RSN) in the 0 to 4-ft profile after harvest was significantly different between the two sites (Table 4). At the Waseca site, higher than normal levels of RSN existed throughout the profile in all three treatments, even the control. Apparently mineralization of N from the previous manure applications coupled with corn receiving some fertilizer N in the three years following alfalfa led to the high RSN levels and explains why only 30 lb N/A was needed to optimize yield. Residual soil NO_3-N levels were almost 100 lb N/A higher when excess N was applied with the 180-lb rate compared to the 90-lb rate. In addition, high levels of RSN were found at all depths in the profile when 180 lb N/A was applied.

In Olmsted Co., where the total rate of manure previously applied was lower and alfalfa had not been grown, RSN was considerably lower; especially in the 0 and 90-lb N plots (Table 4). Similar to Waseca, when comparing the 180-lb to the 90-lb N rate, the extra 90-lb resulted in 86 lb more RSN/A and some leaching movement below 3 ft was evident. These data clearly show how high levels of RSN can accumulate in soils when N from previous manure additions becomes available and fertilizer N in excess of crop needs is applied. As a result, the potential for leaching loss of NO_3 is greatly increased.

Table 4. Residual soil NO_3-N (RSN) after harvest by site in 1995.

N rate	Depth	Site: Waseca	Site: Olmsted
lb/A	ft	------- lb NO_3-N/A -------	
0	0-1	31	14
"	1-2	27	7
"	2-3	20	7
"	3-4	21	19
"	0-4	99	47
90	0-1	36	21
"	1-2	30	12
"	2-3	21	15
"	3-4	28	14
"	0-4	115	62
180	0-1	49	45
"	1-2	53	48
"	2-3	49	32
"	3-4	62	23
"	0-4	213	148

SUMMARY

- Even though corn yields were quite good, the yield response of continuous corn to fertilizer N was limited in these fields with a manure history.
- The present soil N test provided a N recommendation much closer to the optimum economic rate compared to not using the test. 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 research appears necessary to more accurately predict the N availability in fields with a long-term manure history.

CORN YIELD RESPONSE TO STARTER PHOSPHORUS ON CLAY LOAM SOILS IN THE MINNESOTA RIVER BASIN

G. W. Randall, S. D. Evans, G. A. Nelson, J. A. Vetsch, and U. Bolliger[1]

ABSTRACT: Knowing the probability of a corn yield response to starter fertilizer as a function of soil test P would help improve fertilizer P management in the Minnesota River Basin. A study was conducted in 1995 to determine the yield response of corn following soybeans to starter fertilizer (10 gal 10-34-0/A) as affected by soil test P and K. Applications of various rates of fertilizer P and K from 1973-1992 had created soil test P ranging from 3 to 35 ppm (Bray P_1) at Waseca and 4 to 28 ppm (Olsen) at Morris. Although early corn growth usually improved with the use of starter fertilizer, regardless of soil test P level, corn grain yield was not increased by the starter fertilizer when soil test P was >10ppm. Grain moisture at harvest was decreased by starter fertilizer at soil tests <10 ppm at Morris but not at Waseca.

Phosphorus from agricultural sources (fertilizer, manure, wastes, etc.) has been identified as a major source of P in surface waters of the Minnesota River Basin. With this increasing concern and with the long-term goal of improving profitability, farmers will be called upon to manage P in a manner that is both environmentally and economically sound. The purpose of this research is to determine the relationship between soil test P level and corn grain yield response to starter (band-placed) P. This information should lead to improved P management practices for corn and soybean farmers.

METHODS

This study was started in the fall of 1973 on a Webster clay loam at Waseca. Fertilizer P rates of 0, 50, and 100 lb P_2O_5/A were broadcast-applied annually each fall from 1973 through 1984. Beginning in 1985 fertilizer P and K was discontinued on some of the plots while annual applications were continued on others. Due to the applications of various rates of P over the 20-year period at both Waseca and Morris, soil test P varied markedly among the plots. Soil test P in October, 1994 ranged from 3 to 35 ppm (Bray P_1) at Waseca and 4 to 28 ppm (Olsen P) at Morris.

Corn was planted in 1995 following a previous crop of soybeans at both locations. Nitrogen was applied prior to planting as anhydrous ammonia at a rate of 150 lb N/A at Waseca and 120 lb N/A at Morris. These rates were about 30 lb/A higher than recommended because we did not want the N in the starter fertilizer to affect yield. At Waseca, corn (Pioneer 3578) was no-till planted using row cleaners at a rate of 32000 plants/A on April 28. At Morris, the site was field cultivated 2X before planting due to very wet conditions. Corn (Pioneer 3861) was planted at a rate of 28000 plants/A on May 18. Starter fertilizer as 10 gal 10-34-0/A was applied to one-half of each plot. Plant population was thinned to a final stand of 30,500 plots/A at Waseca. Grain yields and moisture were obtained by combine harvesting two rows from each starter plot and two rows from each non-starter plot.

RESULTS AND DISCUSSION

Table 1. Corn grain yield, grain moisture, and extended leaf plant heights (measured on July 3) as affected by starter fertilizer applied to soils of varying soil test P and K at Waseca in 1995.

	Fall '94 Soil Test		Grain Yield		Grain Moisture		Plant Leaf Heights	
Trt. No[1/]	P	K	No Starter	Starter[1/]	No Starter	Starter[1/]	No Starter	Starter[1/]
	- - - ppm - -		- - - bu/A - - -		- - - % - - -		- - - inch - - -	
1	5	103	140a	142a	21.0	20.9	47.4a	52.9b
2	3	150	126a	153b	21.5	21.8	51.2a	58.6b
3	7	143	159a	161a	22.1	20.4	53.6a	57.8b
4	19	136	163a	160a	21.7	21.7	55.9a	59.1b
5	35	145	163a	166a	22.6	21.5	57.8a	60.4b
6	34	112	168a	156a	21.3	20.8	54.1a	57.6b
7	30	110	164a	160a	21.3	20.4	53.9a	57.0b
8	18	104	143a	153a	21.9	21.1	51.3a	54.6b
9	4	113	132a	154b	21.1	21.2	50.6a	55.4b
10	12	104	156a	150a	20.5	21.1	52.9a	55.1b

Statistical analysis of treatment effects for split-plot design			
Treatment (P > F):	<0.01	0.60	<0.01
LSD (0.05):	12		2.9
Starter Fertilizer (P > F):	0.07	0.14	<0.01
Treatment*Starter (P > F):	0.02	0.68	<0.01
LSD (0.05):	16		3.1
C.V. (%):	5.5	4.8	1.6

[1/] Each 6-row plot was split into 3 rows with starter fertilizer (10 gal 10-34-0/A) and 3 rows without starter fertilizer.

[1] Professor, Southern Experiment Station; Professor and Asst. Scientist, West Central Experiment Station; Asst. Scientist and Plot Technician, Southern Experiment Station, respectively.

Grain yields were affected by starter fertilizer and the interaction between soil test P level and starter fertilizer was signficant at both Waseca (Table 1) and Morris (Table 2). At Waseca, yield responses of >20 bu/A to starter P were obtained when the soil test P (Bray P_1) was 3 and 4 ppm and potassium (K) was not limiting. The lower yields with no response to starter P in treatment 1 (soil test P = 5 ppm) suggests that soil test K may have been limiting. Yield responses to starter fertilizer P were not obtained when soil test P ranged between 7 and 35 ppm and soil test K was adequate. The lack of yield response in treatment 3 (soil test P = 7 ppm) was surprising. Lower yields overall in treatments 8 and 10 with a soil test K of 104 ppm again suggests inadequate K. However, when K was adequate and P was inadequate (treatment 2, soil test P = 3 ppm), the addition of 10 gallons/A of 10-34-0 was still not sufficient to optimize corn yields. Grain moisture at harvest was not influenced by starter fertilizer regardless of soil test P.

At Morris, where soil test K was very high in all treatments, yield responses of >20 bu/A were obtained with starter fertilizer when soil test P (Olsen P) was ≤8 ppm (Table 2). Additionally, grain moisture at harvest was 1.3 to 1.7 points lower when starter fertilizer was used on these low P testing plots. Corn grain yield and grain moisture at harvest responses to starter fertilizer were not obtained when soil test P was >10 ppm.

The yield data collected from these two sites, where no tillage and minimum tillage was used, suggest that yields can be optimized with starter fertilizer (10-34-0) as long as soil test P does not drop to very low levels and soil test K is maintained at a high level. Inadequate soil test K or very low soil P levels limit the potential for starter fertilizer to optimize yields.

Table 2. Corn grain yield, grain moisture, and extended leaf plant heights (measured in June) as affected by starter fertilizer applied to soils of varying soil test P level at Morris in 1995.

Trt. No[1]	Soil Test	Grain Yield		Grain Moisture		Plant Leaf Heights	
	Olsen P	No Starter	Starter[1]	No Starter	Starter[1]	No Starter	Starter[1]
	- ppm -	--- bu/A ---		--- % ---		--- inch ---	
1	6	104a	130b	20.2a	18.5b	24.8a	30.3b
2	4	108a	132b	20.8a	19.3b	25.5a	30.5b
3	8	112a	143b	20.1a	18.8b	25.8a	29.3b
4	12	132a	135a	18.8a	19.1a	27.3a	29.9b
5	28	142a	143a	19.5a	19.0a	28.3a	31.0b
6	17	137a	131a	17.4a	18.0a	27.1a	28.4a
7	12	136a	134a	18.9a	18.3a	27.3a	29.4b
8	16	143a	136a	17.7a	18.1a	28.5a	30.1a

Statistical analysis of treatment effects for split-plot design

Treatment (P > F):	0.04	<0.01	0.14
LSD (0.05):	16	1.1	
Starter Fertilizer (P > F):	<0.01	<0.01	<0.01
Treatment*Starter (P > F):	<0.01	<0.01	0.03
LSD (0.05):	19	1.3	2.2
C.V. (%):	7.2	2.8	4.6

[1] Each 8-row plot was split into 4 rows with starter fertilizer (10 gal 10-34-0/A) and 4 rows without starter fertilizer.

SUMMARY

- Corn yield responses to starter fertilizer (10-34-0) generally occurred when soil test P was <10 ppm and did not occur when soil test P was >10 ppm even though very little tillage was performed.
- Soil test K must be kept at a high level to optimize the performance of a 10-34-0 starter fertilizer.
- Because P loss to surface water and the resultant algal blooms are a function of sediment loss and soil test P, keeping the test in the 15 to 20 ppm range with application of starter fertilizer P or the incorporation of broadcast P demonstrates environmental stewardship of our natural resources.
- Soil sampling in grids of 200 to 300' along with variable rate fertilizer application technology will be most helpful in maintaining adequate but not excessive P levels throughout the field. However, for this to succeed, it is extremely important to concentrate fertilizer applications on the low and medium P testing soils (with pH <7.5) rather than building soil test P on high or very high soils with "crop removal" applications of P. Variable rate application of starter fertilizer may be an excellent way to accomplish this.

NO-TILL CORN PRODUCTION IN SOUTHERN MINNESOTA AS AFFECTED BY NITROGEN SOURCE, ROW CLEANERS, STARTER FERTILIZER, AND CROP ROTATION.[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 (RC), and starter fertilizer (SF) on corn production in continuous corn (CC) and a corn-soybean (C-Sb) rotation. These single year data (1995) show an 18.3 bu/A yield advantage for the C-Sb rotation, while grain moisture was reduced 2.6 percent, and grain N concentration was increased 0.1 percent, compared to CC. Anhydrous ammonia resulted in greater corn grain yields, grain N concentrations, and grain N removal in the C-Sb rotation. However, in the CC system grain yield and N concentration were not statistically different between AA and UAN. The use of RC enhanced plant emergence, early plant growth, and grain yield, while reducing grain moisture in both crop rotations. Starter fertilizer enhanced early plant growth in both cropping systems, but did not result in a yield advantage in the C-Sb rotation on this high P testing soil (Bray-P_1 =30 ppm). For the CC system RC had the greatest impact on yield, followed by SF, and nitrogen source (AA), respectively. In the C-Sb rotation RC increased yields more than did N source (AA). Injected post-emergence applications of UAN produced 10.0 and 6.8 bu/A greater corn grain yields compared to preplant broadcast applications of UAN for the C-Sb and CC cropping systems, respectively. Inoculation of no-till fields with night crawlers, to improve soil quality, has thus far been successful. Greater numbers of night crawler middens were found in the C-Sb rotation compared to CC.

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 (CC) and a corn-soybean (C-Sb) rotation.

EXPERIMENTAL PROCEDURES

A research site was established in the spring of 1994 at the Southern Experiment Station on a Webster-Nicollet-Canisteo complex. 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 continuous no-till corn, while the other two sections will rotate between corn and soybean for the corn-soybean rotation.

Treatments were based on current "on-farm" management options for no-till. Individual plots were 10 ft wide by 120 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 cleaners (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 a preplant broadcast application of UAN to a point-injector banded application at the V1-2 stage. Anhydrous ammonia (82-0-0) was injected 15 in. from the row and 7 in. deep with a 5-knife applicator. Urea ammonium nitrate (28-0-0) was injected approximately 3 in. from the row to a depth of 4 in. with a 4-wheel point-injector. Dawn® row cleaners were used on a John Deere Maxi-merge 7100 planter for the RC treatments. Ten gal/A 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 160 and 120 lb N/A for the CC and C-Sb rotation, respectively.

Corn (Pioneer 3578) was planted on April 28 at 32,200 seeds/acre. Weeds were controlled with a pre-emergence application (May 11) of Harness (2.75 pt./A) and Bladex (2.5 qt./A), a post treatment (July 11) of Accent (2/3 oz./A), and spot spraying with 2-4 D. The preplant broadcast application of UAN was applied on April 24. The AA and UAN point-injector treatments were applied on May 31 at VE-V1 in the CC and V2 in the C-Sb rotation. Plant emergence counts were taken on selected treatments by daily counting plants emerged in 50 ft of row. Early plant growth was determined by taking extended leaf heights of 10 plants each from rows 2 and 3 in each plot on June 16 and July 14 (49 and 77 days after planting, DAP). Corn grain was combine harvested from the center two rows each 114 ft in length on September 28. 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.

An area (4 ft long and 2.5 ft wide) of each plot was inoculated with 50 night crawlers on May 23. This area was located 25 ft from the end of each plot and was centered in the 10 ft wide plots (between rows 2 and 3). No attempt was made to confine the night crawlers to that area. On September 28 night crawler middens (huts) were counted to estimate the population of crawlers in the each plot. Counts were taken in the inoculated area and just outside the inoculated area.

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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.

RESULTS AND DISCUSSION

Corn Grain and Plant Growth Parameters (Corn-Soybean Rotation)

Nitrogen source, row cleaners and starter fertilizer significantly affected corn grain and plant growth parameters (Table 1). Anhydrous ammonia resulted in 4.1 bu/A greater corn grain yield, 0.04 percent greater grain N concentration, and 5.4 lb/A more N in the grain compared to UAN. Plant emergence reached 80% two days earlier in RC plots compared to non-RC plots (Figure 1). Extended leaf plant heights, measured 49 and 77 DAP, were 10 and 3 percent taller where RC were used, respectively (Table 1). Row cleaners produced 6.4 bu/A greater yield and resulted in lower grain moisture compared to non use of RC. Plant emergence was not affected by SF. Starter fertilizer increased plant heights at both 49 and 77 DAP, but did not result in greater yields or reduced grain moisture on this high P testing soil (Bray-P_1 = 30 ppm).

The significant three-way interactions for grain yield, N concentration, and N removal ($P > F$ = 0.06, 0.08, and 0.01, respectively) are intriguing (Table 1). However, because the yield range among the 8 treatments is low (< 15 bu/A) and clear-cut reasons for the phenomena are not evident, we will not attempt to explain these interactions unless they reappear in subsequent years. The agronomic significance of these interactions are not clear at this time and could be hybrid and year dependent.

Table 1. Grain yield, grain moisture, grain N concentration, grain N removal, final plant population, and early plant growth as affected by N source / method of application, row cleaners, and starter fertilizer in a corn-soybean rotation in 1995.

Treatments			Grain				Final	Plant Heights	
N-source	Row Cl.	Starter	Moisture	Yield	N Conc.	N Removal	Plant Pop.	49 DAP	77 DAP
			%	bu/A	%	lb N/A	ppAx10^3	inches	
UAN	No	No	31.7	140.3	1.35	89.5	30.9	18.0	78.1
AA	No	No	32.0	143.5	1.35	91.8	29.0	18.4	78.1
UAN	No	Yes	32.1	137.2	1.31	85.2	30.8	21.9	83.7
AA	No	Yes	31.9	145.4	1.39	95.3	30.8	21.9	82.8
UAN	Yes	No	31.7	146.2	1.29	88.9	32.0	20.2	81.8
AA	Yes	No	31.7	152.1	1.37	98.5	30.8	18.9	78.8
UAN	Yes	Yes	31.4	147.2	1.34	93.3	29.6	24.3	85.1
AA	Yes	Yes	31.2	146.4	1.34	92.9	29.5	24.3	85.2
UAN Bdct.	Yes	No	31.8	136.2	1.29	82.9	28.6	17.9	80.9
Statistical analysis of main effects for 2^3 factorial design (8 treatments)									
N source (N)									
UAN			31.7	142.7	1.32	89.2	30.8	21.1	82.2
AA			31.7	146.8	1.36	94.6	30.0	20.9	81.2
$P > F$			0.93	0.01	0.05	<0.01	0.13	0.47	0.20
Row cleaners (RC)									
No			31.9	141.6	1.35	90.5	30.4	20.0	80.7
Yes			31.5	148.0	1.33	93.4	30.5	21.9	82.7
$P > F$			0.01	<0.01	0.45	0.09	0.84	<0.01	0.01
Starter fertilizer (SF)									
No			31.8	145.5	1.34	92.2	30.7	18.9	79.2
Yes			31.6	144.0	1.34	91.7	30.2	23.1	84.2
$P > F$			0.40	0.35	0.78	0.75	0.35	<0.01	<0.01
Statistical analysis of interaction effects for 2^3 factorial design (8 treatments)									
N x RC ($P > F$)			0.74	0.31	0.93	0.61	0.75	0.18	0.50
N x SF ($P > F$)			0.21	0.77	0.93	0.73	0.16	0.49	0.48
RC x SF ($P > F$)			0.12	0.57	0.69	0.94	0.02	0.13	0.84
N x RC x SF ($P > F$)			0.61	0.06	0.08	0.01	0.68	0.25	0.20
C.V. (%)			1.3	3.0	4.2	5.0	4.8	4.2	2.5
Statistical analysis of treatment effect for randomized complete block design (9 treatments)									
$P > F$			0.14	<0.01	0.15	<0.01	0.19	<0.01	<0.01
LSD (0.05)				6.0		6.4		1.3	2.9
C.V. (%)			1.3	2.9	4.0	4.8	5.8	4.2	2.4
Contrast ($P > F$)									
'UAN Broadcast vs Point Injected'			0.61	<0.01	1.00	0.06	0.01	<0.01	0.55

Comparisons of injected vs broadcast UAN (treatment 5 vs 9) were preformed using contrast statistics (Table 1). Injected UAN at V2 produced 10.0 bu/A greater grain yields compared to preplant broadcast UAN. Early plant growth (plant height) at 49 DAP also benefited from injected UAN. Nitrogen deficiency symptoms were evident in the broadcast treatment during the growing season, but grain N concentration was similar to the injected UAN treatment. However, these treatments resulted in lower grain N concentrations than all other treatments.

Corn Grain and Plant Growth Parameters (Continuous Corn)

Row cleaners and starter fertilizer significantly affected most corn grain and plant growth parameters, while N source had little effect (Table 2). Plant emergence in plots where RC were used reached 80% five days earlier compared to where RC were not used (Figure 1). Grain yield and N removal increased 8.6 bu/A and 5 lb N/A, respectively with RC, while grain moisture decreased by 1.0 percent. Also, final plant population was significantly greater when RC were used ($P > F = 0.09$). Starter fertilizer slightly hastened corn emergence when RC were not used, but had no effect with RC use (Figure 1). Plant heights at 49 and 77 DAP increased by 29 and 14 percent, respectively with SF use. Unlike the C-Sb rotation, SF increased grain yield 7.6 bu/A and decreased grain moisture in the CC system where the soil test P was 28 ppm.

A comparison of injected UAN vs preplant broadcast UAN (treatment 5 vs 9) showed a 6.8 bu/A yield advantage for injected UAN. Although this contrast (Table 2) was not statistically significant ($P > F = 0.11$), it is an agronomically significant yield difference. There were no significant interactions for corn grain in the CC system.

Table 2. Grain yield, grain moisture, grain N concentration, grain N removal, final plant population, and early plant growth as affected by N source / method of application, row cleaners, and starter fertilizer in continuous corn in 1995.

Treatments			Grain				Final	Plant Height	
N-source	Row Cl.	Starter	Moisture	Yield	N Conc.	N Removal	Plant Pop.	49 DAP	77 DAP
			%	bu/A	%	lb N/A	ppAx10^3	inches	
UAN	No	No	35.3	116.8	1.25	68.9	26.5	9.1	51.1
AA	No	No	35.3	120.0	1.25	71.3	29.0	9.6	50.6
UAN	No	Yes	34.2	125.1	1.21	71.8	28.2	11.0	58.0
AA	No	Yes	34.2	127.1	1.23	74.1	28.4	11.9	57.2
UAN	Yes	No	34.1	126.3	1.21	72.4	29.8	11.0	57.9
AA	Yes	No	34.2	127.9	1.27	77.1	29.7	10.1	52.9
UAN	Yes	Yes	33.6	131.6	1.17	72.9	28.6	13.0	62.7
AA	Yes	Yes	33.4	137.6	1.28	83.7	29.5	15.5	64.4
UAN Bdct.	Yes	No	34.5	119.5	1.21	68.7	29.0	10.8	57.3
Statistical analysis of main effects for 2^3 factorial design (8 treatments)									
N source (N)									
UAN			34.3	124.9	1.21	71.5	28.3	11.0	57.4
AA			34.3	128.1	1.26	76.5	29.2	11.8	56.3
$P > F$			0.87	0.11	0.11	0.03	0.29	0.01	0.24
Row cleaners (RC)									
No			34.8	122.2	1.24	71.5	28.0	10.4	54.2
Yes			33.8	130.8	1.24	76.5	29.4	12.4	59.5
$P > F$			<0.01	<0.01	0.98	0.03	0.09	<0.01	<0.01
Starter fertilizer (SF)									
No			34.7	122.7	1.25	72.4	28.8	9.9	53.1
Yes			33.9	130.3	1.22	75.6	28.7	12.8	60.6
$P > F$			<0.01	<0.01	0.46	0.16	0.95	<0.01	<0.01
Statistical analysis of interaction effects for 2^3 factorial design (8 treatments)									
N x RC ($P > F$)			0.75	0.76	0.22	0.24	0.55	0.88	0.60
N x SF ($P > F$)			0.71	0.69	0.54	0.50	0.42	<0.01	0.11
RC x SF ($P > F$)			0.43	0.98	0.82	0.89	0.69	0.01	0.45
N x RC x SF ($P > F$)			0.67	0.47	0.82	0.50	0.32	0.02	0.07
C.V. (%)			1.9	4.3	6.7	8.4	7.9	7.1	4.7
Statistical analysis of treatment effect for randomized complete block design (9 treatments)									
$P > F$			<0.01	<0.01	0.62	0.06	0.51	<0.01	<0.01
LSD (0.05)			0.9	8.2				1.4	4.4
C.V. (%)			1.9	4.5	6.3	8.4	7.4	8.5	5.3
Contrast ($P > F$)									
'UAN Broadcast vs Point Injected'			0.42	0.11	1.00	0.40	0.57	0.83	0.79

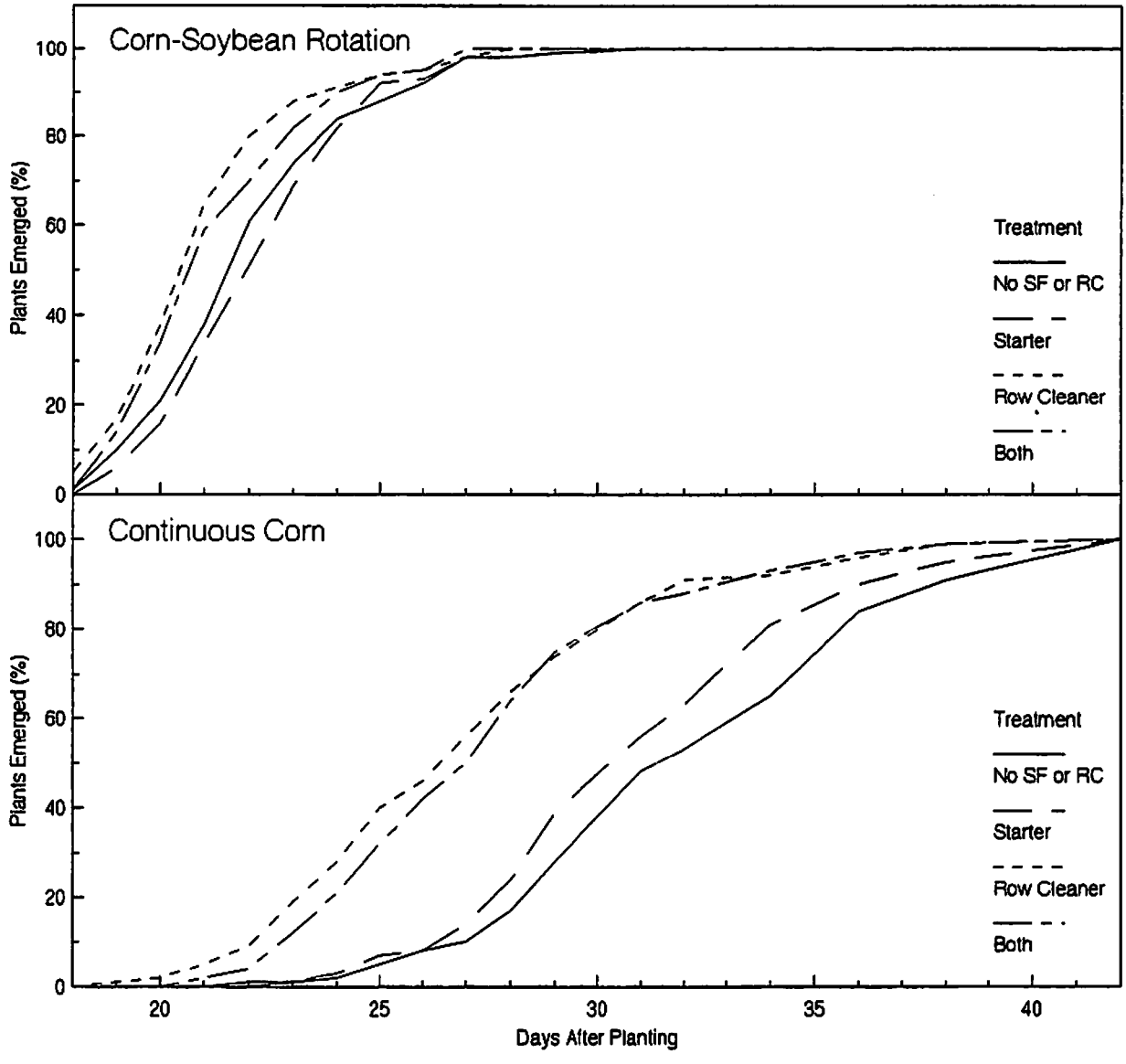
Night Crawlers and Middens

Night crawler middens (huts) were evident in most areas of the CC and C-Sb plots, but were more prevalent in the inoculated areas and in the C-Sb rotation. Variability in midden counts was high. Coefficient of variations (CV) ranged from 27 to 207 percent (Table 3). Generally, plots that received AA had significantly fewer middens compared to UAN.

Table 3. Night crawler middens (huts) in inoculated and non inoculated areas as affected by treatments in 1995.

Treatments			Corn-Soybean Rotation		Continuous Corn	
N-source	Row Cl.	Starter	Inoculated	Non-Inoculated	Inoculated	Non-Inoculated
			middens/meter^2			
UAN	No	No	13.5	4.8	1.3	0.3
AA	No	No	8.8	4.8	1.0	0.0
UAN	No	Yes	13.8	2.3	4.0	0.5
AA	No	Yes	10.8	3.5	2.3	0.3
UAN	Yes	No	13.3	4.0	4.3	1.0
AA	Yes	No	8.5	3.8	1.3	0.3
UAN	Yes	Yes	13.0	4.5	4.3	0.5
AA	Yes	Yes	9.8	3.8	2.0	0.0
UAN Bdct.	Yes	No	15.0	7.0	2.3	0.0
Statistical analysis of main effects for 2^3 factorial design (8 treatments)						
N source (N)						
UAN			13.4	3.9	3.4	0.6
AA			9.4	3.9	1.6	0.1
$P > F$			<0.01	0.93	0.01	0.10
Row cleaners (RC)						
No			11.7	3.8	2.1	0.3
Yes			11.1	4.0	2.9	0.4
$P > F$			0.63	0.79	0.23	0.46
Starter fertilizer (SF)						
No			11.0	4.3	1.9	0.4
Yes			11.8	3.5	3.1	0.3
$P > F$			0.48	0.25	0.09	0.81
Statistical analysis of interaction effects for 2^3 factorial design (8 treatments)						
N x RC ($P > F$)			0.96	0.42	0.23	0.46
N x SF ($P > F$)			0.48	0.79	0.78	0.81
RC x SF ($P > F$)			0.79	0.14	0.23	0.23
N x RC x SF ($P > F$)			0.96	0.53	0.41	0.81
C.V. (%)			28	50	74	207
Statistical analysis of treatment effect for randomized complete block design (9 treatments)						
$P > F$			0.06	0.13	0.08	0.50
LSD (0.05)						
C.V. (%)			27	45	73	220
Contrast ($P > F$)						
'UAN Broadcast vs Point Injected'			0.45	0.04	0.14	0.05

Figure 1. Corn plant emergence as affected by row cleaners, starter fertilizer, and crop rotation in 1995.



CONCLUSIONS

1. No-till corn grain yields averaged 14% greater in the corn-soybean rotation compared to the continuous corn monoculture.
2. Corn grain yields in the corn-soybean rotation increased 6.4 bu/A and 4.1 bu/A with row cleaners and anhydrous ammonia use compared to non row cleaners and UAN, respectively.
3. Starter fertilizer improved early plant growth but did not increase corn grain yields in the corn-soybean rotation where the Bray-P_1 soil test was 30 ppm.
4. Continuous corn grain yields increased with row cleaner and starter fertilizer use by 8.6 and 7.6 bu/A, respectively, but were unaffected by nitrogen source / placement method.
5. Injected UAN at V1-2 increased grain yields by 10.0 and 6.8 bu/A compared to preplant broadcast UAN in the corn-soybean rotation and continuous corn monoculture, respectively. However, the difference was not statistically significant in the continuous corn ($P > F = 0.11$).

RESIDUAL EFFECTS OF NITROGEN APPLIED TO ESTABLISHED REED CANARYGRASS

J. A. Vetsch, G. W. Randall, 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 4-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. Very high N rates (up to 600 lb/A) were applied in 1994 to examine the effect on yield and to determine the potential for downward movement of excess N in the soil profile. Because substantial soil NO_3-N remained in the 0-4 ft profile in the fall of 1994 (when rates of ≥ 400 lb N/A were applied), we measured reed canarygrass yield and N uptake in 1995 to determine the availability of residual N. Our results showed up to 32 percent recovery in 1995 from the 400-lb rate applied in 1994. The two-year recoveries totaled almost 70 percent for the 300, 350, and 400 lb/A rates. Recovery from the 500 and 600-lb rates was < 60 percent and soil NO_3-N accumulated below the 3 ft depth. These results suggest that residual N can be effectively utilized by reed canarygrass and not all will be lost to ground and surface water when optimum N rates are exceeded.

EXPERIMENTAL PROCEDURES

Ninety-six plots, measuring 10 ft by 20 ft, were laid out on established reed canarygrass (variety *Palaton*) in April 1994 on a Webster clay loam soil. Plots were fertilized in 1994 with varying rates of N as ammonium nitrate on April 11 and June 20 after first cutting. In 1995 yields were taken from selected N rates (Table 1) to evaluate the residual effects of N fertilization in 1994. A single treatment (300 lb N/A in 1994) also received 300 lb N/A as ammonium nitrate in 1995. Yields were taken by harvesting a 3 ft by 19 ft swath from each plot on June 9, July 24, and September 20. Forage was analyzed for moisture content and total Kjeldahl N. The total N analyses were conducted 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 in November of 1995. All soil samples were immediately forced-air dried at 125° F, then ground and analyzed for NO_3-N by the Research Analytical Laboratory, St. Paul.

RESULTS AND DISCUSSION

Dry Matter Yield, Total N Concentration, and N Removal by Harvest

Yield data, obtained in 1995 from selected treatments applied in 1994, were taken to determine the potential for plant recovery of residual N. Nitrogen fertilizer applied in 1994 significantly affected dry matter yields, total N concentration, and N removal in 1995 (Table 1). First and second harvest and total (annual) yields were increased significantly by 1994 rates ≥ 200 lb N/A compared to the control (zero N). Nitrogen rates ≥ 300 lb N/A resulted in a yield increase for the third harvest when compared to the control. Total N concentration and N removal were also affected by 1994 N rates. The 300+300 treatment (300 lb N/A in 1994 and 1995) had significantly greater total N concentration for all three cuts and greater dry matter yield and N removal for the 1st cut. However, total (annual) yield for the 300+300 treatment was not significantly greater than from the 400, 500, or 600 lb N/A rates applied in 1994.

Table 1. Residual effects of N applied in 1994 on dry matter yield, total N, and N removal of reed canarygrass in 1995.

	Dry Matter Yield				Total N Concentration			Nitrogen Removal			
1994 Total N Rate	1st cut	2nd cut	3rd cut	Total	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut	Total
lb N/A	----- T DM/A -----				----- % -----			----- lb N/A -----			
0	0.56	0.41	0.29	1.26	1.43	1.57	1.72	16	13	10	39
200	0.94	0.56	0.34	1.84	1.47	1.51	1.67	27	17	11	56
250	1.22	0.63	0.38	2.23	1.57	1.55	1.66	38	19	13	70
300	1.68	0.79	0.58	3.05	2.03	1.75	1.64	68	28	19	115
350	1.76	0.82	0.78	3.36	1.96	1.85	1.94	70	30	31	130
400	1.92	0.93	0.94	3.80	2.27	2.15	2.08	87	39	40	166
500	1.92	0.89	1.00	3.81	2.04	2.45	2.25	78	44	45	167
600	1.83	0.99	1.05	3.87	2.05	2.42	2.28	75	48	48	171
300+300[1]	2.12	0.66	0.92	3.70	2.65	3.31	2.86	111	43	52	206
Statistical Analysis											
Pr. > *F*:	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD (0.05):	0.28	0.15	0.20	0.46	0.34	0.30	0.29	16	8	12	23
CV (%):	13	14	20	10	12	10	10	17	17	28	12

[1] 300 lb N/A applied in 1994 and again in 1995.

[1] Assistant Scientist and Professor, University of Minnesota Southern Experiment Station, Waseca; Soil Scientist, USDA-ARS-US Dairy Forage Research Center, St. Paul.

Annual N Removal and Apparent N Recovery

Apparent N recoveries were calculated from total N removed for 1994 and 1995 (Table 2). First year (fertilization year) recoveries were lower in 1994 compared to previous years. Therefore, considerable residual N was expected for 1995 plant growth. Recoveries in 1995 increased with increasing N rate up to 400 lb N/A. This rate also optimized yield for 1995 (Table 1). The combined N recovery was calculated by adding the N recoveries from 1994 and 1995. The combined (2-year) recoveries approached 70 percent at N rates between 300 and 400 lb N/A, which is similar to the first-year recovery at 400 lb N/A in 1993. However, these are lower than the 80 to 90 percent recoveries observed in 1992 and 1993 with N rates as high as 300 lb/A, but considerably better than 30 to 40 percent values observed in 1994. Observations in 1995 at N rates ≥ 400 lb/A (lower N recoveries and not significantly greater yields) suggest that some residual N may be available for the 1996 growing season. However, since combined recoveries were considerably lower than first year recoveries in 1992 and 1993, some N was probably leached below the root zone, lost to tile lines, or immobilized.

Table 2. Annual N removal and apparent recovery of fertilizer N by reed canarygrass in 1995 as affected by N rate in 1994.

	Total Annual N Removal		Apparent N Recovery[1]		
1994 Total N Rate	1994	1995	1994	1995	Combined[2]
-- lb N/A --	----- lb N/A -----		--------- percent ---------		
0	84	39	–	–	–
200	187	56	51	8	59
250	202	70	47	12	59
300	216	115	44	25	69
350	230	130	42	26	68
400	230	166	36	32	68
500	241	167	31	26	57
600	246	171	27	22	49

[1] Apparent N Recovery = (Total N removal - N removal from control) ÷ Total N applied in 1994.
[2] Recovery of N applied in 1994 by dry matter in 1994 and 1995.

Soil Nitrate-N

Soil samples were taken in November to determine if substantial quantities of residual soil nitrate remained in the 0-5 ft profile and if the fertilizer N had moved down through the soil profile. When N rates of > 400 lb/A were applied, soil nitrate accumulated below 3 ft (Table 3). Movement of soil nitrate to depths below 3 ft suggests the potential for leaching losses to ground and surface drainage waters. The 300+300 treatment also shows accumulation of residual soil nitrate in the profile and the potential for movement below the root zone or loss to tile drainage. This suggests that annual applications of 300 lb N/A may exceed crop requirement and can result in leaching losses from the soil profile.

Table 3. Nitrate-N remaining in the 0-5 ft profile in November 1995 as influenced by N rates applied to Reed Canarygrass.

N Rate		Soil Profile Depth					
1994	1995	0 - 1'	1 - 2'	2 - 3'	3 - 4'	4 - 5'	0 - 5'
---- lb N/A ----		---------- lb NO_3-N/A ----------					
0	0	8	2	1	2	2	15
400	0	8	2	2	10	9	31
500	0	7	1	15	28	23	74
600	0	9	2	9	35	29	84
300	300	14	8	23	19	10	74

Recommendation

This report concludes four years of research in N fertilization of reed canarygrass at Waseca. Based on this research the following recommendations for nitrogen fertilization of reed canarygrass can be made. Single early-season (April) applications of N are as effective as split applications for dry matter production. A single early-season application of 200 lb N/A is recommended for optimum yields. If growing conditions are excellent and a first cut yield > 2.3 T DM/A is obtained, then an additional 50 to 100 lb N/A may be warranted after first cutting. Nitrate concentration in the forage can reach toxic levels when single applications of N exceed 200 lb/A. Thus, forage nitrate concentrations need to be monitored and feed rations may have to be adjusted. At these recommended N rates for optimum production, we would not expect N loss from the soil profile.

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/]

1995

ABSTRACT: Four single crop production components (ridge tillage; three-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 (berseem clover or crimson clover). Each corn strip following wheat or soybeans was fertilized at four N rates (0, 60, 100, and 150 lb N/A) to determine N contribution of legumes. Results from 1995 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. Strip yields of corn were enhanced by about 6% in both E-W and N-S row orientations while soybean yields were increased by 6% in E-W rows and were unaffected in N-S rows compared to conventional systems. Wheat yields in strips were reduced slightly (1%) compared to conventional systems in E-W rows. Wheat introduced into the traditional corn-soybean strip system reduced the negative border effects of corn on soybeans.

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 two-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 three-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) at Freeborn and at a rate of 32000 ppA in rows 2-5 and 38400 ppA in rows 1 and 6 at Waseca. Nitrogen rates were changed to 0, 60, 100, and 150 lb N/A in 1995. Individual plots are 8 rows wide x 30' long within each strip. Weeds were controlled with broadcast 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 variety, "Sturdy", which was planted in 1991-1994 was replaced with a cyst nematode resistant variety, "Bell" in 1995. Soybean was planted at a rate of 9 to 10 beans/foot of row in 30" rows. Weeds were controlled with a preemergence, broadcast application of Lasso (3 lb ai/A), and postemergence, broadcast application of Pursuit (4 oz ai/A), and by ridge cultivation. Each individual row was harvested with a plot combine.

"Grandin" spring wheat was planted at a rate of 94 lb/A with a minimum-till drill in 8" rows following broadcast-application of 65 lb N/A and field cultivating the ridges. In 1991-1993, annual alfalfa, "Nitro" was companion seeded with wheat at 10 lb/A and hairy vetch was planted after wheat harvest at a seeding rate of 30 lb/A. Starting in 1994, alfalfa was replaced with berseem clover (10 lb/A) and hairy vetch was replaced with crimson clover (15 lb/A). Broadleaf weeds, when present, were controlled with a broadcast-application of Bromoxynil in wheat strips when no legume was planted.

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

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

RESULTS

Corn grain yield following wheat without interseeded legumes was greater in 1995 than the 4-yr average (1991-94) in all rows at both sites. The only exception is the west outside row in N-S rows. Hail in the first week of August caused damage to the corn plants, especially the west outside row at the Freeborn site. As a result, the west outside row yielded only 11% greater than the center two rows in 1995 when compared to a 28% yield advantage in 1991-94. The increase in the fertilizer N rate from 120 lb N/A to 150 lb N/A combined with better growing conditions may have resulted in greater yields in 1995 compared to the previous years. The yield advantage of the narrow strips for corn in the 3-crop (wheat-corn-soybean) rotation was 10 bu/A (6%) in the E-W system and 8.7 bu/A (6%) in the N-S row orientation compared to the whole-field averages (Table 1). The greater yield advantage for the E-W strips in 1995 compared to previous years may be due to increase in: a) fertilizer N rate by 30 lb N/A and b) seeding rate of corn by 1800 ppA in rows 2-5 and by 2400 in rows 1 and 6. On the other hand, at the Freeborn site with N-S rows, yield advantage for the strips was 8.7 bu/A (6%) compared to a 12.2 (9%) advantage in 1991-94 due mainly to the west outside rows suffering hail damage.

Grain moisture of the strip was 0.8 points greater than the center two rows in E-W rows because of greater moisture content in the outside rows. In N-S rows, corn grain in the strip had 0.5 points more moisture compared to the center two rows.

Similar to corn yields, soybean yields were greater in all rows at both sites in 1995 compared to the 1991-94 averages. Unlike the previous years, soybean yields were increased by 2.7 bu/A (6%) in the strip in E-W rows (Table 3), due mainly to the second row from north yielding 29% greater than the center two rows in 1995. The north row (next to corn) yielded 2.3 bu/A (5%) less while the south row (next to wheat) yielded 1.8 bu/A (4%) more than the center two rows in the E-W row orientation. In N-S rows, yield of row 6 (next to wheat) was 8.9 bu/A (15%) more while the row bordering corn (row 1) suffered a 8.8 bu/A (22%) yield loss compared to the center two rows. This suggests that including wheat resulted in increased yields in the adjacent soybean row compared to the row next to corn. 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 in the two-crop alternate strips were comparable to the conventional systems at both sites in 1995 (Table 4) mainly due to the second row yielding the highest at both locations. Outside rows (rows 1 & 6) bordering corn yielded 15% less (6.1 bu/A) than the center two rows in the E-W system and 15% less (5.6 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 25 and 19% less, respectively, than the center two rows. Wheat yields were affected slightly (0.9 bu/A) in the E-W system by the soybean borders (Table 5).

Surface residue coverage before planting was ideal for all crops (Table 6). Residue coverage before planting corn in the wheat alone strips dropped from 83% in 1992-94 to 61% in 1995. Liquid hog manure was injected into the ridges of the wheat alone strips and the ridges were rebuilt in the fall of 1994. This resulted in reduced surface coverage in 1995. After planting, residue coverage was still > 30% following corn and wheat. Residue coverage after soybean was only 17% due to field cultivating the ridges before planting spring wheat, but this was offset by mid-May with a well-established stand of wheat 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	Year	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip[2]
		bu/A					
E-W Rows	1995	194.8	170.4	171.8	171.0	211.8	10.0
	1991-94	154.3	139.9	148.8	142.0	170.8	2.0
N-S Rows	1995	182.9	162.8	151.9	145.4	168.4	8.7
	1991-94	168.8	140.0	136.3	135.4	174.1	12.2

[1] 5-yr (1991-1995) averages for corn fertilized at 120 lb N/A annually during 1991-94 and at 150 lb N/A in 1995.
[2] 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	Year	Row/Position 1	2	3&4	5	6	Moisture Adv.of 6-row strip[2]
		%					
E-W Rows	1995	27.7	25.0	24.9	25.0	27.0	-0.8
	1991-94	33.7	32.5	31.5	31.5	29.5	-0.2
N-S Rows	1995	23.9	22.5	22.2	22.5	22.7	-0.5
	1991-94	23.4	23.5	24.2	23.5	22.7	0.6

[1] Corn fertilized at 120 lb N/A annually in 1991-94 and at 150 lb N/A in 1995.
[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.

Row Direction	Year	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip[1]
		bu/A					
E-W Rows	1995	40.5	55.1	42.8	47.5	44.6	2.7
	1991-94	32.1	36.4	39.1	40.0	35.1	-2.1
N-S Rows	1995	30.9	40.5	39.7	40.5	45.8	-0.2
	1991-94	27.7	34.5	35.4	35.5	33.9	-1.7

[1] 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.

Row Direction	Year	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip[1]
		bu/A					
E-W Rows	1995	40.0	47.6	41.7	42.5	31.2	-0.9
	1991-94	35.2	38.5	39.8	38.0	26.3	-3.5
N-S Rows	1995	31.3	42.1	38.6	37.4	34.6	-1.5
	1991-94	27.5	32.2	35.5	32.7	28.0	-3.6

[1] 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[1]
		bu/A			
East-West	1995	54.4	56.5	55.8	-0.9
	1991-94	43.6	42.1	41.1	0.2
North-South	1991-94	42.1	38.6	35.9	0.3

[1] 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 as influenced by previous crop at Freeborn Co. (1992-95).

Previous crop[1]	Before planting		After planting	
	1995	1992-94	1995	1992-94
	%			
Corn	44	63	39	37
Soybean	53	51	17	21
Wheat	61	83	42	35
Wheat + berseem clover	85	88	70	56
Wheat + crimson clover	76	90	64	48

[1] In 1992-93 wheat was interseeded with either alfalfa or hairy vetch. In 1994, alfalfa and hairy vetch were replaced with berseem clover and crimson clover, respectively.

CONCLUSIONS

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

2. Unlike previous years, soybean yield was highest in row 2 for both three- and two-crop systems in E-W rows in 1995 for reasons unknown.

3. Contrary to previous years, corn benefitted more in E-W strips than in N-S strips due to greater yield advantage for the strip compared to the whole-field averages.

4. Hail damage, especially to the west outside corn row resulted in less yield advantage for the N-S strips in 1995 than in the previous years compared to the whole-field averages.

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

6. 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.

FERTILIZER AND MANURE NITROGEN MANAGEMENT IN SOUTHEASTERN MINNESOTA[1/]

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

1995

ABSTRACT: A 4-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. Four-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 fertilizer N. 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 in 1993 but substantial in 1995. Thus, 4-year average yields were slightly higher with the biennial applications. Nitrate-N concentrations in the soil water at 5' and 7.5' were not greatly different between the two manure application treatments. 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 and 1995) 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, 1994, and 1995 and by hand-harvesting in 1993.

Soil water samples were obtained periodically throughout the season (May - Oct.) 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, slightly below average in 1995, and were quite respectable in 1994. Optimum yield each year and the greatest economic return to the fertilizer during the 4-yr period 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 4-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 grain yields in the first two years, but not in 1994 and 1995 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 consistently.

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). Four annual applications averaging 4550 gal/A (152 lb total N/A/yr) (trt. no. 9) produced 4-year average corn yields which were similar to those from the 90-lb fertilizer N rate. Four-year average yields for the every-other-year (biennial) manure treatment were slightly higher compared to the annual application. This was largely due to the substantial residual effect in 1995 from the manure applied in 1994.

[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, 1994, and 1995.

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
1995	34.8	16.6	16.4	35.4

Table 2. Nutrient application rates as liquid dairy manure in 1992, 1993, 1994, and 1995.

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
1995	9	5000	174	83	82	177
	10	0	0	0	0	0
1992-93	9	8200	292	150	124	183
Total	10	8650	389	157	123	183
1992-95	9	18200	608	313	266	511
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				Four-Yr	Return[1/]
No.	N rate	Time of Application	1992	1993	1994	1995	Avg.	to fert.
	lb/A		Yield (bu/A)					$/A
1	0	Spr. preplant (PP)	33	58	63	86	60	-
2	60	"	82	95	139	108	106	95
3	90	"	103	96	147	123	117	116
4	120	"	113	106	165	127	128	136
5	150	"	112	108	157	131	127	128
6	60 + 30	Spr. PP + SD (8-leaf)	100	105	153	126	121	122
7	60 + 60	"	105	105	155	134	125	126
8	90	SD (8-leaf)	89	100	150	124	116	113
9[2/]	Liq. dairy manure, annually	Spring injected	113	99	144	126	120	-
10[2/]	Liq. dairy manure, every other year	Spring injected	136	80	167	124	127	-
	Treatment Statistical Analyses							
	P > F:		<0.01	<0.01	<0.01	<0.01		
	LSD (0.05):		11.0	8.2	14.4	16.9		
	LSD (0.10):				12.0	14.0		
	CV (%):		8.5	6.5	6.9	9.6		

1/ Economics based on the following prices: Corn = $2.40/bu, N = $0.20/lb, and $3.00/acre/application.
2/ See Table 2.

Stover and silage yields were optimized at the 90-lb N rate in 1995 (Table 4). Stover production was slightly but not statistically (P = .10 level) lower when all of the N was sidedressed. Stover N concentration was optimized with the 120-lb N rate while grain N was optimized with the 60-lb N rate. Grain N concentration for the biennial manure treatment was not different from the 0-lb control, which suggests that available N in these plots ran out before N uptake and translocation to the grain had been completed. Nitrogen uptake in the stover, grain, and silage (total N uptake) was optimized at N rates of 90 and 120 lb/A. Nitrogen uptake for the manure treatments averaged slightly lower than for the 90-lb fertilizer N treatment. Chlorophyll content was optimized at the 120-lb N rate. Sidedressing all of the N gave slightly lower chlorophyll readings compared to the preplant application. This was likely due to the short 18-day period between N application (June 30) and the time the chlorophyll measurements were taken (July 18). Chlorophyll content was quite low for the biennial manure treatment, which indicates available N carrying over from the 1994 application was insufficient to meet the early-season N needs. Grain moisture and final plant population were not affected by the fertilizer N or manure treatments.

Table 4. Grain moisture, yield, N concentration, N uptake, final plant population and chlorophyll content as influenced by fertilizer and manure treatments in 1995.

Trt.	Grain Moisture	Yield		N Concentration		N Uptake			Final Plant Pop	Chlorophyll V13 (Jul 18)	
		Stover	Silage	Stover	Grain	Stover	Grain	Silage			
#	%	---- TDM/A ---		----- % ------		-------- lb N/A --------			ppA*1000	SPAD	Rel. %
1	26.0	1.249	3.289	0.43	1.11	10.6	45.1	55.7	30.79	43.8	80.2
2	25.9	1.980	4.539	0.51	1.23	20.1	62.7	82.8	30.59	49.7	91.0
3	25.5	2.239	5.153	0.57	1.24	25.1	72.0	97.1	30.86	52.3	95.8
4	25.7	2.210	5.219	0.61	1.24	26.7	74.8	101.5	31.26	53.4	97.8
5	26.5	2.213	5.314	0.65	1.28	28.6	79.7	108.3	30.73	54.6	100.0
6	25.9	2.029	5.017	0.60	1.26	24.5	74.9	99.4	31.03	51.9	95.0
7	26.3	2.116	5.283	0.66	1.26	27.9	79.7	107.6	30.76	52.0	95.2
8	26.5	1.967	4.900	0.61	1.23	24.1	72.2	96.4	30.96	50.4	92.2
9	26.4	2.252	5.300	0.48	1.20	21.4	71.5	92.9	30.39	50.6	92.7
10	25.8	2.120	5.065	0.56	1.11	24.0	65.9	89.9	30.66	47.5	86.9
Treatment Statistical Analysis											
P > F:	0.91	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	0.86	<0.01	<0.01
LSD (0.05):		0.378	0.486	0.09	0.11	5.4	12.3	12.9		1.8	3.2
LSD (0.10:		0.314	0.403	0.08	0.09	4.5	10.2	10.7		1.5	2.7
C.V. (%):	4.1	12.8	6.8	11.4	6.3	16.0	12.1	9.5	2.2	2.4	2.4
Contrasts 'PP vs Split, 90 PP vs 90 Split, 90 PP vs 90 SD, 90 Split vs 90 SD'											
PPvsSp,P>F:	0.35	0.25	0.83	0.21	0.63	0.89	0.36	0.35	0.63	0.13	0.13
90PPvs90Sp,P>F	0.62	0.26	0.57	0.48	0.68	0.81	0.64	0.72	0.74	0.58	0.59
90PPvs90SD,P>F	0.20	0.15	0.29	0.33	0.93	0.71	0.98	0.90	0.84	0.03	0.03
90Spvs90SD,P>F	0.42	0.74	0.62	0.79	0.62	0.90	0.65	0.63	0.90	0.09	0.09

Soil Nitrogen

Residual soil nitrate (RSN) prior to fertilization at the preplant stage was low (Table 5). Higher NO_3-N concentrations at the VE and V4 stages for treatment 7 show the effect of the first (preplant) application of 60 lb N/A. The value of 21.5 exceeded the commonly acknowledged critical value of 21 for the PSNT test. However, yield responses of 18 and 26 bu/A were obtained with the second additions of 30 and 60 lb N/A in these split treatments compared to single 60-lb preplant treatment. This suggests a PSNT value >21 is needed for optimum corn production on these soils. In treatment 8, RSN approximately doubled between the PP and V4 stages due to mineralization prior to the sidedress application of N. Soil NH_4-N did not change consistently between the PP and V4 stages.

Table 5. Early-season soil NO_3-N and NH_4-N concentration as influenced by time of N application in 1995.

Trt. No.	Treatment N rate	Treatment Time	Depth	Time of Sampling[1] Preplant	VE	V4
	lb/A		feet		NO_3-N	
7	60 + 60	Split	0-1	5.2(1.9)[2]	13.8 (1.5)	21.5 (1.4)
	60 + 60	Split	1-2	6.3 (0.3)	10.3 (1.1)	17.7 (2.1)
8	90	SD	0-1	4.0 (0.3)	6.6 (0.4)	10.1 (0.6)
	90	SD	1-2	5.7 (0.2)	5.6 (0.5)	8.9 (1.2)
					NH_4-N	
7	60 + 60	Split	0-1	8.6 (1.1)	8.3 (0.7)	10.1 (0.4)
	60 + 60	Split	1-2	5.0 (0.8)	5.0 (1.0)	7.1 (0.5)
8	90	SD	0-1	8.4 (0.8)	7.1 (0.4)	9.7 (0.8)
	90	SD	1-2	5.2 (0.4)	4.2 (0.4)	8.2 (0.5)

[1] Preplant = 5/2, VE = 6/2, and V4 = 6/22.
[2] ( ) = Standard error of the mean.

Residual soil NO_3-N (RSN) in the soil profile in early November, 1995 was greatly affected by the fertilizer and manure treatments (Table 6). RSN in the 0-8' profile ranged from 45 lb/A for the 0-lb N rate to 186 lb/A for the 150-lb rate. Much of the increase in RSN at the 150-lb N rate was due to consistently higher NO_3-N concentrations at each depth throughout the 8-foot profile compared to the 120-lb rate. Accumulation of RSN below the 4-foot depth is significant because of a higher potential for leaching to the 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 similar to that remaining for the 60 and 90-lb fertilizer N treatments (Table 6). Even though more total N had been applied with the biennial treatment (673 lb/A vs 608 for the annual treatment) during the 4-year period, consistently less RSN remained throughout the soil profile. This would suggest greater loss of N, perhaps by leaching from the soil profile, but the soil water data shown in Table 7 does not indicate this to be the case in 1995.

Nitrate-N in Soil Water

Even though NO_3-N concentrations in the soil water at the 5 and 7.5-foot depths were quite variable, the concentrations were increased consistently at the 5-foot depth from about 2 to 3 mg/L for the 0-lb N rate to about 20 mg/L for the 150-lb rate (Table 7). Little difference in NO_3-N concentration was found between the PP, split, and sidedress N treatments. Nitrate-N at 5 feet was consistently higher for the biennial application of manure compared to the annual application. The opposite was true at 7.5'. At the 7.5' depth, NO_3-N ranged from about 1.5 to 2 mg/L for the 0-lb N rate to about 17 mg/L for 120-lb N rate. Nitrate-N concentrations for the two manure treatments at the end of four years fell between the concentrations found for the 60 and 90-lb fertilizer N rates.

Table 6. Soil NO_3-N concentrations in the 0-8' soil profile after harvest as influenced by fertilizer N and manure treatments in 1995.

Trt. No.	Treatment N rate	Treatment Time	Depth (ft) 0-1'	1-2'	2-3'	3-4'	4-5'	5-6'	6-7'	7-8'	0-8'
	lb/A		Nitrate N-Conc (ppm)								lb/A
1	0	0	3.0	1.0	0.7	0.9	1.2	1.3	1.6	1.8	45
2	60	PP	4.5	2.6	1.8	2.7	2.5	2.4	2.1	1.9	82
3	90	PP	5.4	3.0	2.4	3.0	3.4	2.7	2.8	3.2	103
4	120	PP	4.7	3.4	4.1	4.0	4.0	3.4	3.1	3.1	119
5	150	PP	7.2	5.4	7.4	6.5	5.2	4.9	4.5	5.4	186
6	60 + 30	Split	6.0	2.8	2.2	2.9	3.5	3.0	2.7	3.0	104
7	60 + 60	Split	5.8	3.6	4.1	4.9	4.6	4.3	4.0	3.5	138
8	90	SD	5.5	4.0	3.5	3.6	3.1	3.1	2.6	2.9	113
9	Annual	PP	5.4	2.6	2.2	2.9	3.6	3.3	3.0	3.0	104
10	Biennial	PP	4.5	2.0	1.2	2.2	2.9	3.0	2.6	2.0	81
Treatment statistical analysis											
P > F:			0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD (.10):			1.7	1.3	1.8	1.5	1.3	1.1	0.9	0.6	31
CV (%):			28.	36.	50.	37.	31.	30.	26.	18.	24.

Table 7. Nitrate-N concentration in the soil water at the 5' and 7.5' depths as influenced by nitrogen and manure treatments in 1995.

Trt. No.	Treatment N rate	Treatment Time	Date 5/26	7/18	8/10	10/13
	lb/A		NO_3-N (mg/L) at 5'			
1	0	-	2.6 (1.0) [1]	3.6 (0.7)	3.5 (0.8)	2.2 (1.1)
2	60	PP	7.0 (1.4)	7.5 (1.3)	-	7.7 (0.2)
3	90	PP	8.5 (0.6)	11.1 (1.8)	10.6 (2.0)	13.4 (3.2)
4	120	PP	18.1 (6.8)	26.3 (4.7)	17.9 (4.9)	14.9 (3.2)
5	150	PP	20.1 (9.4)	17.9 (5.3)	18.5 (5.0)	-
6	60 + 30	Split	-	21.4 (7.4)	19.6 (6.6)	-
7	60 + 60	Split	16.8 (5.6)	12.3 (4.9)	17.9 (6.2)	-
8	90	SD	12.2 (4.8)	12.4 (4.8)	12.6 (4.5)	9.3 (0.8)
9	Annual	PP	12.1 (7.3)	10.2 (6.1)	13.5 (9.2)	11.6 (3.4)
10	Biennial	PP	15.4 (5.3)	13.6 (4.7)	15.8 (5.0)	19.2 (2.9)
			NO_3-N (mg/L) at 7.5'			
1	0	-	1.8 (1.1)	-	1.7 (0.5)	1.5 (0.9)
2	60	PP	5.6 (1.4)	5.1 (1.1)	5.6 (1.3)	5.9 (0.2)
3	90	PP	14.0 (1.9)	14.0 (2.8)	13.6 (2.9)	-
4	120	PP	18.3 (2.8)	17.4 (2.9)	16.2 (2.0)	16.6 (3.0)
9	Annual	PP	8.8 (5.8)	9.4 (6.8)	13.8 (8.8)	9.3 (6.4)
10	Biennial	PP	5.9 (1.9)	7.0 (1.0)	5.8 (0.8)	5.8 (0.6)

[1] ( ) = Standard error of the mean.

MUNICIPAL SOLID WASTE COMPOST USE ON IRRIGATED COARSE TEXTURED SOILS[1]

M. MAMO, C.J. ROSEN, T.R. HALBACH, AND J.F. MONCRIEF[2]

ABSTRACT

Two field experiments were conducted at Becker to assess corn yield and nitrate leaching on soils amended with municipal solid waste (MSW) compost. The MSW composts (Truman and Swift) were applied in the spring of 1992. The compost rates were 0, 20, 40, and 80 dry T/A with either 0, or 220 lbs N//A split applied as urea. In 1993 at Becker, MSW compost was also applied on new plots to evaluate the effect of split vs one time application. The compost rate was 40 T/A (yearly application) and 120 T/A (one time application) with either 0, 110, or 220 lbs N/A split applied as urea. In 1995, yield in the 1992 established plots was relatively higher on residual MSW compost plots compared to the control. The 1993 established plot gave a significantly higher grain yield at all compost rates compared to the nonamended control. In the nonamended control plots, response to N fertilizer was significant up to 220 lbs N/A. Providing N at a rate higher than 110 lbs N/A on compost amended soil did not significantly increase grain yield. Without N application, the yearly compost application gave significantly higher grain yield compared to the one time compost application. In 1995, nitrate leaching did not increase on compost amended soils compared to nonamended fertilized control.

INTRODUCTION

Limited storage capacity of landfills, failure to meet regulatory guidelines, and increasing operating costs has prompted research into alternative methods of waste management. Composting of municipal solid waste (MSW) has been considered as one alternative to landfilling. In addition, composting involves resource conservation and recycling and the final product can be marketable. The benefits of adding organic matter to maintain soil productivity and soil quality are well known. Thus, MSW compost can be used in soil as a potential source of organic matter. Composting transforms organic materials into a stabilized organic matter which can be applied to agricultural land to improve soil fertility. However, improvements in soil fertility from compost is dependent on the quality and quantity of compost.

Compost supplies essential plant nutrients such as nitrogen, phosphorus, and sulfur, of which nitrogen is of main interest. Since, a large fraction of the nitrogen in the compost is organic, the release of the nitrogen into the inorganic form is necessary before plants can use it. If a large amount of inorganic nitrogen is released from the compost, the potential for nitrate to contaminate the ground water is high unless the commercial inorganic fertilizer application rate is adjusted accordingly. Therefore, the estimation and prediction of nitrogen release potential are key factors for the efficient use of compost nitrogen with respect to environmental quality and crop profitability.

The overall goals of this project were: 1) to determine residual effects of MSW compost on corn production, and soil chemical and physical properties 2) to compare annual split with one time MSW compost application, 3) to monitor levels of nitrate in soil water, and 4) to assess if any water stress is induced by compost amendments on plants.

MATERIALS AND METHODS

To accomplish the above goals, two field experiment were established at the Sand Plain Research Farm in Becker on a Hubbard loamy sand. The first experiment was established in 1992, and the second in 1993.

1995 Becker Compost Utilization Project (established in 1992)

- The treatments for the 1992 established experiment are listed in Table 1. MSW compost was applied only in the first year. Nitrogen fertilizer was applied every year.

[1] Support for this project was provided by the Minnesota Pollution Control Agency (MPCA) and Prairieland Composting Facility. Their support is greatly appreciated.

[2] M. Mamo, C.J. Rosen, T.R. Halbach, and J.F. Moncrief are Graduate student, Professor, Extension Specialist, and Professor, respectively.

- Corn variety 3921 Pioneer (85 day) was planted May 10, 1995 at a planting rate of 30,700 kernels per acre in 30" rows with starter fertilizer banded at 160 lbs N/A (8-10-30).
- Granular fertilizer urea 46-0-0 was split applied: one-half on 5/25/95 and the other half on 6/16/95. The urea was sidedressed with a Gandy applicator on either sides of each row and irrigated in with 0.5-1" of water for incorporation.
- Solid set irrigation was provided according to the check book method.
- Four whole plant samples were taken from each plot for chemical analysis on 6/21/95.
- Ear leaf samples were taken on 7/28/95 for chemical analysis.
- Soil water samples from suction cups at 3 feet were taken weekly throughout the season.
- The middle two 20 feet of row were harvested for grain and stover on 10/5/95 and 10/12/95, respectively.

1995 Becker Compost Utilization Project (established in 1993)

- The treatments for the 1993 established experiment are listed in Table 2. MSW compost was applied either annually for three consecutive years (1993-1995) or at one cumulative rate the first year (1993). Nitrogen fertilizer was applied every year at 0, 110, and 220 lbs N/A.
- Corn variety 3921 Pioneer (85 day) was planted May 10, 1995 at a planting rate of 30,700 kernels per acre in 30" rows with starter fertilizer banded at 160 lbs N/A (8-10-30).
- Granular fertilizer urea 46-0-0 was split applied: one-half on 5/25/95 and the other half on 6/16/95. The urea was sidedressed with a Gandy applicator on both sides of each row and irrigated with 0.5-1" of water for incorporation.
- Solid set irrigation was provided according to the check book method.
- Four whole plant samples were taken from each plot for chemical analysis on 6/21/95.
- Ear leaf samples were taken on 7/28/95 for chemical analysis.
- Soil water samples from suction cups at 4 feet were taken weekly throughout the season.
- The middle two 15 feet of row were harvested for grain and stover on 10/5/95 and 10/12/95, respectively.

Plant Water Stress Measurement

- The plant water status console was used to measure water stress. The console measures the negative pressure or tension with which water is held in the plant. The console is equipped with a gauge, a cylinder containing compressed N_2 gas, and a chamber with a lid where leaf is placed.
- Leaf facing direct solar radiation was excised and held between wet paper towel (to avoid water loss). Leaf was placed in pressure bomb chamber with the end tip exposed to the outside. Pressure was exerted until the end tip of the leaf withdraws or loses droplets of sap. A magnifying glass was used to help detect the first sap droplets from the leaf. The pressure at which the first water droplet was detected corresponded to the tension at which water was held by the plant.

RESULTS

1992 established experiment-residual effect (Becker, MN):

YIELD

When N fertilizer was not applied, grain yield was higher at all compost rates compared to the control (Table 3). The residual effect of MSW compost still remained in 1995. Grain yield of residual compost with optimum N rate was higher than the control at the same N rate. The highest grain yields were obtained when compost rate was supplied with optimum N fertilizer rate (220 lbs N/A). Stover yield was also increased when fertilizer was applied with the compost treatments.

SOIL WATER NITRATE

Soil water NO_3-N was generally high for the 20 T/A Truman compost with no N application (Figs. 1a, and b). Unlike 1994, all compost rate at the 220 lbs N/A did not result in higher NO_3-N loss than the 0 lbs N/A. However, Compared to the control with N, the compost rates at 20, 40, and 80 T/A did not increase the leaching losses of NO_3-N. Figure 1c shows NO_3-N leaching of Swift compost amended with or without fertilizer N. Addition of N

fertilizer increased NO_3-N leaching throughout the growing season. The Swift compost without N fertilizer had much lower NO_3-N leaching. The latter suggests that most of the N lost comes from the added commercial fertilizer.

1993 established experiment-residual effect and annual application (Becker, MN)

YIELD

Grain and stover yields were much higher for all compost rates with no N application compared to yield from the control with no compost and N application (Table 4). The higher grain and stover yield of the compost with no N suggests residual compost effect. Without N applied, grain yield at a rate of 120 T/A compost was similar for both composts. With no N application, the split application of MSW compost improved yield for both compost sources compared to the one rate of 120 T/A. The addition of inorganic fertilizer in the split compost application rate did not improve the yield significantly. With the exception of the nonamended control, the 220 lbs N/A did not improve yield significantly compared to the 110 lbs N/A.

SOIL WATER NITRATE

All rates of Truman and Wright composts at 0 lbs N/A had lower leaching losses compared to the 110 and 220 lbs N/A treatments (Figs. 2a, b, c, d, e, and f). Truman compost amended at 120 T/A with 110 lbs N/A generally gave higher NO_3-N losses compared to the annual rate of 40 T/A and the control. Wright compost amended in split at 40 T/A with 110 and 220 lbs N/A gave higher NO_3-N losses throughout most of the growing season compared to the Truman compost at the same rate.

PLANT MOISTURE STRESS

Water stress measurements were made on two clear and warm days (air temperature: A.M. = 75-80 °F, and P.M.= 85-95 °F). Unless of rain events, irrigation was not made before stress measurements. The mean leaf water potential with compost as the main effect is presented in Table 5. In the 1993 established experiment, compost type and measurement date were not significant. Plant moisture stress was significantly different between morning and afternoon measurements. None of the compost treatments were significantly different from the control.

Table 1. MSW compost treatments for the 1992 established experiment, Becker, MN.

Compost type	N rate LBS/A	Compost rate T/A
Control	0	0
Control	220	0
Control§	440	0
Truman	0	20
Truman	220	20
Truman	0	40
Truman	220	40
Truman§	440	40
Truman	0	80
Truman	220	80
Swift	0	40
Swift	220	40

§ The 440 lbs N/A was applied only in 1992 and 1993. In 1994 and 1995 0 lbs N/A was applied.

Table 2. MSW compost treatments for the 1993 established experiment, Becker, MN.

Compost type	N rate LBS/A	Compost rate T/A			
		1993	1994	1995	Total
Control	0	0	0	0	0
Control	110	0	0	0	0
Control	220	0	0	0	0
Truman	0	40	40	40	120
Truman	110	40	40	40	120
Truman	220	40	40	40	120
Truman	0	120	0	0	120
Truman	110	120	0	0	120
Truman	220	120	0	0	120
Wright	0	40	40	40	120
Wright	110	40	40	40	120
Wright	220	40	40	40	120
Wright	0	120	0	0	120
Wright	110	120	0	0	120
Wright	220	120	0	0	120

Table 3. Residual effect of compost type, compost rate, and nitrogen rate on grain yield, stover yield, and plant population on the 1992 field site in Becker, MN. 1995.

Compost type	N rate LBS/A 1995	Compost rate T/A 1992	Grain Yield BU/A	Stover Yield T/A	Plant/A Population x 1000
Control	0	0	68.6	3.54	23.6
Control	220	0	128.8	5.07	25.5
Control§	440	0	66.0	3.14	25.1
Truman	0	20	98.4	3.71	25.3
Truman	220	20	146.4	6.02	26.5
Truman	0	40	98.7	3.54	25.6
Truman	220	40	139.4	5.44	25.5
Truman§	440	40	83.0	3.71	24.3
Truman	0	80	113.8	4.25	24.4
Truman	220	80	142.4	5.54	24.9
Swift	0	40	115.0	4.36	25.3
Swift	220	40	142.8	5.55	25.6
Significance			**	**	††
LSD			28.9	1.51	2.4

§ The N rate at 440 lbs/A was applied only in 1992 and 1993.
†† Significant at 10% **Significant at 1% NS= Not significant

Table 4. Effect of compost type, compost rate, and nitrogen rate on grain yield, stover yield, and plant population at the 1993 established site-1995.

Compost type	N rate LBS/A	Compost rate T/A	Grain Yield BU/A	Stover Yield T/A	Plant/A Population x 1000
Control	0	0	78.2	1.63	21.1
Control	110	0	127.0	2.34	23.1
Control	220	0	149.5	3.09	25.4
Truman	0	40+40+40	136.0	2.42	22.5
Truman	110	40+40+40	142.8	2.78	22.5
Truman	220	40+40+40	147.0	3.19	24.4
Truman	0	120	116.8	1.66	21.1
Truman	110	120	145.2	2.75	23.7
Truman	220	120	153.2	2.89	24.3
Wright	0	40+40+40	145.3	2.70	23.7
Wright	110	40+40+40	142.5	2.92	23.1
Wright	220	40+40+40	152.9	3.10	24.8
Wright	0	120	117.7	1.89	22.4
Wright	110	120	152.7	3.06	24.1
Wright	220	120	166.8	2.84	24.4
Significance			**	**	**
LSD			14.8	0.39	2.4

**Significant at 1% NS= Not significant

Table 5. Plant moisture stress measured during the 1995 growing season on the 1993 established experiment, Becker, MN.

Compost type	N rate LBS/A	Compost rate T/A	Leaf Water Potential† MPa	
	1995	1993-95	Date: 8/9/95	
			8:15-9:27 A.M.	1:10-2:20 P.M.
Control	220	0	0.69(0.09)	0.89(0.35)
Truman	220	40+40+40	0.75(0.16)	0.95(0.13)
Truman	220	120	0.67(0.12)	0.83(0.10)
Wright	220	40+40+40	0.74(0.11)	1.08(0.17)
Wright	220	120	0.75(0.07)	0.88(0.08)
			Date: 8/18/95	
			8:10-9:10 A.M.	12:00-1:05 P.M.
Control	220	0	0.51(0.11)	1.02(0.05)
Truman	220	40+40+40	0.52(0.12)	1.10(0.15)
Truman	220	120	0.52(0.07)	1.03(0.04)
Wright	220	40+40+40	0.56(0.08)	1.06(0.09)
Wright	220	120	0.51(0.08)	1.06(0.13)

Compost	NS
Time	**
Time*Compost	NS
Date	NS
Time*Date	**
Compost*Date	NS
Time*Compost*date	NS

†Number in parentheses is standard deviation. Measurements made on clear days void of irrigation and precipitation.

BECKER, MN

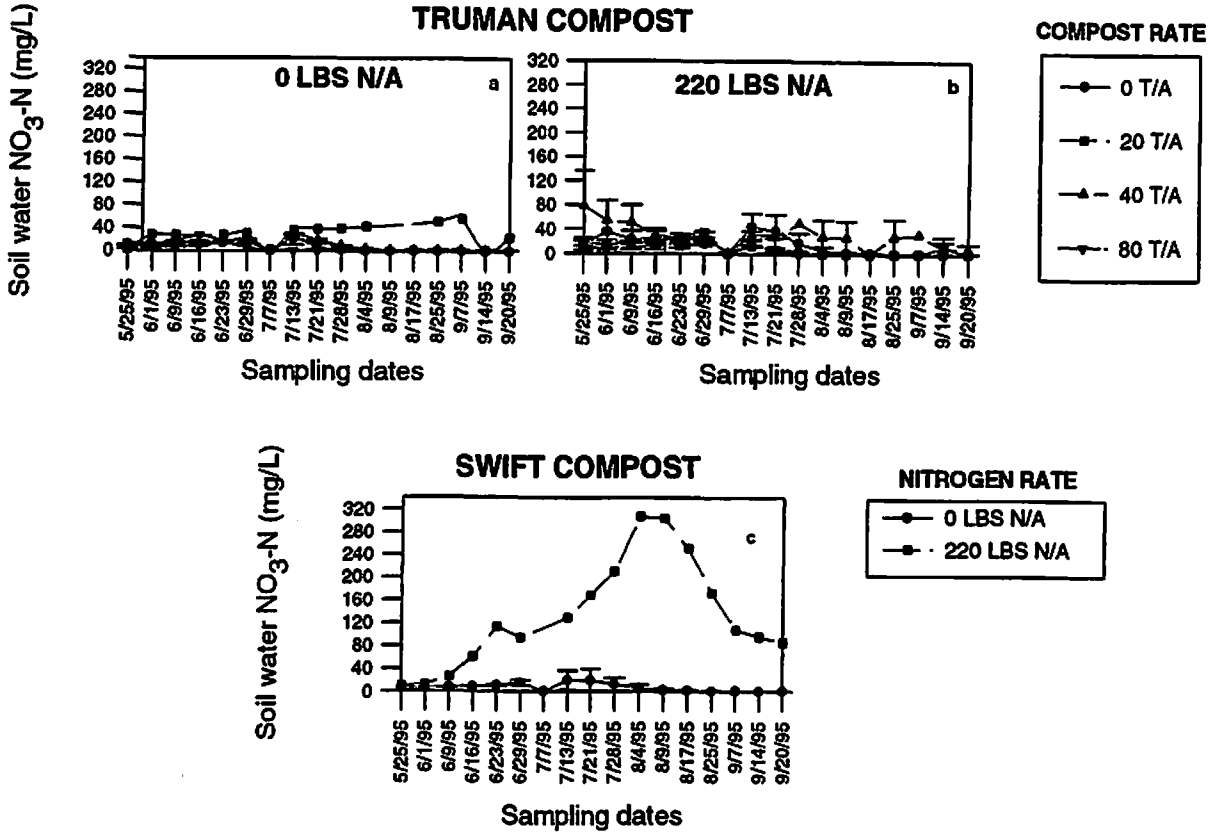
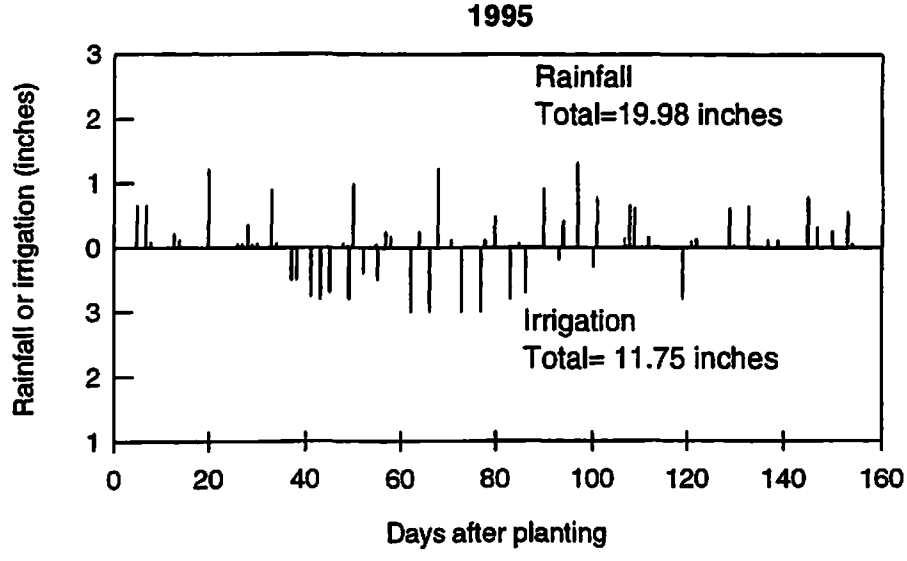


Fig. 1- SOIL WATER NITRATE-1995 GROWING SEASON
Compost utilization plots established in 1992



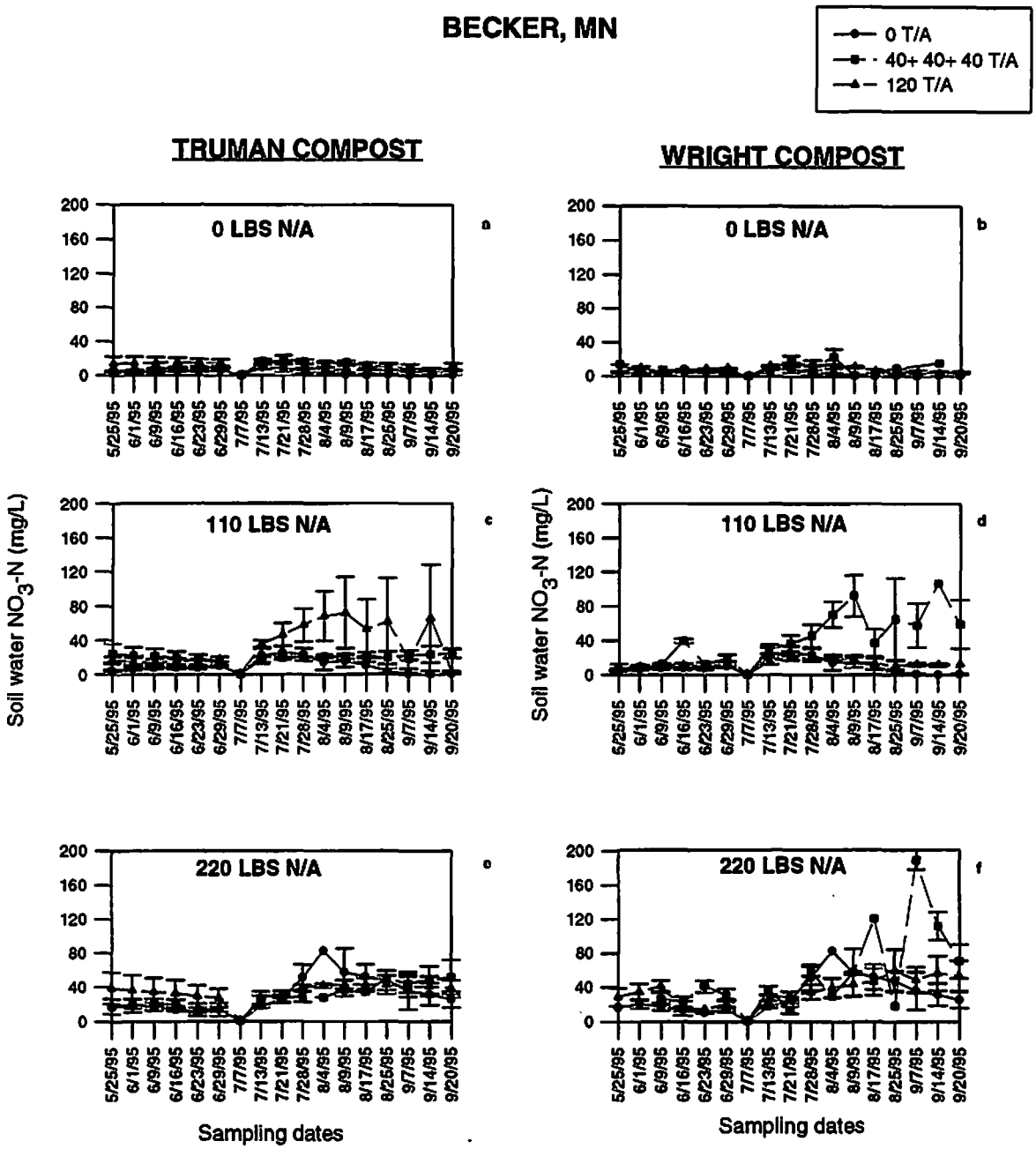


Fig. 2- SOIL WATER NITRATE- 1995 GROWING SEASON
Compost utilization plots established in 1993

LAND SPREADING OF YARD WASTE: RESIDUAL EFFECTS - 1995[1]

Carl Rosen, Thomas Halbach, Dave Birong, and Wenshan Wang[2]

ABSTRACT: The fourth 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 1995, 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 and third years of the study, 1993 and 1994, increases in growth and yield were greater with increasing yard waste application rates than with applied fertilizer N. Results in 1995 were similar to those in 1993 and 1994. In 1993 and 1994, 1 - 2 lbs of N per dry ton were supplied by the yard waste. In 1995, 0.5 lb N per dry ton was supplied by the yard waste. Yields in 1995 were optimized with a 40 ton/A yard waste application plus 100 lb N/A. Nitrate leaching tended to increase with fertilizer N application and yard waste application. Residual soil nitrate-N increased with increasing yard waste application and to a lesser extent with 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, third, and fourth year after application.

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 fourth 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 200 lbs/A 0-0-60 were broadcast and incorporated prior to planting. Pioneer hybrid 3751 (100 day maturity) was planted on May 10, 1995 at a population of 32,000 seeds/A (2.5 feet 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 24 and the remainder on June 14, 1995. 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 Associate Professor (visiting scholar), 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 21 after all fertilizer N was applied. Ear leaf samples were collected on July 28 at 50% silking. Two, 20 foot rows were harvested for grain and stover yield from each plot on October 5 and October 12, 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 and nitrogen fertilizer (Table 1). The addition of yard waste also increased total yield indicating a significant release of nutrients during the fourth year after incorporation. Without added fertilizer nitrogen, each ton of yard waste increased yield by 0.75 to 1 bu/A. When nitrogen fertilizer was applied, the increase in yield per ton of yard waste was 0.25 to 0.5 bu per A. Yields were optimized when 40 ton/A yard waste and 100 lb N/A were applied. Yields with 40 ton/A yard waste and 100 lb N/A were greater than those with 200 lb N/A without yard waste. Reasons for this yield increase with yard waste over the fertilized controls appear to be due to more than a simple nitrogen response. 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 tended to decrease tissue N concentration, presumably due to a dilution effect (Table 2). At the silking stage, yard waste amendment had no effect on ear leaf N concentrations. At harvest, yard waste application increased concentrations of N in stover and grain. Nitrogen uptake increased with increased rates of yard waste. Yard waste application supplied approximately 0.5 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. Except for cob tissue at harvest, N fertilizer increased tissue N concentrations 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 also increased residual nitrate-N content in the soil, but to a lesser extent than yard waste application. 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. Initial levels of nitrate-N in the water increased with increasing yard waste application. In most treatments, peak nitrate-N concentrations at the four foot depth occurred at about 10 weeks after planting, which corresponded to a week of high amounts of irrigation and rainfall. 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 lower nitrate-N concentrations compared to the treatment where no yard waste applied with 200 lb N/A. Nitrate concentrations in soil water from treatments receiving yard waste and 200 lb N/A were similar to those in the 200 lb N/A treatment without yard waste. Higher levels of nitrate-N earlier in the season with the yard waste application may result in higher risk of nitrate leaching; however, concentrations of nitrate in the soil water with the fertilized control at the recommended rate were higher than those with 40 ton/A yard waste with 100 lb N/A (the optimized yield treatment). These results suggest that if N rate is adjusted to yard waste application, leaching losses would be no greater than the fertilized control.

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	3.4	25918	42	32
20	0	5.9	25700	65	29
40	0	7.0	25918	90	28
80	0	8.3	26463	102	26
0	100	8.5	25156	126	25
20	100	11.3	25809	145	25
40	100	12.8	26027	166	25
80	100	13.0	25483	164	25
0	200	9.5	25374	140	24
20	200	11.3	25156	158	24
40	200	12.4	24720	164	24
80	200	13.1	26245	167	24
Significance		**	NS	**	**
BLSD (5%)		2.0	--	15	2
Main effects					
	Yard Waste Rate				
	0	7.1	25483	103	27
	20	9.5	25555	123	26
	40	10.7	25555	140	26
	80	11.5	26063	145	25
	Significance	**	NS	**	++
	BLSD (5%)	1.1	--	9	2
	Linear	**	NS	**	**
	Quadratic	**	NS	**	NS
	Nitrogen Application				
	0	6.1	26000	75	29
	100	11.4	25619	150	25
	200	11.6	25374	157	24
	Significance	**	NS	**	**
	BLSD (5%)	1.0	--	7	1
Interaction					
	Yard Waste x Nitrogen	NS	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	3.29	1.43	0.78	0.34	0.93	0.15	0.89	1.18	2.22	2.4	6.1	22.0	30.5
20	0	3.05	1.80	0.66	0.32	0.95	0.21	1.14	1.82	3.17	2.8	7.4	34.5	44.7
40	0	3.11	1.50	0.62	0.29	0.99	0.29	1.46	2.52	4.27	3.5	8.5	50.1	62.1
80	0	3.01	1.63	0.53	0.35	0.99	0.26	1.81	2.87	4.94	2.8	13.0	57.1	72.9
0	100	3.98	2.30	0.55	0.38	1.05	0.36	2.30	3.52	6.18	4.0	18.2	74.9	97.1
20	100	3.87	2.62	0.54	0.37	1.21	0.43	2.51	4.06	7.00	4.4	19.1	98.6	122.1
40	100	3.88	2.70	0.51	0.41	1.27	0.50	3.04	4.65	8.19	5.2	25.7	118.7	149.6
80	100	3.84	2.51	0.43	0.50	1.30	0.50	2.90	4.59	7.99	4.2	29.6	119.1	152.9
0	200	4.03	3.01	0.54	0.64	1.31	0.43	2.48	3.92	6.83	4.7	31.5	103.1	139.3
20	200	3.96	3.10	0.52	0.56	1.40	0.46	2.61	4.42	7.49	4.8	29.3	123.9	158.0
40	200	4.01	3.09	0.49	0.62	1.40	0.53	2.44	4.60	7.57	5.1	30.5	129.0	164.6
80	200	3.82	2.98	0.48	0.65	1.39	0.56	3.20	4.69	8.45	5.4	43.0	130.6	179.0
Significance		**	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (5%)		0.17	0.44	0.07	0.10	0.10	0.06	0.52	0.42	0.78	0.9	9.4	14.5	19.8
Main effects														
Yard Waste Rate														
0		3.77	2.24	0.62	0.46	1.10	0.31	1.89	2.87	5.07	3.7	18.6	66.7	89.0
20		3.63	2.51	0.57	0.42	1.19	0.37	2.08	3.43	5.88	4.0	18.6	85.7	108.3
40		3.67	2.43	0.54	0.44	1.22	0.44	2.32	3.92	6.68	4.6	21.6	99.2	125.4
80		3.56	2.37	0.48	0.50	1.23	0.44	2.64	4.05	7.13	4.1	28.5	102.3	134.9
Significance		**	NS	**	++	**	**	**	**	**	**	**	**	**
BLSD (5%)		0.11	--	0.04	0.07	0.06	0.04	0.31	0.24	0.46	0.5	5.8	8.5	11.6
Linear		**	NS	**	++	**	**	**	**	**	++	**	**	**
Quadratic		NS	NS	NS	++	*	**	NS	**	*	**	NS	**	*
Nitrogen Application														
0		3.12	1.59	0.65	0.33	0.97	0.23	1.33	2.10	3.66	2.9	8.7	40.9	52.5
100		3.89	2.53	0.51	0.42	1.21	0.45	2.69	4.20	7.34	4.5	23.1	102.8	130.4
200		3.96	3.04	0.51	0.62	1.38	0.49	2.68	4.41	7.58	5.0	33.6	121.6	160.2
Significance		**	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (5%)		0.08	0.21	0.04	0.05	0.05	0.03	0.25	0.21	0.39	0.4	4.5	7.2	9.8
Interaction														
Yard Waste x Nitrogen		NS	NS	++	NS	NS	NS	NS	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	2.15	1.61	2.95	2.54	9.25
20	0	2.62	1.59	2.61	2.18	9.00
40	0	3.61	2.61	4.57	3.46	14.25
80	0	4.62	3.54	5.76	3.43	17.35
0	100	3.45	3.31	4.49	2.13	13.38
20	100	3.90	3.29	6.48	3.21	16.88
40	100	4.30	5.15	7.48	3.12	20.05
80	100	6.92	9.40	11.14	4.16	31.62
0	200	3.73	3.66	5.39	4.04	16.82
20	200	4.00	7.45	15.68	9.55	36.68
40	200	4.32	6.57	14.89	10.19	35.97
80	200	8.27	10.03	15.02	9.93	43.25
Significance		**	**	**	**	**
BLSD (5%)		1.83	4.11	6.44	2.76	12.87
Main effects						
	Yard Waste Rate					
	0	3.11	2.86	4.28	2.90	13.15
	20	3.51	4.11	8.26	4.98	20.86
	40	4.08	4.78	8.98	5.59	23.43
	80	6.60	7.66	10.64	5.84	30.74
	Significance	**	**	**	**	**
	BLSD (5%)	1.00	2.25	3.77	1.70	7.34
	Linear	**	**	**	**	**
	Quadratic	++	NS	NS	*	NS
	Nitrogen Application					
	0	3.25	2.34	3.97	2.90	12.46
	100	4.64	5.29	7.40	3.15	20.48
	200	5.09	6.92	12.74	8.43	33.18
	Significance	**	**	**	**	**
	BLSD (5%)	0.90	1.86	2.92	1.31	6.01
Interaction						
	Yard Waste x Nitrogen	NS	NS	NS	++	NS

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

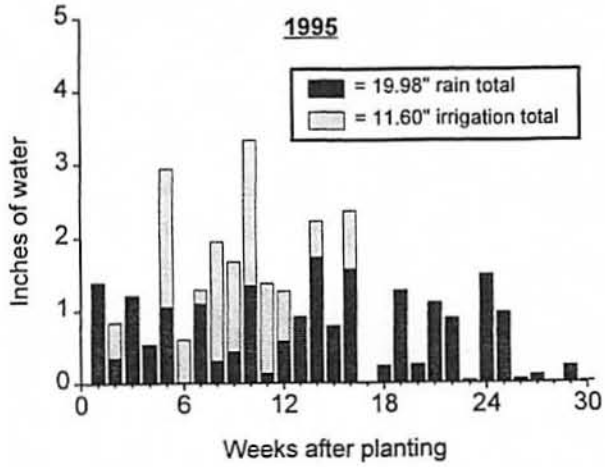

Figure 1. Rainfall and irrigation during the 1995 growing season.