Each of the four plots produced the greatest soybean yield compared to the other three plots at least one season during the 10-year period (Table 2). Likewise, each of the four plots produced the lowest soybean yield compared to the other three plots within at least one season during the 10-year period. Over the 10-year period, the range in soybean yield among the four plots (plot range) expressed as a percentage of the plot average averaged 17%. The range in soybean yield expressed as a percentage of the plot average was as low as 6% in 1991 and as high as 28% in 1988. The range in soybean yield expressed as a percentage of the plot average was greater than 10% in 9 of 10 growing seasons, and greater than 25% in 4 of 10 growing seasons studied. As with corn, the plot range was large compared to the plot average in 1988, when yields were depressed due to hot, dry growing conditions. The range in soybean yield for each of the four plots across the 10-year period (10-year range) expressed as a percentage of the 10-year average was greater than 50% for all plots. Over the 10-year period, seasonal variability in soybean yield was 2.8 times that of plot variability (7.6 vs. 2.8 bu/acre).

Conclusions

These results suggest the importance of taking great care when interpreting yield maps. For both corn and soybean, a yield range between the highest and lowest yielding plot of more than 25% of the four-plot average occurred in 4 out of 10 of the growing seasons, but when averaged over 10-years, there was no significant yield difference between the four corn plots or between the four soybean plots.

Year-to-year yield variability was approximately three times greater for both corn and soybean than plot-to-plot yield variability. The 10-year time frame this study encompassed included two relative harsh growing seasons (1988 which was hot and dry, and 1993 which was cool and wet). These growing seasons should not be considered anomalies, as harsh climatic conditions resulting in poor crop production do occur regularly.

Basing yield predictions on individual year data would result in quite different and perhaps erroneous conclusions than if yield predictions were based on longer-term (10 year) averages. Emphasizing yield map variability observed in relatively uniform fields during poor growing seasons (when the plot range was very large compared to the four-plot average) is especially risky, and may lead to erroneous conclusions. These results underscore the necessity of in-season field observations to aid yield map interpretation, especially when relatively large yield variations occur during poor growing seasons.

Table 1. Continuous corn yields from four plots over a 10-year period from 1986 through 1995 at Lamberton.

Plot	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	10-yr avg.	10-yr range	10-yr std. dev.	Avg. across years	
	bu/acre														
Lamberton															
1	138	120	63	141	125	117	127	63	110	125	113	78	27.8		
2	155	129	91	146	137	112	138	43	98	116	117	112	33.0		
3	139	128	104	144	140	112	101	69	108	127	117	75	23.2		
4	128	134	78	141	134	102	121	57	129	105	113	85	27.5		
Plot avg.		140	128	84	143	134	111	122	58	111	118				115
Plot range	27*	14*	41**	6	15*	16*	36**	26**	31**	22*				23.2*	
Plot std. dev.	11.2	5.9	17.4	2.6	6.3	6.6	15.2	11.0	12.8	9.9				9.9	
									Avg. across plots:		115	87	27.9		

*,** Range in corn yield exceeded 10 and 25% of the plot average, respectively.

Table 2. Continuous soybean yields from four plots over a 10-year period from 1986 through 1995 at Lamberton.

Plot	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	10-yr avg.	10-yr range	10-yr std. dev.	Avg. across years	
	bu/acre														
Lamberton															
1	35.9	44.6	26.3	30.2	41.2	44.1	25.2	33.1	33.1	38.8	35.3	19.4	6.9		
2	34.6	42.3	24.4	26.1	40.6	40.8	24.7	26.0	41.9	43.8	34.5	19.4	8.3		
3	38.8	38.9	28.5	26.2	38.6	46.9	20.4	28.4	42.8	40.9	35.0	26.5	8.5		
4	40.3	39.9	32.1	28.5	40.3	45.8	27.1	26.0	33.1	40.4	35.4	19.8	6.8		
Plot avg.		37.4	41.4	27.8	27.8	40.2	44.4	24.4	28.4	37.7	41.0				35.0
Plot range	5.7*	5.7*	7.7**	4.1*	2.6	6.1*	6.8**	7.1**	9.7**	4.9*				6.0*	
Plot std. dev.	2.6	2.6	3.3	2.0	1.1	2.6	2.9	3.3	5.4	2.1				2.8	
									Avg. across plots:		35.0	21.2	7.6		

*,** Range in soybean yield exceeded 10 and 25% of the plot average, respectively.

ORGANIC CROP ROTATION STUDY AT LAMBERTON -- 1996

P.M. Porter, C.A. Perillo, D.R. Huggins and S.R. Quiring[1]

Abstract

The 1996 growing season marked the eighth year of the ongoing Organic Rotation Study at Lamberton. The purpose of the experiment is to evaluate both the effect of manure application (versus no added fertility) and the effect of cropping sequence on crop yield — emphasizing corn yield but also evaluating yield of soybean, oat, and alfalfa. Manure application in the organically managed study employing no herbicides or synthetic fertilizer increased corn yields for all rotation lengths (continuous, 2-, 3-, and 4 year rotations). Corn yields in the manured and non-manured treatments averaged over all rotation lengths were 155 and 69 bushels acre^{-1}, respectively. Length of rotation had no effect on corn yields in the manured treatments, but impacted yields in the non-manured treatments with continuous corn yielding less than corn in 2-, 3-, and 4-year rotations. Soybean yields in the manured and non-manured treatments averaged 37.7 and 33.5 bushels acre^{-1}, respectively. For soybeans, highest yields were obtained with the 4-year rotation compared to the 2- and 3-year rotations, with the increase especially pronounced in the manured treatments. Oat yields were unaffected by rotation length or manure application.

Introduction

This on-going study evaluates various crop rotations managed organically under both high and low fertility levels. The crop rotations include i) continuous corn, ii) a 2-year corn-soybean rotation, iii) a 3-year corn-soybean-oat rotation, and iv) a 4-year corn-soybean-oat-alfalfa rotation. The site of the study (Elwell Agroecology Farm on the Southwest Experiment Station) had a 30+ year history of no synthetic fertilizer use and minimal pesticide use. The study began in 1990, and at that time the Bray 1 phosphorus level was 10 ppm and the potassium level was 171 ppm. All the crop rotations have been grown both with and without poultry manure applications. There were no chemical weed control practices used, only mechanical weed control methods. The 1996 yield results are reported here. Previous results were presented in earlier editions of this publication.

Experimental Procedure

The study involved a randomized complete block design with a split-plot arrangement and 4 replicates. Rotation length was the main plot variable, and fertility management was the sub-plot variable. Main plot size was 60 ft by 155 ft, and sub-plot size was 30 ft by 155 ft. The composted poultry manure rate was based on the soil test results from the previous fall sampling and University of Minnesota Extension recommendations. The rate used was expected to meet the crop requirement of the most limiting nutrient (P or N). The manure was broadcast and incorporated prior to secondary tillage in the spring (Table 1). Soil samples for phosphorus and potassium were taken on Nov. 21 to a depth of 1 ft with 8 composite cores per sub-plot. Soil nitrate samples were taken on Nov. 16 in 1 ft increments to a depth of 5 ft with 2 composite cores per sub-plot.

After oat and oat/alfalfa treatments were planted, the plots were harrowed and packed in an effort to increase weed control and improve soil to seed contact. Corn and soybean plots were rotary-hoed and cultivated in an effort to control weeds. Tillage and rotary hoeing in like crops in all rotations were treated the same, but row-cultivation in corn varied depending on fertility level. As in the past, all plots except those with oats under-seeded with alfalfa were moldboard plowed in the fall.

Total weed counts were taken in all but the alfalfa plots. All weed species were identified and counted in each sample. In corn and soybean two samples 4-ft long and 5-ft wide were collected for grassy weeds, and one sample 145 ft by 5 ft was collected for broadleaf weeds. In oats and alfalfa three 1-ft squares per plot were collected for both grassy and broadleaf weeds.

Results and Discussion

In 1996, corn yields were increased with the addition of manure: manured and non-manured treatments averaged 154 and 69 bushels acre^{-1}, respectively (Table 2). Length of rotation had no effect on corn yields in the manured treatments, but impacted yields in the non-manured treatments. Without manure, the continuous corn yield substantially less than corn in the 2-, and 3-year rotations, which in turn yielded less than corn in the 4-yr rotation.

Soybean yields were significantly impacted ($P=0.06$) by manure application, with the manured treatments yielding 37.8 bushels acre^{-1} and the unfertilized treatments yielding 33.5 bushels acre^{-1}. These results are the opposite of what was observed in 1994 and 1995, where the manured treatments yielded less than the unfertilized treatments. Better weed control was obtained in 1996 compared with the previous years, and may have contributed to these results. Soybean yields were not significantly impacted ($P=0.13$) by rotation length, however, there was a trend toward greater yields in the 4-year rotation compared with the 2-year rotation.

Oat yields were unaffected by rotation length but increased with manure application (75.2 vs 45.5 bushels acre^{-1} for the fertilized and unfertilized treatments, respectively). The manured alfalfa treatments yielded more than the unfertilized treatments (5.33 vs. 3.02 tons acre^{-1}, respectively.

[1] P.M. Porter (assist. prof. - Dept. Agronomy and Plant Genetics), C.A. Perillo (assist. scientist), D.R. Huggins (assist. prof. - Dept. Soil, Water, and Climate), and S.R. Quiring (senior plot tech.), located at the Southwest Experiment Station, Lamberton, MN.

Table 1. 1996 management information for the organic crop rotation study at Lamberton.

Rotation	Spring tillage and dates	Seed, rate, and planting date †	Rotary hoeing dates	Cultivation dates	Fertilizer rates and dates
Continuous corn	Field cultivator 5/18 (twice)	Pioneer P3769 33000 seeds acre^{-1} 5/18	5/29 5/30 6/03	6/13 6/27	354-240-282 on 5/18
Corn-soybean	Field cultivator 5/18 (twice)	Pioneer P3769 33000 seeds acre^{-1} 5/18	5/29 5/30 6/03	6/13 6/27	354-240-282 on 5/18
Corn-soybean-oats	Field cultivator 5/18 (twice)	Pioneer P3769 33000 seeds acre^{-1} 5/18	5/29 5/30 6/03	6/13 6/27	354-240-282 on 5/18
Corn-soybean-oats-alfalfa	Field cultivator 5/18 (twice) 5/18	Pioneer P3769 33000 seeds acre^{-1} 5/18	5/29 5/30 6/03	6/13 6/27	69-47-55 on 5/18
Corn-soybean	Field cultivator 5/22 5/29	Parker 150,000 seeds acre^{-1} 5/30	6/03 6/11	6/27	0-0-0‡
Corn-soybean-oats	Field cultivator 5/22 5/29	Parker 150000 seeds acre^{-1} 5/30	6/03 6/11	6/27	17-12-14 on 5/21
Corn-soybean-oats-alfalfa	Field cultivator 5/22 5/29	Parker 150,000 seeds acre^{-1} 5/30	6/03 6/11	6/27	38-26-30 on 5/21
Corn-soybean-oats	Field cultivator 4/26 harrow / packer 4/27	Dane 85 lbs acre^{-1} 4/26	none	none	63-43-51 on 4/26
Corn-soybean-oats-alfalfa	Field cultivator 4/26 harrow / packer 4/27	Dane and Pioneer P5262 85 and 12lbs acre^{-1} 4/26 and 4/26	none	none	63-43-51 on 4/26
Corn-soybean-oats-alfalfa	none	Planted previous year	none	none	73-50-59 on 8/02

† Hybrid or variety is listed, followed by seeding rate in seeds acre^{-1} and planting date.
‡ 354-240-282 was inadvertently applied to one plot (not included in yield results).

Table 2. Rotation length and fertility effects on corn, soybean, oats and alfalfa yields in an organically-managed study at Lamberton, 1996.

Rotation	With manure	Without manure
Corn yield	— bushels acre^{-1} —	
Continuous corn	164.4	47.6 c
Corn-soybean	148.1	65.3 b
Corn-soybean-oats	158.5	70.4 b
Corn-soybean-oats-alfalfa	147.3	91.9 a
Mean	154.6	68.8
CV (%)	10.7	
Pr> F	(Fert 0.01, Rot 0.14, FXR 0.01)	
$LSD_{(0.05)}$	16.4	16.4
Soybean yield	— bushels acre^{-1} —	
Soybean-corn	34.3	32.8
Soybean-oats-corn	37.3	32.3
Soybean-oats-alfalfa-corn	41.9	35.4
Mean	37.8	33.5
CV (%)	13.7	
Pr> F	(Fert 0.06, Rot 0.13, FXR 0.59)	
$LSD_{(0.05)}$	NS	NS

Rotation	With manure	Without manure
Oat yield	— bushels acre^{-1} —	
Oats-corn-soybean	77.2	49.3
Oats-alfalfa-corn-soybean	73.2	41.6
Mean	75.2	45.5
CV (%)	14.4	
Pr> F	(Fert 0.01, Rot 0.23, FXR 0.68)	
$LSD_{(0.05)}$	NS	NS
Alfalfa yield	— ton acre^{-1} —	
Alfalfa-corn-soybean-oats	5.33 a	3.02 b
With vs. without manure		
CV (%)	14.4	
Pr>F	0.01	
$LSD_{(0.05)}$	1.36	

ANHYDROUS AMMONIA - KNIFE SPACING STUDY[1]

S.D. Evans and G.A. Nelson[2]

Abstract

This is the last year of a 3 year study initiated in Morris, MN in 1994 and repeated in 1995 and 1996 to study the effects of nitrogen application on grain yield at 2 anhydrous ammonia applicator knife spacings. Nitrogen was sidedressed at 0, 36, 72, 108, and 144 lb/A using 30- and 60-inch applicator knife spacings. In 1994 and 1995 there was an increase in grain yield up to 72 lb N/A and in 1996 there was an increase in grain yield up to 108 lb N/A but there was no difference in grain yield due to knife spacing in any of the years.

Objectives

Anhydrous ammonia is the dominant source of inorganic nitrogen used in corn production. Normally anhydrous ammonia is injected into the soil through knives that run 6 to 10 inches deep. Horse-power requirements and fuel consumption are high during this process. It would be advantageous to space anhydrous ammonia knives 60 inches apart, rather than the conventional 30-inch spacing, to reduce horse-power and fuel requirements during the anhydrous ammonia application process. At the 60-inch spacing no ammonia is applied in the tractor wheel tracks. This study was designed to evaluate corn grain yield response due to spacing of anhydrous ammonia applicator knives at 30-inch intervals versus 60-inch intervals. The anhydrous ammonia was applied sidedress at the V5 stage of corn with a conventional ammonia applicator.

Experimental Procedures

The experiment was established on Nutley clay soils in 1994 and 1996 and on a Nutley clay/Flom loam complex in 1995. Each year the experimental design was a randomized complete block with 4 replications. The experimental sites were seeded to oats the year before the study, had no nitrogen applied, and were fall chisel plowed. Soil tests taken the fall before the study year indicated high P and K levels, (data not shown). Nitrate-N soil tests, 0-2 foot, taken the fall before the study year showed concentrations of 18 lb/A in 1994, 22 lb/A in 1995, and 28 lb/A in 1996. The 1994-96 individual plots were 6 rows (15ft) wide and 45 feet long. The experimental site was field cultivated for seedbed preparation each year and seeded to Ciba Geigy 4172 corn in 1994 and 1995 and DeKalb 442 corn in 1996 at 30,100 seeds per acre. A 6-row J.D. Maxemerge planter was used for seeding. Grass control was achieved with pre-emergence applications of Alachlor @ 3.0 lb/A a.i. or Metolachlor @ 3.0 lb/A a.i. Broadleaf weeds were controlled with post-emergence applications of Bentazon @ 0.75 lb/A a.i. or Halosulfuron-methyl @ 0.047 lb/A a.i. Each year the study was row cultivated prior to nitrogen application. Anhydrous ammonia was sidedress applied on June 8, 1994, June 21, 1995, and June 26, 1996. Corn was in the V5 stage, 4-5 collars visible at the time of nitrogen applications. Nitrogen was applied at rates of 36, 72, 108, and 144 lb/A at 30- and 60-inch knife spacings. A check treatment was also included by running knives at 30- and 60-inch spacings through the check plots without applying any nitrogen. Soil conditions were dry at ammonia sidedress application in 1994 with rain 1 week after application, wet soil conditions were prevalent in 1995 with frequent rains before and after ammonia application, and in 1996 soil conditions were dry before ammonia application with rain 1 1/2 weeks after application. Growing season rainfall was 17.51 inches, 20.70 inches, and 11.69 inches for 1994, 1995, and 1996, respectively, compared to an average of 15.71 inches. The study was harvested with a plot combine each fall. Grain yield, grain moisture, date of tasseling, and date of silking were recorded.

Results

There were significant differences in grain yield due to nitrogen rate (Table 1) in all years. Grain yield was maximized at 72 lb/N in 1994 and 1995, and at 108 lb/N in 1996. Grain moisture at harvest was variable but generally the highest at the 0 lb/N treatment, (data not shown). Tasseling and silking were the latest for the 0 lb/N treatment in all years of the study (data not shown). There were no significant effects on grain yield, grain moisture, tasseling, or silking due to knife spacing in any year. The knife spacing x nitrogen rate interaction was not significant in 1994, but was significant in 1995 and 1996. Examination of the 1995 and 1996 data indicates that most of the effects from the knife spacing by nitrogen rate interactions were attributed to nitrogen rate. Three years of results show no differences in grain yield between 30- and 60-inch anhydrous ammonia knife applicator spacings at sidedress.

---

[1] Funding provided by the West Cent. Expt. Sta., Univ. of Minnesota.

[2] Professor (retired) and Assistant Scientist, West Cent. Expt. Sta., Univ. of Minnesota

Table 1. Effect of applicator knife spacing on corn grain yield, Morris 1994, 1995, and 1996.

Nitrogen Rate	Knife Spacing	1994 Grain Yield	1995 Grain Yield	1996 Grain yield	1994-96 Average Grain yield
-lb/A-	-inches-	-bu/A-	-bu/A-	-bu/A-	-bu/A-
0	30	80.5	103.6	82.5	88.9
36	30	106.9	115.7	101.1	107.9
72	30	150.3	162.6	131.7	148.2
108	30	142.7	162.8	147.1	150.9
144	30	159.3	163.2	155.0	159.2
0	60	80.5	89.5	91.9	87.3
36	60	113.5	139.0	126.0	126.2
72	60	148.9	155.7	147.8	150.8
108	60	153.3	158.7	146.5	152.8
144	60	159.8	162.4	144.7	155.6
Nitrogen Rate Sig. Level (%)		99	99	99	
BLSD (.05)		20.5 bu	7.6 bu	9.4 bu	
Knife Spacing Sig. Level (%)		34	12	84	
N Rate x Knife Spacing Sig. Level (%)		2	99	98	
C.V. (%)		16.7	5.8	7.9	-

SOUTHERN EXPERIMENT STATION
35838 120th STREET
WASECA, MINNESOTA 56093-4521

WEATHER DATA - 1996

Month	Period	Precipitation 1996	Precipitation Normal[1/]	Avg. Air Temp. 1996	Avg. Air Temp. Normal[1/]	Growing Degree Units 1996	Growing Degree Units Normal[1/]
		- - - - inches - - - -		- - - - - °F - - - - -			
January	1 - 31	3.26	0.98	7.4	10.2		
February	1 - 28	0.14	0.97	16.3	16.1		
March	1 - 31	3.29	2.28	24.1	29.1		
April	1 - 30	1.11	2.97	41.2	43.1		
May	1 - 10	1.56		48.0		32.0	
	11 - 20	1.08		57.1		95.0	
	21 - 31	0.78		56.6		86.5	
	Total	3.42	3.65	53.9	57.7	213.5	327
June	1 - 10	1.10		60.8		110.5	
	11 - 20	3.77		71.7		208.5	
	21 - 30	0.58		74.7		232.5	
	Total	5.45	4.11	69.1	67.1	551.5	515
July	1 - 10	0.65		69.8		199.0	
	11 - 20	0.33		70.5		201.5	
	21 - 31	0.82		66.0		176.5	
	Total	1.80	4.21	68.7	71.3	577.0	646
August	1 - 10	2.64		70.6		204.0	
	11 - 20	1.00		67.1		170.5	
	21 - 31	3.45		68.0		197.5	
	Total	7.09	4.20	68.5	68.4	572.0	567
September	1 - 30	1.81	3.56	60.0	59.9	229.0	316
October	1 - 31	2.90	2.45	49.2	47.9	-	31
November	1 - 30	4.16	1.72	24.3	32.3		
December	1 - 31	1.93	1.35	12.2	16.2		
Year	Jan-Dec	36.36	32.45	41.3	43.4	2143.0[2/]	2402
Growing Season	May-Sep	19.57	19.73	64.0	64.9	2143.0	2371

1/ 30-year normal from 1961 - 1990.
2/ 50 to 86° F base, May 1 until first fall frost.

Notes:
1) Highest 24-hour precipitation on August 26 - - - 2.75"
2) Growing degree units 10% below normal for season.
3) Highest temperature on June 29 - - - 96F.
4) Last spring frost - - - May 13.
5) First fall frost - - - September 14.

NUTRIENT LOSSES TO TILE LINES AS INFLUENCED BY SOURCE OF N

Waseca, 1996

T.K. Iragavarapu, G.W. Randall, and M.A. Schmitt†

ABSTRACT: A study was started in 1994 to compare the effects of liquid dairy manure and urea applied at similar N rates on N and P movement in the soil and into tile lines and corn production. Corn yields and N uptake were significantly greater for the urea treatment compared to the dairy manure treatment. 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. Out of the 36 tile water samples analyzed, ortho-phosphate was detected in 20 samples (55%) while total P was detected in 35 samples (97%). Average total P concentrations (0.03 mg/L) were identical between manure and urea. Ammonium-N was detected in three of the four samples analyzed from each of the treatments and the NH_4-N concentration did not differ between the two N sources. Coliform bacteria was not detected in any of the six water samples analyzed from the dairy manure treatment. 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 ft depth, there was no clear trend. Nitrate-N concentrations were low (< 6 mg/L) at the 8 ft depth and were similar between the two treatments. Water was found in only 12 of the 40 possible piezometers at the 4 ft depth whereas at the 6 and 8 ft depths 28 and 26, respectively, of the piezometers had water. All the samples analyzed from the 4 ft. depth had detectable amounts of NO_3-N while 78 and 27% of the water samples from the 6 and 8 ft depths, respectively, had detectable amounts of NO_3-N. Soil test P and K values were greater for the dairy manure applied plots compared to the urea treated plots.

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 and P 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 10, 1995 at a rate of 9000 gal/acre and the plots were moldboard plowed immediately. On April 26, 1996, urea was broadcast-applied by hand to 4 plots at a rate of 135 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 (66 lb) and 25% of the organic N (86 x 0.25 = 22 lb) plus 15% of the total N of the manure that was applied in the fall of 1994 (257 x 0.15 = 39 lb) and 5% of the total N of the manure applied in the fall of 1993 (203 x 0.05 = 10 lb) was available for a total of 135 lb N/A.

Corn (P3556) was planted on May 2 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 13. 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

† Research Associate, Professor, Southern Experiment Station, Waseca and Assoc. Professor, Dept. of Soil, Water, and Climate, St.Paul, respectively.

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. 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 14, 1996.

RESULTS

Corn grain yield, grain N removal, silage yield, and N uptake were significantly ($P \leq 0.05$) greater in plots that were fertilized with urea compared to those plots that received liquid dairy manure (Table 2). The 19 bu/A yield "advantage" for the urea treatment suggests that sufficient N was not provided by the dairy manure treatment. Visual observations during the season indicated color (dark green) and growth/height advantage for the urea treatment. This is evident from the significantly lower chlorophyll content in leaves of the corn plants in the dairy manure treatment than in the urea treatment during the R2 growth stage of corn. We believe that cooler and drier than normal weather conditions in April, May, and July resulted in slower mineralization of organic N in the manure. This resulted in insufficient N available for plant uptake at the rapid growth stage of corn. Perhaps the assumption that 90% of the ammonium-N and 25% of the organic N in the manure applied in Nov. 95 plus 15% of the total N of manure applied in Nov.1994 and 5% of the total N of the manure applied in Nov. 1993 was available to the 1996 crop was an overestimate of N availability from dairy manure under these conditions.

Table 1. Nutrient analyses and application rate of liquid dairy manure applied in November, 1995.

Dry matter	Total N	NH_4-N	Organic N	Total P_2O_5	Total K_2O
%	lb/1000 gal				
5.1	17.8	8.2	9.6	8.0	22.8
	lb/acre				
	160	74	86	72	205

Table 2. Influence of nitrogen source on corn production and N utilization at Waseca in 1996.

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	27.8	52.9	6.16	106.3	135.0	1.10	70.0	23.2
Dairy Manure	27.0	40.9	4.93	79.6	116.1	0.98	53.7	23.6
Check[1/]	-	24.5	2.15	30.2	38.7	0.94	17.2	20.0
LSD (0.05)	NS	6.9	0.55	10.7	16.7	NS	16.1	NS
CV (%)	1.8	4.2	2.8	3.3	3.8	4.1	7.4	4.3

[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.

Below normal precipitation was recorded in April, May, July, and September months. As a result, little or no tile flow occurred during these months. June rainfall was 1.2" above normal. Although rainfall was 2.9" above normal in August tile flow did not occur because of high ET losses. 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 1996.

Month	Tile Flow	NO_3-N Concentration	NO_3-N Loss
	acre-in.	mg/L	lb/A
		Urea	
April	-	-	-
May	-	-	-
June	3.34	11.8	8.8
July	0.02	11.2	0.0
August	-	-	-
September	-	-	-
October	-	-	-
November	0.96	6.7	1.5
Dec	0.26	6.0	0.4
Total	4.58	Avg = 8.9	10.7
		Dairy manure	
April	-	-	-
May	-	-	-
June	3.83	11.9	10.4
July	0.03	9.0	0.1
August	-	-	-
September	-	-	-
October	-	-	-
November	1.01	6.3	1.5
December	0.40	5.5	0.6
Total	5.27	Avg = 8.2	12.6

Residual NO_3-N in the 0-5 ft. soil profile at the end of the 1996 growing season was slightly greater in plots that received dairy manure compared to those that received urea (Table 4). This was especially true in the 0 to 1 ft. soil layer where nitrates in the dairy manure treatment were twice as high as in the urea treatment. This suggests that some late-season availability of N from the manure when the crop uptake of N has ceased may have occurred resulting in greater amounts of NO_3-N accumulated in the top 2 ft. of the dairy manured plots than those treated with urea.

Table 4. Influence of nitrogen source on residual NO_3-N in the soil profile in November, 1996.

Profile Depth	Nitrogen Source: Urea	Nitrogen Source: Dairy manure
ft	NO_3-N (lb/A)	
0-1	16.1 (2.2)†	32.8 (5.0)
1-2	9.7 (1.4)	14.1 (3.3)
2-3	8.5 (1.3)	5.6 (1.2)
3-4	13.1 (0.9)	9.3 (0.6)
4-5	18.9 (2.1)	16.9 (2.3)
Total (0-5')	66.3	78.7

† Numbers in parentheses represent the standard error around the mean.

Soil samples were collected from the plow layer (0-8") in June 1996 to measure the influence of dairy manure vs. urea on soil fertility. Soil pH was similar between the two treatments while soil test P was 14 ppm greater and soil test K was 104 ppm greater in the dairy manure treatment compared to the urea treated plots (Table 5). The same four plots that received dairy manure in the fall of 1995 received dairy manure a rate of 8,000 gal /acre in Nov. 1993, and 10,000 gal/acre in Nov. 1994. In all three years, the amounts of P_2O_5 and K_2O added through the manure were in excess of crop removal of these nutrients. This indicates that repeated application of dairy manure at rates based on N requirement of corn crop can result in a build up of soil test P and K.

Table 5. Influence of nitrogen source on soil pH, soil test P and K in the 0-8" soil profile in June, 1996.

	Nitrogen source	
	Urea	Dairy manure
pH	5.9	6.0
Phosphorus-Bray P_1 (ppm)	26 (3)†	40 (2)
Potassium (ppm)	150 (13)	254 (14)

† Numbers in the parentheses represent the standard error around the mean.

The detection limit for ortho-P in tile water samples was lowered from 0.04 mg/L in 1995 to 0.01mg/L in 1996. As a result, ortho-P was detected in 61% of the water samples from the plots that received dairy manure and in 50% of the water samples from the urea treated plots in 1996 (Table 6). Total phosphorus was detected in all 18 samples analyzed from the urea treatment and in 17 samples from the manured plots. However, average concentrations of ortho-P (0.01-0.02 mg/L) and total P (0.03 mg/L) were very low for both the urea and dairy manure treatments. Coliform bacteria (E.Coli) was not detected in any of the 6 samples analyzed from the manure applied plots. Ammonium-N was detected in three of the four samples analyzed from each of the dairy manure and urea treatments. Ammonium-N concentrations were similar between the dairy manure and urea treatments.

Table 6. Ortho-phosphorus, total phosphorus, coliform bacteria, and ammonium-N detects in tile water samples in 1996.

	Ortho-P		Total P		*E.Coli* Bacteria		NH_4-N	
	Manure	Urea	Manure	Urea	Manure	Urea	Manure	Urea
Number of samples analyzed	18	18	18	18	6	0	4	4
Number of detects[1/]	11	9	17	18	0	-	3	3
% of samples with detects	61	50	94	100	0	-	75	75
Concentration range of detects (mg/L)	0.01-0.03	0.01-0.02	0.02-0.09	0.02-0.08	-	-	0.02	0.02-0.03
Average concentration among detects (mg/L)	0.02	0.01	0.03	0.03	-	-	0.02	0.02

[1/] Detection level is 0.01 mg/L for ortho-P, 0.02 mg/L for total P, and 0.02 mg/L for NH_3-N.

Nitrate-N concentrations in the PSC samplers at the 4-ft depth were consistently greater in plots that received urea compared to those that received dairy manure at all five sampling dates (Fig 1). There was no clear trend at the 6 ft depth. At the 8 ft depth the nitrate-N concentrations were similar between the two treatments at all sampling dates except July 9. Nitrate-N concentrations increased from June 4 to June 19 in both treatments at the 4-ft depth. This increase was also seen at the 6-ft depth, but was most dramatic with urea.. Concentrations of NO_3-N at the 8-ft depth were low (< 6 mg/L) for both treatments. Water samples were collected five times from the piezometers in 1996. Nitrate-N detects in the piezometer water samples are given in Table 7. Across the five sampling dates between June 4 and August 28, water was found in only 12 of a possible 40 piezometers at the 4 ft. depth whereas at the 6 and 8 ft depths 28 and 26, respectively, of the piezometers had water. 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. In general, more detects were found in the urea treated plots compared to the dairy manure plots. Variation around the mean nitrate-N concentration was greater for the piezometer samples compared to the tile lines or the PSC samplers.

Table 7. Nitrate-N detects in piezometer water samples in 1996.

		6-4		6-19		7-9		7-23		8-28	
	Depth	Manure	Urea	Manure	Urea	Manure	Urea	Manure	Urea	Manure	Urea
	ft.										
	4	0	1	4	3	0	0	0	0	1	3
# of samples	6	4	4	1	4	4	4	1	2	2	2
analyzed	8	3	4	3	3	2	4	2	1	2	2
	4	-	1	4	3	-	-	-	-	1	3
	6	2	4	1	4	2	4	0	2	1	2
# of detects[1/]	8	2	0	2	1	1	0	0	0	1	0
	4	-	100	100	100	-	-	-	-	100	100
% of samples	6	50	100	100	100	50	100	0	100	50	100
with detects	8	67	0	67	33	50	0	0	0	50	0
	4	-	6.0	1.7-23.0	8.4-20.9	-	-	-	-	0.9	1.2-2.2
Conc. range	6	0.5-7.2	0.8-23.6	2.8	0.9-60.7	0.5-2.6	0.6-30.2	-	0.6-2.0	2.6	1.9-4.6
of data (mg/L)	8	3.1-5.9	-	4.4-17.7	2.0	14.7	-	-	-	1.0	-
	4	-	6.0	14.7	15.4	-	-	-	-	0.9	1.8
Avg. conc. among	6	3.8	8.4	2.8	18.9	1.5	8.1	-	1.3	2.6	3.2
detects (mg/L)	8	4.5	-	11.0	2.0	14.7	-	-	-	1.0	-

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

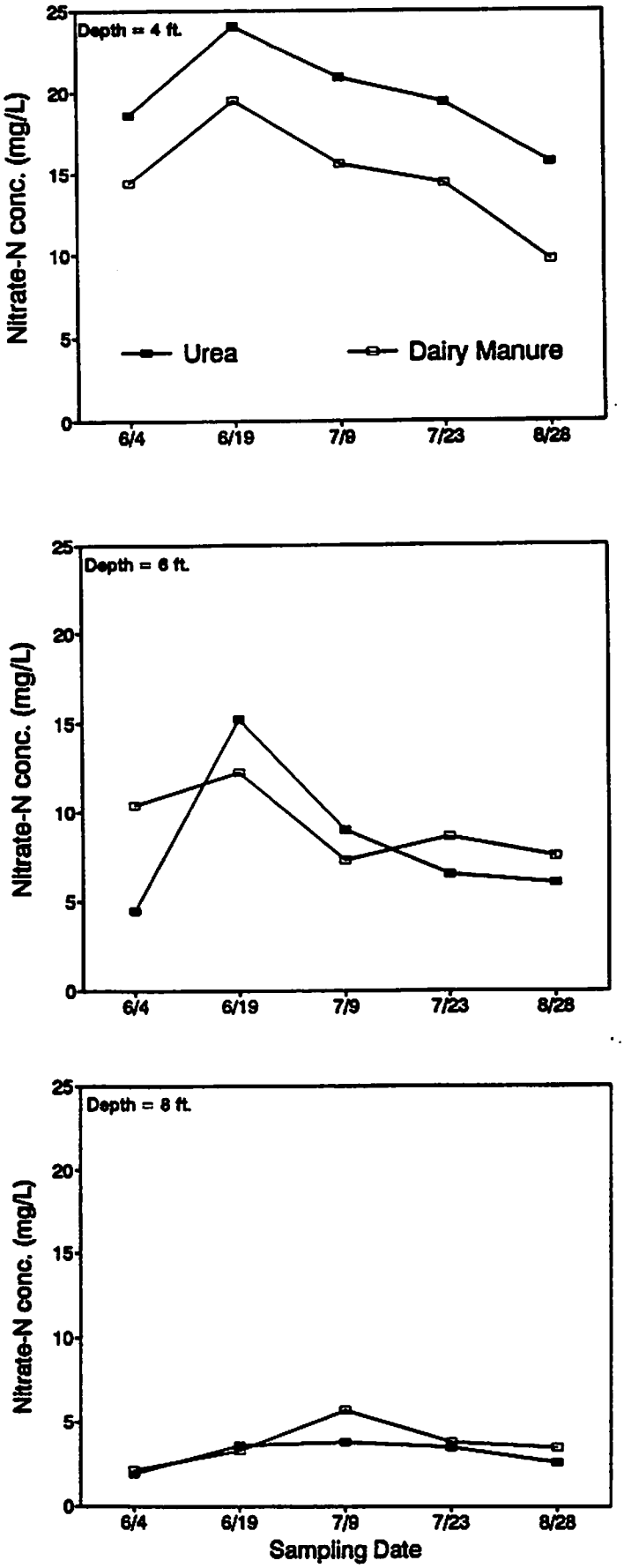


Fig 1. Nitrate-N concentrations in porous suction cup samplers in 1996

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

Waseca, 1996

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

ABSTRACT: A study was conducted in 1996 to determine the influence of time of N application, N source, and nitrification inhibitor on the yield and uptake of N by corn and the loss of NO_3 to tile drainage. These third-year results showed significant grain and silage yield increases over the control from all N treatments. Highest yields and N uptake were obtained with the spring preplant AA with N-Serve treatment and the spring preplant urea treatment. Yields and N uptake were not different among the fall and spring AA without N-Serve, fall AA with N-Serve, and sidedress AA treatments. Highest NO_3-N concentrations in the grain and stover were found with the spring urea treatment. Flow-weighted NO_3-N concentrations in the drainage water from the corn plots were highest with the fall AA without N-Serve and spring AA with N-Serve treatments. In soybeans, NO_3-N concentrations in the water were not greatly different among the N treatments, which had been applied for the 1995 corn crop. Nitrate-N losses in the drainage water from corn were 5 lb/A lower when N-Serve was used in the fall and 2 lb/A lower when used in the spring. Nitrated-N losses under soybeans ranged from only 5.0 to 6.4 lb NO_3-N/A, indicating little carryover from the 1995 crop. Highest NO_3-N concentrations averaging 18.3 mg/L were found in the fallow plots. Residual soil NO_3-N in November was slightly higher in the urea treatment than in any of the five AA treatments.

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 experiment 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 November 6, 1995. Average soil temperature at the 4" depth on that date was 33°F with an average of 33°F over the following 10-day period. The spring preplant anhydrous ammonia and urea treatments were applied on May 1. The sidedress AA treatment was applied at the V3 stage on June 14.

The corn area (1995 soybean area) was field cultivated once before planting, while the soybean area (1995 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 3730) was planted at 32,000 seeds/acre on May 17 with a JD Max-Emerge planter. Corn rootworm insecticide was not used. Weeds were chemically controlled with a preemergence application of Harness (2.75 pt/A) plus Broadstrike Plus (0.25 lb/A) on May 25. Soybeans (Sturdy) were planted in 30" rows at 9 beans per foot of row on May 29. Weeds were chemically controlled with 3.0 lb/A Lasso preemergence (June 1) plus a post emergence application of Pursuit (1.1 oz/A) at the 1st trifoliate stage (July 25).

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 thinned to a uniform population of 31,360 plants/acre. Chlorophyll content in the ear leaf was measured with a Minolta SPAD meter on August 2 (R1). 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 4 feet from all plots on November 14. Chemical analyses of plant, water, and soil were performed by the Research Analytical Laboratory, University of Minnesota.

1/ Partial funding provided by DowElanco and Minnesota Agric. Exp. Stn.

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

RESULTS AND DISCUSSION

Plant

ver N concentration, yield, and N uptake at physiological maturity were increased over the control by all of the N treatments (Table ..,. Stover yield differences did not exist among the treatments that received N. However, stover N concentration and N uptake were generally greater for the preplant urea and sidedress AA treatments compared with the fall and spring preplant AA treatments. Chlorophyll content of the ear leaf at the R-1 stage was increased significantly above the control by all of the N treatments. When comparing the relative chlorophyll content of each N treatment to the content of the highest treatment, all showed adequate chlorophyll suggesting sufficient N (>96% relative chlorophyll) for optimum yield. Final population was excellent and was not affected by the treatments.

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 (11/6)	No	0.54	2.60	28.2	97.8	30.10
AA Fall (11/6)	Yes	0.52	2.60	27.0	96.2	30.03
AA PP (5/1)	No	0.48	2.64	25.4	97.7	29.72
AA PP (5/1)	Yes	0.50	2.56	25.3	96.6	29.79
Additional trts						
Urea PP (5/1)	No	0.67	2.97	39.6	100.0	30.10
AA SD (6/14)	No	0.64	2.64	33.6	97.8	30.20
Check (No N)	- -	0.38	2.08	15.7	71.4	29.86
Statistical Analysis Latin square (Primary trts)						
P > *F*:		0.58	0.91	0.62	0.63	0.54
LSD (0.05):						
CV (%):		13	6	13	2	1
atistical Analysis Completely randomized (7 trts)						
> *F*:		<0.01	0.02	<0.01	<0.01	0.25
LSD (0.05):		0.09	0.41	6.0	3.7	
CV (%):		12	11	15	3	1

Grain yield, N concentration, and N uptake, silage yield, and total N uptake were increased significantly over the control by all of the N treatments (Table 2). Grain yields were increased significantly over the fall AA treatments and the spring preplant AA treatment without N-Serve by preplant AA with N-Serve and the preplant urea treatment. A wet 8-day period beginning on June 16 may have caused some denitrification and/or leaching of nitrate below the upper portions of the root zone, which could explain the somewhat lower yields with the fall treatments and the preplant AA without N-Serve treatment. Including N-Serve with the spring AA would have delayed nitrification during this very cool spring and thereby optimized N availability to the corn. Also, the spring broadcast application of urea because of its incorporation within the seed zone likely was more available to the small corn plants, giving them an early boost and perhaps a greater root system. The timing of these events may also have been critical because ear size was being determined at this time. The urea treatment also produced the greatest grain N concentration and silage yield (Table 2). This resulted in significantly higher N uptake in both the grain and silage compared with most of the other N treatments. Differences in grain N concentration, grain N uptake, silage yield, and total N uptake were not significant among the fall and spring preplant applied AA treatments.

The General Linear Models procedure in SAS® was used to "contrast" the four primary treatments and determine if significant differences existed. The significance levels in Table 3 show no differences between fall AA with N-Serve and without N-Serve. However, both grain moisture and yield were less for the fall AA treatments compared to spring preplant AA when averaged across the N-Serve treatments. Grain yield for spring preplant AA with N-Serve was significantly greater than for preplant AA without N-Serve.

Water

Weather conditions during the 1996 growing season were cooler and slightly wetter than normal. Rainfall in June was 1.24" above normal followed by a very dry July when rainfall was 2.4" below normal. August rainfall was almost 3" above normal while November was the fifth wettest November on record at 2.4" above normal. Consequently tile drainage was heaviest in June and November when the lines flowed 18 and 10 days, respectively (Table 4). Drainage from the 16 corn plots averaged 3.79" with a 2.08" range among the four time/method treatments. Soybeans showed slightly less tile drainage compared to corn with an average of 3.15" from the 16 plots and a range of only 0.43" among the four time/method treatments. Ideally, drainage should be uniform among the time/method atments, 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 (11/6)	No	152.6	29.9	1.16	84.1	6.21	112.3
AA Fall (11/6)	Yes	154.3	30.3	1.12	82.0	6.24	109.0
AA PP (5/1)	No	154.0	31.3	1.16	84.4	6.28	109.8
AA PP (5/1)	Yes	168.3	30.6	1.16	92.2	6.54	117.5
Additional trts							
Urea PP (5/1)	No	175.5	31.5	1.28	106.2	7.12	145.8
AA SD (6/14)	No	157.8	32.4	1.17	88.3	6.38	121.9
Check (No N)	--	104.9	34.4	0.86	42.9	4.57	58.6
Statistical Analysis Latin square (Primary trts)							
P > *F*:		0.03	0.06	0.84	0.20	0.34	0.45
LSD (0.05):		10.6					
CV (%):		4	2	6	7	4	7
Statistical Analysis Completely randomized (7 trts)							
P > *F*:		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD (0.05):		22.9	1.7	0.11	18.1	0.90	21.2
CV (%):		10	4	7	15	10	13

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	0.69	0.22	0.73
Grain N Concentration	0.45	0.66	0.96
Grain Moisture	0.38	0.02	0.12
Grain Yield	0.72	0.05	0.02
Stover Yield	0.99	0.96	0.50
Silage Yield	0.85	0.20	0.21
Final Population	0.81	0.18	0.83
Stover N Uptake	0.66	0.24	0.95
Grain N Uptake	0.65	0.14	0.12
Silage N Uptake	0.57	0.46	0.20
Relative Chlorophyll	0.30	0.90	0.47

Annual flow-weighted NO_3-N concentrations in the drainage water from the corn plots were highest for the fall AA without N-Serve and spring AA with N-Serve treatments (Table 5). But, the differences in monthly flow-weighted concentrations among the treatments really points to the relationship between time of N application and the time when excess rainfall and leaching occurred. In May, when very little drainage occurred, NO_3-N concentrations were highest for fall AA without N-Serve. During June when drainage was greatest, highest NO_3-N concentrations occurred with fall AA without N-Serve and spring preplant AA with N-Serve. The high concentrations with the latter treatment is surprising, but could indicate less denitrification with this treatment and subsequently higher yields. In November when drainage averaged about 0.4", significantly higher NO_3-N concentrations occurred with the spring preplant AA treatment with N-Serve. The late fall application of AA with N-Serve showed lowest NO_3-N concentrations throughout the year.

In the soybean plots, where N had been applied either in the fall of 1994 or spring of 1995, NO_3-N concentrations were consistently lower compared with the corn plots (Table 5). The average NO_3-N concentration was 8.2 mg/L with very little difference among the four N treatments. Nitrate-N concentrations under a 10-yr continuous fallow system (no fertilizer N applied) was 40% higher compared to the corn plots that received 120 lb N/A and 125% higher compared with the soybean plots.

Table 4. Tile water discharge from the corn, soybean, and fallow plots in 1996.

N application		Month			Year[1]
Time	Inhibitor	May	June	November	Total
		---------- acre-inches ----------			
				Corn	
Fall (11/6)	No	0.06	4.34	0.33	4.76
Fall (11/6)	Yes	0.08	3.20	0.48	3.82
Spring (5/1)	No	0.14	3.34	0.37	3.90
Spring (5/1)	Yes	0.00	2.45	0.18	2.68
				Soybean	
Fall (10/28/94)	No	0.11	2.82	0.36	3.29
Fall (10/28/94)	Yes	0.13	2.64	0.37	3.15
Spring (4/25/95)	No	0.05	2.46	0.36	2.87
Spring (4/25/95)	Yes	0.07	2.83	0.39	3.30
				Fallow	
NONE		0.04	2.33	0.21	2.70

[1] Includes two days of flow in December.

Table 5. Flow-weighted NO_3-N concentrations for each month from the corn, soybean, and fallow plots in 1996.

N application		Month			Year[1]
Time	Inhibitor	May	June	November	Average
		---------- NO_3-N (mg/L) ----------			
				Corn	
Fall (11/6)	No	10.7	14.4	8.9	14.1
Fall (11/6)	Yes	8.3	12.1	6.3	11.3
Spring (5/1)	No	9.6	13.6	8.1	12.8
Spring (5/1)	Yes	—	15.1	12.8	14.9
				Soybean	
Fall (10/28/94)	No	7.6	8.2	8.8	8.2
Fall (10/28/94)	Yes	8.5	7.1	8.6	7.3
Spring (4/25/95)	No	9.8	8.4	9.8	8.6
Spring (4/25/95)	Yes	10.0	8.4	10.0	8.6
				Fallow	
NONE		18.6	18.3	19.7	18.3

[1] Includes two days of flow in December.

Nitrate-N losses in the drainage water for 1996 varied considerably among the N treatments for corn, but losses under soybeans were not affected by the previous N treatments (Table 6). N-Serve reduced the NO_3-N losses by 5.2 lb/A when applied in the fall and by 2.0 lb/A when applied in the spring. Nitrate-N loss in the fallow system, where mineralization of soil organic matter was the NO_3 source, was similar to the average loss from the corn plots. 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 interpretation of the data (Table 7). Normalized values for corn were highest with the spring AA with N-Serve and fall AA without N-Serve treatments. Fall application of AA with N-Serve showed the lowest normalized value. Nitrate-N losses from the soybean plots as a function of the N treatments applied to corn in the previous year were considerably lower than from the corn plots. This probably reflects the low amount of residual N remaining from the 1994-95 treatments. Differences among the treatments were small, ranging from 1.58 lb NO_3-N/acre-inch of water for the fall AA with N-Serve treatment to 2.05 for the spring AA without N-Serve treatment. Normalized NO_3-N losses for the corn-soybean system ranked in the order: fall AA with N-Serve < spring AA without N-Serve = fall AA without N-Serve = spring AA with N-Serve. Continuous fallow gave the highest normalized loss of 4.0 lb NO_3-N/acre-inch of drainage. 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 1996.

N application		Month			Year[1]
Time	Inhibitor	May	June	November	Total
		---------- NO_3-N (lb/A) ----------			
		Corn			
Fall (11/6)	No	0.2	13.9	0.6	14.7
Fall (11/6)	Yes	0.2	8.7	0.6	9.5
Spring (5/1)	No	0.3	10.0	0.7	11.1
Spring (5/1)	Yes	0.0	8.4	0.5	9.1
		Soybean			
Fall (10/28/94)	No	0.2	4.9	0.6	5.7
Fall (10/28/94)	Yes	0.2	4.1	0.7	5.0
Spring (4/25/95)	No	0.1	4.9	0.9	5.9
Spring (4/25/95)	Yes	0.2	5.4	0.8	6.4
		Fallow			
NONE		0.2	9.2	0.9	10.8

[1] Includes two days of flow in December.

Table 7. "Flow-normalized" NO_3-N losses to tile drainage in a corn-soybean sequence in 1996.

Crop System[1]	Time/Method of N Application			
	Fall No Inhibitor	Fall Inhibitor	Spring No Inhibitor	Spring Inhibitor
	---------- NO_3-N lost (lb/acre-inch of drainage) ----------			
Corn	3.09	2.48	2.85	3.39
Soybean[2]	1.72	1.58	2.05	1.93
Corn-Soybean System	2.53	2.08	2.51	2.59

[1] Continuous fallow (10 years without fertilizer N) = 4.00
[2] N applied for the 1995 corn crop at 120 lb N/A.

Soil

Residual soil nitrate-N (RSN) remaining in the 0-4' profile in November was about 2 times greater in the fallow plots compared to the plots that received the six N treatments (Table 8). All N treatments contained slightly more RSN in the 4-ft profile compared with the check (no N) treatment. Slightly higher RSN was found in the urea treatment with little difference among the five AA treatments. About one-half of the RSN in the 4-ft profile was found in the top foot.

Table 8. Residual soil nitrate-N in November 1996 from all fallow and corn plots as influenced by N treatment.

Profile depth	Fallow NO_3-N	N Treatment for Corn						
		Fall AA	Fall AA+NI	PP AA	PP AA+NI	Urea	SD AA	Check (No N)
feet	--- lb/A ---	---------- lb/A ----------						
0 - 1	42	20	28	24	24	31	29	21
1 - 2	29	9	7	9	7	14	11	6
2 - 3	19	5	4	8	6	10	5	4
3 - 4	18	6	5	9	6	7	5	3
Total in 0 - 4' profile	108	40	44	49	42	62	50	33

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 5-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 and again in 1996 to determine the availability of residual N. Our results showed up to 8 percent recovery in 1996 from the fertilizer N applied in 1994. Three-year recoveries totaled 74, 64, and 57 percent for 400, 500, and 600 lb N/A rates, respectively. These results suggest that residual N can be effectively utilized by reed canarygrass and little residual nitrate 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 and 1996 yields were taken from selected N rates (Table 1) to evaluate the residual effects of N fertilization in 1994. A single treatment (300 annually) received 300 lb N/A as ammonium nitrate in 1994, 1995 and 1996. Yields were taken by harvesting a 3 ft by 19 ft swath from each plot on June 13, July 25, and September 13. Forage was analyzed for moisture content and total Kjeldahl N. The total N analyses were conducted by Dr. Russelle's Laboratory in St. Paul.

RESULTS AND DISCUSSION

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

Yield data, obtained in 1996 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 1996 (Table 1). First and second harvest and total (annual) yields were increased significantly by 1994 rates ≥400 lb N/A compared to the control (zero N). A 1994 rate of 600 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 increased significantly greater than the control by 1994 N rates ≥400 lb/A. The '300 annually' treatment (300 lb N/A in 1994, 1995, and 1996) had significantly greater total N concentration for all three cuts but did not result in greater dry matter yield and N removal. In general dry matter yields in 1996 were much lower than usual due to cold temperatures in May (4° F below normal), which resulted in reduced first cut yields, and very dry conditions from June 20 to August 5, which resulted in reduced second cut yields.

Table 1. Residual effects of N applied in 1994 on dry matter yield, total N, and N removal of reed canarygrass in 1996.

	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	0.210	0.280	0.154	0.645	1.35	1.46	1.73	5.7	8.3	5.3	19.3
300	0.335				1.36			8.9			
350	0.418				1.42			11.7			
400	0.654	0.517	0.237	1.408	1.29	1.56	2.00	16.6	16.1	9.6	42.3
500	0.662	0.569	0.273	1.504	1.66	1.75	2.03	21.8	20.0	11.1	52.9
600	0.938	0.490	0.453	1.881	1.60	1.72	2.17	29.8	17.0	19.9	66.7
300 Annually[1]	0.771	0.289	0.382	1.441	2.57	3.22	3.13	38.6	18.3	23.8	80.7
Statistical Analysis											
Pr. > *F*:	<0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD (0.05):	0.282	0.194	0.167	0.515	0.29	0.29	0.21	9.0	7.6	8.5	20.3
CV (%):	33	29	36	24	12	10	6	32	31	40	25

[1] 300 lb N/A applied annually in 1994, 1995 and 1996.

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, 1995 and 1996 (Table 2). First year (fertilization year) recoveries were lower in 1994 compared to previous years. Therefore, considerable residual N was expected for plant growth in subsequent years. Nitrogen removal and apparent N recovery in 1996 (two years after fertilization) were considerably less than in 1994 (fertilization year) and 1995 (one year after fertilization). The combined N recovery was calculated by adding the N recovery from 1994, 1995 and 1996. The combined (three-year) recoveries of 74 and 64 percent at N rates of 400 and 500 lb/A respectively, are similar to recoveries obtained at these N rates in 1993. A three-year recovery of 57 percent at the 600 lb/A N rate was considerably lower than the two-year recovery of 77 percent at that N rate applied in 1993 (data from 1995 Bluebook). Observations at 600 lb N/A in 1996 (lower combined N recovery and significantly greater 3rd cut yield) suggest that some residual N may be available at the this N rate for the 1997 growing season. However, since combined recoveries were considerably lower than first year recoveries in 1992 and 1993, some N was probably immobilized or lost from the rooting zone.

Table 2. Annual N removal and apparent recovery of fertilizer N by reed canarygrass in 1996 as affected by N rate in 1994.

	Total Annual N Removal			Apparent N Recovery[1]			
1994 Total N Rate	1994	1995	1996	1994	1995	1996	Combined[2]
-- lb N/A --	-------- lb N/A --------			--------- percent ---------			
0	84	39	19	–	–	–	–
400	230	166	42	36	32	6	74
500	241	167	53	31	26	7	64
600	246	171	67	27	22	8	57

[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, 1995 and 1996.

Recommendation

This report concludes five 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.

EVALUATING SOIL N TEST METHODS ON A FIELD WITH A MANURE HISTORY

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

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. Results from this trial indicate that the recommended rate of fertilizer N would have been improved at this site if a preplant, 0-2 foot soil sample would have been taken. This test would have suggested a 65-lb N credit from the 100-lb recommendation based on past crop, soil organic matter, and yield goal. The resulting 35-lb N recommendation would have optimized grain yield, which agrees extremely well with the data obtained.

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

The site for 1996 was a Nicollet clay loam soil at the Southern Experiment Station in Waseca. This site had been cropped to alfalfa in 1992-4 and corn in 1995. It received 10000 gal/acre of dairy manure in the spring of 1995.

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. A randomized complete block design with four replications was used for the experiment. Pioneer 3730 was planted on April 30 and thinned to a uniform population of 31050 plants per acre. Weeds were controlled very well with a combination of herbicides and cultivation.

Grain yields were combine harvested by taking 89 feet of row. Stover yields were hand harvested by taking 15 feet of row at physiological maturity.

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

Chlorophyll measurements were taken each week from the V9 stage of growth through R3. Thirty plants in each plot were measured and the average reported. SPAD meter values were normalized by calculating the relative value based on the highest treatment reading being equal to 100 percent.

RESULTS AND DISCUSSION

Corn yields were very good despite cool spring temperatures (Table 1). Statistical analyses showed that grain yields were optimized at the 30-lb N rate. Stover and silage yields increased with increasing N rate up to 150 and 180 lb N/acre, respectively. Stover and grain N concentration was optimized at 120 and 180 lb N/A, respectively. Removal of N in the stover, grain, and silage was optimized at the 150, 180, and 180-lb N rates, respectively. These rates are surprisingly high considering that grain yield was optimized with only 30 lb N/A. However, because stover yields continued to increase with N rates through 150 lb/A and N concentrations in the grain increased with increasing N rate, N removal by the plant did not reflect an economic grain yield response. The reason for this disagreement, which is rather unusual, may be that this hybrid continues to accumulate N at higher rates of applied N even though grain yield does not respond - - at least under the weather conditions encountered in 1996. Relative chlorophyll content throughout the season suggests that corn production was optimized at the 60-lb N rate, based on other studies where relative values greater than 95% indicated optimum yields.

1/ Professor, Southern Experiment Station, Waseca; Assoc. Professor, Dept. of Soil, Water, and Climate, St. Paul; and Assistant Scientist, Southern Experiment Station, Waseca.

Table 1. Corn grain yield, silage yield, and relative chlorophyll content as influenced by N applied to fields with a manure history in 1996.

N Rate	Yield			N Conc.		N Removal			Relative Chlorophyll Content[1]					
	Grain	Stover	Silage	Stover	Grain	Stover	Grain	Silage	V9	V12	R1	R2	R2-3	R3
lb/A	bu/A	- T DM/A -		- percent -		--- lb/A ---			---------- percent ----------					
0	165	2.90	6.81	0.70	1.16	41	90	131	91	95	89	88	87	87
30	177	3.31	7.50	0.67	1.20	44	100	144	94	98	93	90	94	93
60	176	3.45	7.61	0.69	1.37	48	114	162	98	96	96	93	97	96
90	166	3.62	7.55	0.72	1.39	52	109	161	97	97	97	96	98	97
120	177	3.70	7.90	0.82	1.39	61	117	178	100	100	98	98	100	99
150	176	3.83	7.99	0.84	1.40	64	117	181	97	98	100	96	99	100
180	185	4.00	8.37	0.91	1.55	72	133	200	99	98	100	100	99	99
Pr. > *F*:	0.09	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD (0.10):	11	0.29	0.35	0.09	0.10	9	12	12	3	2	2	3	2	2
CV (%):	5	7	4	10	6	13	9	6	3	2	1	3	1	2

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

Soil NO_3-N analysis (Table 2) indicated carryover of nitrate-N throughout the 0- to 3-ft profile at the preplant sampling. Residual N values from samples taken at emergence and when the corn was about 10 inches tall were similar to the preplant N concentrations at the 2-3 foot depth only. Residual soil nitrate-N (RSN) in the surface foot was somewhat lower at the later sampling times suggesting some had been leached to lower depths, denitrified and/or taken up by the crop (10 inch corn). Carryover of RSN in the 0- to 4-ft profile at the end of the 1996 season was very low in the 0 and 90-lb N treatments with a slight accumulation at the 180-lb rate. It is interesting to note the higher NO_3-N concentrations below two feet, which suggests that some of the excess N applied was being leached from the upper portion of the profile.

Table 2. Soil NO_3-N as influenced by time and depth of sampling in a field with a manure history in 1996.

Sampling		Soil Nitrate-Nitrogen (Depth)					
Time	N Rate	0 - 1'	1 - 2'	2 - 3'	3 - 4'	0 - 2'	0 - 4'
	lb/A	---------- ppm ----------					lb NO_3-N/A
Preplant	0	9.6	9.7	9.1	6.8	9.6	141
V1 (emergence)	0	6.3	8.3	9.7		7.3	
V4 (10 inch corn)	0	5.6	8.5	8.6		7.0	
Post Harvest	0	4.2	1.4	0.6	1.5		30
"	90	3.7	2.2	2.3	3.9		48
"	180	5.5	5.4	6.8	6.5		97

SUMMARY

- Even though corn yields were quite good, the yield response of continuous corn to fertilizer N was limited in this field 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.

ENHANCING NO-TILLAGE SYSTEMS FOR CORN WITH STARTER FERTILIZER, ROW CLEANERS AND NITROGEN PLACEMENT METHODS[1]

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

ABSTRACT: No-till production often gives slower corn growth, lower yields, and reduced profitability in the northern Corn Belt. A 2^3 factorial experiment was conducted on a tile drained Nicollet-Webster clay loam soil complex in 1996 to determine the effect of starter fertilizer, row cleaners, and N source/placement method on no-till production of continuous corn and corn after soybeans. Surface residue coverage prior to planting was >95% in both cropping systems and did not fall below 50% in late August in either system. Corn emergence was very slow due to cold soil temperatures in May but was enhanced about 1 to 2 days by the use of row cleaners in the continuous corn system. Midden counts, an indication of night crawler activity, were very low in continuous corn but increased to high levels in the corn-soybean rotation. Fewer middens were found with anhydrous ammonia (AA) compared to spoke-wheel injected UAN. Starter fertilizer (10 gal 10-34-0/acre) decreased final stand about 3 to 5% for both cropping systems. Early growth of continuous corn was stimulated by starter fertilizer and yields were increased 8.3 bu/acre when using AA as the N source but not when UAN was spoke-injected next to the row. Row cleaners increased continuous corn grain yield 4.6 bu/acre but had no effect on corn yields following soybeans. Corn yields following soybeans were not affected by N source or starter fertilizer. Preplant application of UAN + Agrotain reduced continuous corn yields by 7.5 bu/acre and corn yields following soybeans by 10.3 bu/acre compared to UAN spoke-injected at the V1 stage.

INTRODUCTION

No-till corn production in the northern portions of the Corn Belt has provided serious challenges to corn growers and often has not been economically competitive with conventional or slightly reduced tillage systems. This is especially true on the highly productive but more poorly drained clay loam soils of northern Iowa and southern Minnesota where approximately 8 million acres of corn are grown. These soils are cold at the time of planting and are slow to warm. Due to slow root development, early plant growth is retarded and delayed silking, high moisture at maturity, and reduced corn yields result. These systems and their effects occur most frequently with continuous corn but also are noticeable and do impact corn following soybeans. Yet, to meet guidelines of 30% surface crop residue coverage after planting on highly erodible land, no tillage is required following soybean. Thus, no tillage is strongly advocated by the USDA-NRCS on these soils and is promoted actively on soils that have less erosion potential.

Three management options may correct these problems or at least help no-till corn production to be more competitive. First, fluid starter fertilizer (10-34-0) placed with the seed as a "pop-up" may help stimulate early root and shoot growth, thereby allowing the plant to capture more sunlight energy in June for earlier maturity and higher yields. Second, using row cleaners to clear the residue from a 4 to 6" zone over the row should allow greater warming of the soil in the seed zone and better seed to soil contact to improve emergence. Third, placement of fluid UAN within 2 to 3" of the row with a spoke-wheel injector may stimulate early plant growth compared to injection of N midway between the rows.

The primary objective of the project is to determine the effects and interactions of starter fertilizer, row cleaners, and N source/placement method on corn grain yield in continuous corn and corn-soybean rotation no-till cropping systems. A secondary objective is to evaluate preplant, broadcast-applied UAN with Agrotain compared to post emergence, spoke-wheel injected UAN in both cropping systems.

EXPERIMENTAL PROCEDURES

The experiments were conducted on a tile drained Nicollet-Webster clay loam soil complex located at the Southern Experiment Station, Waseca, Minnesota. The tile lines were spaced 75' apart and all corn rows were perpendicular to the tile lines. The continuous corn plots were located on the same plots as in 1995, and the stalks had not been chopped. Corn also followed soybeans that had been planted in 1995 and corn in 1994. Each plot was 10' wide (4 - 30" rows) by 120' long. The experimental design was a 2^3 factorial with complete randomization within each of the four replicates. The UAN + Agrotain treatment was randomized within the other eight treatments and was compared to treatment No. 7 using contrast statistics.

Corn (Pioneer 3556) was planted on May 2 at a population of 32000 plants/acre with a John Deere Max-Emerge planter equipped with 1" fluted coulters. Row cleaners (Dawn) were used on one-half of the plots. Fluid 10-34-0 was applied with the seed at a rate of 10 gal/acre on one-half of the plots. Additional P was not applied because soil test Bray P_1 was 26 and 30 ppm (very high) on the continuous corn and corn-soybean rotation sites, respectively. Force insecticide was used to control corn root worm in the continuous corn. Weeds were very well controlled with a preemergence application of Harness plus Bladex. None of the plots were cultivated.

---

[1] Funding provided by the Fluid Fertilizer Foundation and the University of Minnesota, Southern Experiment Station.
[2] Assistant Scientist and Professor, respectively, University of Minnesota, Southern Experiment Station.

Nitrogen as UAN (28% N) was broadcast applied with Agrotain to treatment No. 9 on April 18. At the V1 stage (May 31) UAN was spoke-wheel injected 4" deep about 2 to 3" from the row on one-half of the plots whereas anhydrous ammonia (AA) was injected about 7" deep midway between the rows. The N rate used was 160 lb N/acre for continuous corn and 120 lb N/acre for corn after soybeans.

Surface residue measurements using the line transect method were taken at a 45° angle to the rows periodically during the season. Emergence rate was determined by daily counting the number of plants that had emerged from 30 feet of row in each plot. This was done until no more plants emerged (June 12). Final plant population was determined from 120 feet of row in each plot on June 21. Middens, a small hut formed from residue around a night crawler's burrow, were counted in a 10 ft^2 area in each plot at four times during the season. Extended-leaf plant heights were determined from 10 plants per plot on July 1. Grain yields and moisture content were taken on October 21 by harvesting the center two rows of each plot with a JD3300 plot combine. The stalks were not chopped prior to snowfall in November.

RESULTS

Continuous Corn

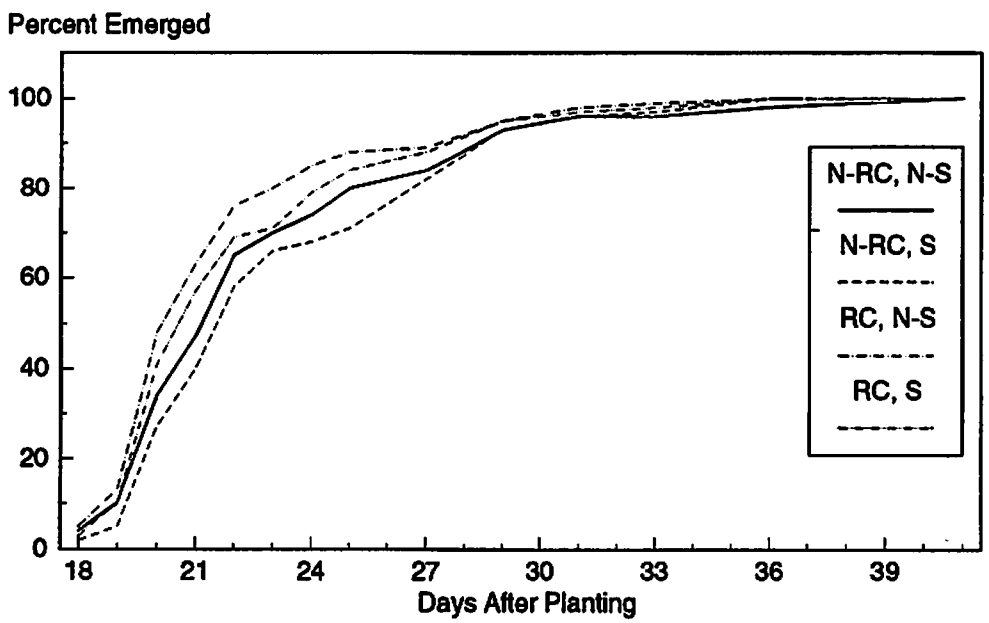
Surface residue coverage was extremely high throughout the season and is reflective of the high yields of very durable stover produced by the hybrid grown in 1994 and 1995 (Table 1). Coverage totaled nearly 100% on April 11 and decreased to about 70% by August 30. At the time of corn emergence coverage averaged about 90%. Residue cleaners did not have a lasting effect on clearing the residue from the row. High winds redistributed some of the residue back on the row before measurements were taken. Residue coverage was less after N application where AA was knifed in compared to the spoke wheel injection of UAN.

Table 1. Surface residue accumulation as influenced by row cleaners and method of N application in continuous corn and corn-soybean no-till cropping systems in 1996.

Trt. No.	N Source	Row Cleaner	Continuous Corn Date 4/11	5/30	7/17	8/30	Corn after Soybean Date 4/11	5/30	7/11	8/30
			%				%			
3	UAN	No	100	95	94	74	97	85	77	57
4	AA	No	98	91	77	64	97	77	58	53
7	UAN	Yes	99	98	92	74	98	81	74	60
8	AA	Yes	99	90	77	70	96	80	63	46
9	UAN	Yes	98	90	90	72	97	76	77	61

Corn emergence was very slow in 1996 due to cold temperatures in May (Figure 1). Soil temperature at the 2-inch depth on residue-free soil averaged only 56.1°F for the month. Corn did not begin to emerge until 18 days after planting and continued to emerge during the following 12-day period. Row cleaners resulted in 1 to 2-day earlier corn emergence. Starter fertilizer delayed corn emergence about 1 day.

Figure 1. Emergence rate of continuous corn as influenced by row cleaners and starter fertilizer in 1996.



Midden counts were extremely low in all continuous corn plots through July (Table 2). Counts were not taken again in 1996 because they were so low, indicating almost a complete lack of night crawler activity.

Plant heights, taken on July 1, were significantly increased about 2 inches by spoke-wheel injected UAN, row cleaners, and starter fertilizer compared to injected AA, no-row cleaners, and no starter fertilizer (Table 3). The highly significant interaction between N source and starter fertilizer was due to no increase in plant height with starter fertilizer when UAN was used but a 4.5" increase for starter fertilizer when AA was used. Apparently the N in the spoke-wheel injected UAN stimulated early plant growth and starter fertilizer was not necessary. Starter fertilizer, however, did enhance early growth when AA was applied 15" from the row.

Final plant population was not directly affected by N source or row cleaner use (Table 3). Starter fertilizer reduced plant population by 3% (850 plants/acre) when averaged across row cleaners and N sources. The significant interaction between N source and row cleaners was due to the plant population being 1200 plants/acre lower when row cleaners were not used and UAN was applied; however, when AA was applied, row cleaners had no effect on population.

Grain yield was increased 4.6 bu/acre with the use of row cleaners when averaged across N sources and starter fertilizer (Table 3). The main effects of N source and starter fertilizer did not affect corn grain yield; however, the interaction was highly significant. When UAN was used, yield was not affected by starter fertilizer. On the other hand, an 8.3 bu/acre response to starter was obtained when AA was used. Preplant broadcast application of UAN + Agrotain resulted in a statistically significant yield decrease of 7.5 bu/acre compared to the spoke-wheel application of UAN.

Table 2. Midden counts as influenced by row cleaners and method of N application in continuous corn and corn-soybean rotation no-till cropping systems in 1996.

Trt. No.	N Source	Row Cleaner	Continuous Corn Date 4/11	5/30	7/17	Corn after Soybean Date 4/11	5/30	7/11	8/30
			- - - - - - - - - - Middens/10 sq. feet - - - - - - - - - -						
3	UAN	No	0.1	0.3	0.0	2.4	5.3	9.5	19.0
4	AA	No	0.4	0.0	0.1	2.8	7.1	4.6	12.5
7	UAN	Yes	0.6	0.4	0.4	3.0	7.9	8.3	21.9
8	AA	Yes	0.3	0.3	0.1	2.4	6.5	3.5	13.4
9	UAN	Yes	0.5	0.8	0.3	3.6	9.0	9.8	23.1

Grain moisture was one-half point lower with the use of starter fertilizer when averaged across N sources and row cleaners (Table 3). Similar to grain yield, a highly significant interaction occurred between N source and starter fertilizer. Grain moisture was one point lower when starter fertilizer was used with AA, but moisture was not affected by starter fertilizer when UAN was used.

Nitrogen concentration in the corn grain was not affected by treatment main effects (N source, row cleaner, and starter fertilizer). The significant interaction between N source and row cleaner (P value 0.053) was a result of greater N concentration in the corn grain with UAN when row cleaners were not used compared to greater N concentration in the grain with AA when row cleaners were used. Grain N uptake was not affected by treatment application.

Corn-Soybean Rotation

Surface residue coverage was very high throughout the season because both soybean residue from 1995 and corn residue from 1994 were present (Table 1). Similar to continuous corn, wind redistributed the residue after planting, and measurements taken 4 weeks after planting showed no effect of row cleaners on surface residue coverage. Measurements taken 6 weeks after N application show consistently lower residue coverage with the AA treatment. At the end of August residue coverage still exceeded 50% and was consistently higher for the spoke-injected UAN treatments.

Corn emergence started 18 days after planting and was complete within a 10-day period (Figure 2). Emergence rate was not influenced by row cleaners or starter fertilizer.

Midden counts, an indication of night crawler activity, were much higher in the corn-soybean rotation compared to continuous corn and continued to increase during the season (Table 2). Prior to N application, no consistent differences were evident among the treatments. However, after N application midden counts were substantially lower for the AA plots compared to the UAN plots. This was likely due to the disturbance of their habitat by the knife injection of AA and possibly some mortality associated with the caustic nature of AA.

Figure 2. Emergence rate of corn following soybeans as influenced by row cleaners and starter fertilizer in 1996.

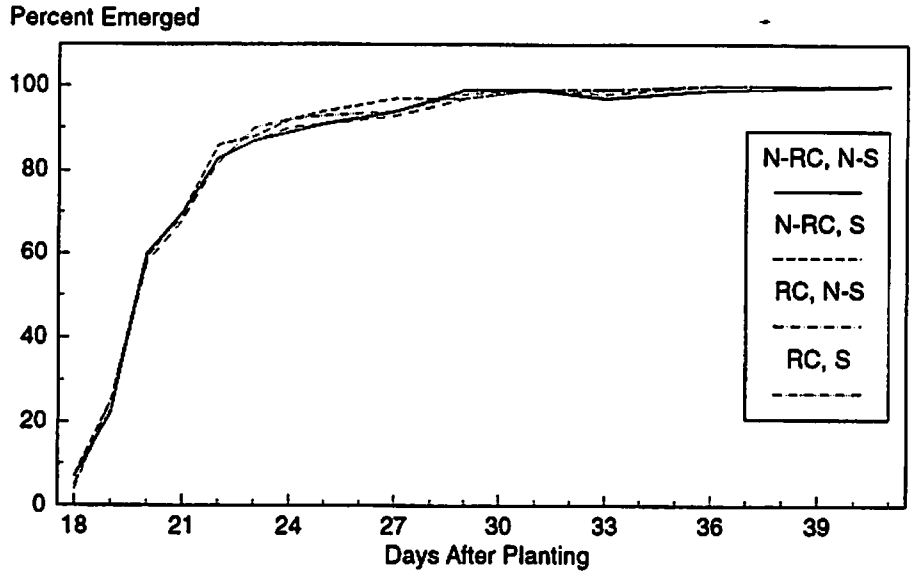


Table 3. Plant height, final population, corn grain yield, grain moisture, grain N concentration, and N uptake as affected by N source, row cleaners, and starter fertilizer in a no-till continuous corn system in 1996.

Treatments				Plant		Corn Grain			
No.	N Source	RC	SF	Height	Population	Yield	Moist.	N	N Up.
				inch	pl/acre	bu/acre	%	%	lb/acre
1	UAN	No	No	31.4	27100	130.1	21.2	1.12	69.0
2	AA	No	No	28.1	29060	126.9	21.8	1.07	64.0
3	UAN	No	Yes	31.2	26100	128.0	21.4	1.15	69.4
4	AA	No	Yes	31.4	27120	135.7	21.1	1.11	71.3
5	UAN	Yes	No	34.4	28350	137.5	20.9	1.07	68.9
6	AA	Yes	No	28.4	27150	129.3	22.1	1.17	71.5
7	UAN	Yes	Yes	34.3	27280	135.1	21.0	1.11	71.1
8	AA	Yes	Yes	34.0	27730	137.1	20.8	1.18	76.3
9	UAN Bdct	Yes	Yes	33.6	27770	127.6	20.8	1.11	67.1
Statistical analysis of main effects for 2^3 factorial design									
N Source (NS)									
UAN				32.8	27210	132.7	21.1	1.11	69.6
AA				30.5	27760	132.3	21.4	1.13	70.8
Pr. > F:				<0.001	0.156	0.830	0.093	0.527	0.544
Row Cleaner (RC)									
No				30.5	27340	130.2	21.4	1.11	68.4
Yes				32.8	27630	134.8	21.2	1.13	72.0
Pr. > F:				<0.001	0.459	0.025	0.273	0.502	0.075
Starter Fertilizer (SF)									
No				30.6	27910	131.0	21.5	1.10	68.4
Yes				32.7	27060	134.0	21.0	1.14	72.0
Pr. > F:				<0.001	0.034	0.126	0.019	0.326	0.066
Statistical analysis of interaction effects for 2^3 factorial design									
NS x RC (Pr. > F)				0.141	0.023	0.174	0.371	0.053	0.161
NS x SF (Pr. > F)				<0.001	0.646	0.011	0.005	0.843	0.222
RC x SF (Pr. > F)				0.273	0.120	0.861	0.336	0.874	0.927
NS x RC x SF (Pr. > F)				0.325	0.101	0.922	0.533	0.634	0.575
C.V. (%)				4.7	3.9	4.1	2.4	7.8	7.6
Contrast analysis of treatment 7 vs 9									
Injected vs Bdct. (Pr. > F)				0.497	0.496	0.051	0.621	0.905	0.306

Plant heights, taken on July 1, were about 4 inches higher for the starter fertilizer treatments when averaged across N source and row cleaner treatments (Table 4). Neither N source nor row cleaner affected plant height, and there were no significant interactions among N source, row cleaners, or starter fertilizer.

. ıant population was not affected by N source or row cleaner use, but similar to continuous corn, it was reduced about 5% (1400 plants/acre) with starter fertilizer when averaged across N sources and row cleaners (Table 4).

Corn grain yield following soybeans was not affected by N source, row cleaners, or starter fertilizer (Table 4). However, yields averaged about 28 bu/acre more than did continuous corn. Preplant broadcast application of UAN + Agrotain resulted in a statistically significant yield decrease of 10.5 bu/acre compared to the spoke-wheel injection of UAN. This was similar to the continuous corn plots and suggests that broadcast UAN may be immobilized by the high amount of residue on the soil surface.

Grain moisture content at harvest was not affected by any of the treatments.

Nitrogen concentration in the corn grain was not affected by treatment main effects (N source, row cleaner, and starter fertilizer). The significant interaction between N source and starter fertilizer (P = 0.047) occurred because grain N concentration was not affected by starter fertilizer when UAN was used; whereas grain N increased 0.09 percentage points with starter fertilzier when AA was used.

Table 4. Plant height, final population, corn grain yield, grain moisture, grain N concentration, and N uptake as affected by N source, row cleaners, and starter fertilizer in a no-till corn-soybean rotation in 1996.

Treatments				Plant		Corn Grain			
No.	N Source	RC	SF	Population	Height	Yield	Moist.	N	N Up.
				pl/acre	inch	bu/acre	%	%	lb/acre
1	UAN	No	No	29090	34.5	158.2	23.1	1.15	85.6
2	AA	No	No	28660	32.3	160.4	23.0	1.18	89.0
3	UAN	No	Yes	27390	37.0	158.3	23.0	1.14	84.9
4	AA	No	Yes	27620	37.9	163.8	23.2	1.24	96.2
5	UAN	Yes	No	28550	34.7	158.2	22.9	1.21	90.7
6	AA	Yes	No	29370	33.6	160.8	23.2	1.12	84.9
7	UAN	Yes	Yes	27230	38.1	163.8	22.3	1.18	91.8
8	AA	Yes	Yes	27860	37.2	159.5	22.7	1.23	92.4
9	UAN Bdct	Yes	Yes	27720	38.5	153.3	22.3	1.19	85.8
Statistical analysis of main effects for 2^3 factorial design									
N Source (NS)									
UAN				28060	36.1	159.6	22.8	1.17	88.3
AA				28380	35.2	161.1	23.0	1.19	90.7
Pr. > F:				0.454	0.150	0.478	0.376	0.406	0.366
Row Cleaner (RC)									
No				28190	35.4	160.2	23.1	1.17	88.9
Yes				28250	35.9	160.6	22.8	1.18	90.0
Pr. > F:				0.886	0.380	0.854	0.283	0.685	0.686
Starter Fertilizer (SF)									
No				28920	33.7	159.4	23.0	1.16	87.6
Yes				27520	37.6	161.4	22.8	1.20	91.3
Pr. > F:				0.003	<0.001	0.365	0.327	0.197	0.157
Statistical analysis of interaction effects for 2^3 factorial design									
NS x RC (Pr. > F)				0.324	0.734	0.266	0.547	0.083	0.067
NS x SF (Pr. > F)				0.769	0.150	0.682	0.682	0.047	0.182
RC x SF (Pr. > F)				0.955	0.602	0.924	0.283	0.829	0.839
NS x RC x SF (Pr. > F)				0.606	0.175	0.235	0.866	0.551	0.888
C.V. (%)				4.1	4.3	3.7	3.2	6.2	8.1
Contrast analysis of treatment 7 vs 9									
Injected vs Bdct. (Pr. > F)				0.540	0.740	0.020	1.000	0.960	0.229

THE EFFECTS OF RESIDUE MANAGEMENT AND HERBICIDE APPLICATION METHODS ON LOSS OF AGRICULTURAL CONTAMINANTS IN SURFACE WATER [1]

N.C. Hansen, J.F. Moncrief, and S.C. Gupta [2]

ABSTRACT

Tillage and herbicide application method are being evaluated on runoff plots in Scott County, Minnesota. This report includes the first and second years of a three year continuous corn study in which runoff losses of sediment, herbicides, phosphorus, and chemical oxygen demand are being evaluated. Tillage treatments are moldboard plow, chisel plow, and ridge tillage and the preemergent herbicides alachlor and cyanazine are applied by broadcasting or banding methods. Tillage effects on runoff and contaminant loss differed between snowmelt and rainfall induced runoff. Snowmelt runoff represented the largest fraction of annual runoff and was in the order of ridge till>chisel plow>moldboard plow. For rainfall induced runoff, the order was moldboard plow>chisel plow>ridge till. Surface residue associated with the ridge till and chisel plow systems was effective in reducing soil loss, especially following planting and before canopy closure. Phosphours loss in rainfall runoff was lower from the ridge till system than from the other tillage systems but on an annual basis the three tillage systems lost similar amounts of total P. For ridge tilled plots the majority of P loss was lost as soluble P in snowmelt runoff, while for chisel and moldboard plowed plots, P losses came from snowmelt and rainfall induced runoff. Total loss of COD was lower in the ridge till system than in the chisel and moldboard plow systems.

Banding of herbicides significantly reduced herbicide loss for the moldboard and chisel plow systems. Losses from the ridge till system were low regardless of application method. Following cultivation, weed control was similar for both herbicide application methods, and yield did not differ. However, if cultivation was not performed, high weed pressure and yield losses would be expected when herbicides are applied in a band. For broadcast application, runoff losses of alachlor and cyanazine were in the order of moldboard plow > chisel plow > ridge till. Thus, herbicide banding and/or conservation tillage are effective management tools for reducing herbicide losses to surface runoff.

INTRODUCTION

Contamination of surface and ground waters from sediment and land applied agricultural chemicals is a significant concern. Among the contaminants, nitrate, phosphorus, and sediment have received the most attention. The primary concern with the Minnesota River is biochemical oxygen demand (BOD), phosphorus (P), and suspended solids primarily from diffuse sources during high flow years. Several high use herbicides have been detected in the Minnesota River and its tributaries. Use of tillage approaches that manage crop residue, such as no-till, ridge till, and chisel plowing systems, have been promoted for sustainable production and for reducing runoff and contaminant losses from agricultural fields. These methods are effective in reducing upland erosion during the critical period between planting and canopy development and therefore reducing the contribution of sediment to streams and rivers. This study was designed to assess the impact of moldboard plowing vs. ridge tilling or chisel plowing on runoff and loss of sediment, herbicides, phosphorus, oxygen demand. The specific objectives of this study are

1. To compare runoff, contaminant loss, and yields from plots managed with moldboard plow, chisel plow, or ridge till based systems.
2. To evaluate seasonal differences in runoff and contaminant losses from various tillage systems.
3. To assess and demonstrate the impacts of herbicide application method on the loss of pesticides in surface water.

MATERIALS AND METHODS

The plots are located on the Ed Nytes farm in Scott County, Minnesota. They are situated on a cropped hillslope with southerly aspect and 10% slope. The field drains into Raven Creek, a tributary of Sand Creek in the Lower Minnesota River basin. Soil types at the site are Clarion silt loam (Typic Hapludoll, fine-loamy, mixed, mesic) and a Lakeville-Burnsville gravely sandy loam (Typic Hapludalfs, coarse-loamy, mixed, mesic). In 1995, eight rectangular runoff plots were established. Treatments were ridge

[1] Support for this project was provided by the Metropolitan Council. Their support is greatly appreciated.
[2] N.C. Hansen is a graduate student and J.F. Moncrief and S.C. Gupta are professors in the Department of Soil Water and Climate at the University of Minnesota, St. Paul, MN 55108

MATERIALS AND METHODS

The plots are located on the Ed Nytes farm in Scott County, Minnesota. They are situated on a cropped hillslope with southerly aspect and 10% slope. The field drains into Raven Creek, a tributary of Sand Creek in the Lower Minnesota River basin. Soil types at the site are Clarion silt loam (Typic Hapludoll, fine-loamy, mixed, mesic) and a Lakeville-Burnsville gravely sandy loam (Typic Hapludalfs, coarse-loamy, mixed, mesic). In 1995, eight rectangular runoff plots were established. Treatments were ridge till and moldboard plow in combination with broadcast or band herbicide application methods. In 1996, twelve plots were established and treatments were ridge till, moldboard plow, and chisel plow in combination with broadcast or band herbicide application. For both years tillage was done up and down the slope. Treatments were replicated twice and arranged in a randomized complete block design. Each plot was 10 feet wide and 70 feet long up and down the slope. Plots are bordered on the top and two sides with corrugated sheet metal driven vertically four inches into the soil and overlapping adjacent sheets to prevent leakage into or out of the plots. Galvanized steel runoff collectors are installed on the downslope end of each plot to collect and channel runoff into a four inch PVC pipe. The pipe delivers water to a tipping bucket flow meter that is monitored with magnetic closure switches and a datalogger (Campbell Scientific CR10). Composite runoff samples from each plot were taken for each event in both a one gallon glass collection bottle (for herbicide analysis) and a 6 gallon plastic container (for phosphorus, oxygen demand, and sediment determinations).

Water samples were retrieved immediately following each runoff event and determinations are made for total sediment, total phosphorus, soluble phosphorus, chemical oxygen demand, and herbicide concentrations. Sediment trapped in the collection pans and tipping buckets was also collected, dried, and weighed following each event. Total solids were determined gravimetrically on evaporated sample aliquots. Chemical oxygen demand was determined using the accu-TEST COD method. Soluble P determination was made colorametrically on prefilterd samples (0.45 um). Total P was determined colorametrically on samples following a complete nitric/perchloric acid digestion. Aqueous phase herbicide isolation was by prefiltration with Whatman GFF glass fiber filters followed by C-18 solid phase extraction. Analysis was performed using high resolution, fused silica capillary gas chromatography coupled with a mass spectrometer. The liquid phase fraction generally represents 80-90% of total herbicide loss for alachlor and cyanazine.

Corn was planted on May 20, 1995 (Pioneer 3737) and May 02, 1996 (Pioneer 3751). Alachlor (lasso) and cyanazine (bladex) were applied on May 24, 1995 and May 17, 1996 by either banding or broadcasting. Applications were made with a CO_2 backpack sprayer at a delivery rate of 20 gallons per acre. Broadcast application was made using Delvan 80° flat fan nozzles and the rates were 2.0 quarts a.i./acre for alachlor and 1.8 quarts a.i./acre for cyanazine. Banded application was done in a ten inch band over the 30 inch row and application rates were one third of the broadcast rates. All treatments were cultivated one time on July 05, 1995 and on June 26, 1996.

Rain depth and intensity were monitored with a tipping-bucket rain gauge. Snow depth and density were determined manually with a snow tube throughout winter and spring. Percent residue cover and percent weed cover is measured by the NRCS line transect method before and after planting and cultivation. Yield was assessed by hand harvesting two 30 foot rows for each plot.

RESULTS AND DISCUSSIONS

Precipitation and Runoff

Total rainfall recorded on site from the period of March 10 to December 31, 1995 was 24.0 inches, resulting in 16 individual runoff events. Total depth of runoff for this time period averaged 1.6 inches for moldboard plowed plots and 0.88 inches for ridge till plots. Figure 1 shows the cumulative rainfall and runoff hydrographs for both tillage treatments. Volume of runoff was not affected by herbicide application method. The 1995 cumulative runoff is dominated by the snowmelt event (March 10-12) and a high intensity rainfall event occurring shortly after planting (June 07). For the snowmelt event, runoff averaged 0.30 inches from ridge till plots and 0.03 inches from moldboard plowed plots. Ridge tilled plots retained two times more snow on the surface than the moldboard plowed plots and had ten times the volume of runoff. Moldboard plowing minimizes snowmelt runoff by leaving a rough surface with large surface depressional storage. Ridges trap more snow and have little storage area when ridges are built parallel to the slope. The snowmelt event of March 10 does not represent the total snowmelt for 1995 because the plots were installed after the major snowmelt events for that year. The June 07 runoff event resulted from a 1.5 inch rain storm occurring in less than one hour and is the most intense rain event that has occurred during this study. This event occurred after planting and before canopy closure, which corresponds to the period of highest susceptibility to erosive loss. Average runoff from the moldboard plowed plots for this event was 1.0 inches and for ridge tilled plots was 0.5 inches.

For 1996, annual rainfall was below average at 23.3 inches. Runoff for 1996 averaged 7.6 inches for ridge tilled plots, 6.8 inches for chisel plowed plots, and 3.2 inches for moldboard plowed plots (figure 1). Snowmelt runoff was 90 percent of the annual total for ridge tilled and chisel plowed plots and 80 percent for moldboard plowed plots. Moldboard plowed plots had less runoff than the other tillage systems because runoff is limited by surface roughness prior to planting. However, for events just after planting in early May, runoff from moldboard plowed plots was greater than for ridge tilled and chisel plowed plots (figure 2). These differences were less significant later in the summer. This illustrates that residue cover is effective in reducing runoff during the critical period following planting and prior to canopy closure. Although runoff after planting is less than 10% of annual runoff, this corresponds to the period of greatest susceptibility to erosion and herbicide losses. In general, the volume of runoff from ridge tilled and chisel plowed plots was greater than for moldboard plowed plots during snowmelt events and rain induced events prior to planting. Following planting, runoff volume was in the order of moldboard>chisel>ridge till and was inversely related to the percent surface residue cover left by each tillage system (Table 1).

Table 1. Percent cover between crop rows of moldboard plowed, ridge tilled, and chisel plowed plots. Determination were made using the NRCS line transect method on April 01, June 15, and September 14 for 1995 and April 26, June 25, and July 23 for 1996.

		Pre-plant %	Post-plant/ Pre-cultivation %	Post-cultivation %
1995	Moldboard	13	7	1
	Ridge till	96	89	29
1996	Moldboard	10	18	14
	Ridge till	93	63	50
	Chisel plow	40	33	21

Erosive Loss

Total solids lost from plots during 1995 averaged 6000 lbs/acre for moldboard plowed plots and 560 lbs/acre for ridge tilled plots (figure 3). The June 07 event dominated annual sediment loss and illustrates the effectiveness of crop residue in reducing erosion during high intensity rainfall events. This event also illustrates that the most severe soil loss occurs from single intense rainfall events. For the June 07 event, runoff volume from ridge till plots was half that of moldboard plow plots and sediment concentration was four times less. Runoff events occurring during June were responsible for 98 % of the annual loss of sediment from moldboard plowed plots. For ridge tilled plots, sediment loss during the snowmelt event was a significant portion of the annual total.

For 1996, the loss of total solids was 1900 lbs per acre for moldboard plowed plots, 1400 lbs per acre for chisel plowed plots, and 780 lbs per acre for ridge tilled plots (figure 3). Soil loss in 1996 was less than in 1995 because 1996 was drier than 1995 and spring precipitation was not as intense. However, a large percentage of soil loss still occurred in the month of June. The ridge till system was very effective in reducing erosion during this critical period while the chisel plow system was less effective but was better than the moldboard plow based system.

Phosphorus Loss

Loss of soluble P from moldboard plowed plots averaged 0.23 lbs/acre during the 1995 experimental period, while ridge till plots averaged 0.17 lbs/acre (figure 4). Concentrations of soluble P during snowmelt runoff were relatively high for both tillage systems and the high runoff volume from ridge tilled plots contributed a substantial fraction of the annual P loss. In rainfall induced runoff events, lower runoff volume for ridge tilled plots than for moldboard plowed plots was offset by higher concentrations of soluble P. In reduced tillage systems such as ridge till, the surface soil can have elevated P levels due to lack of incorporation and the residue can also be a source of soluble nutrients in runoff water. On four individual events, loading of soluble P from ridge till plots exceeded that from moldboard plots despite a smaller volume of runoff. Loss of total P (for 11 events between 6/6 and 9/30) was 3.3 lbs/acre for moldboard plowed plots and 0.65 lbs/acre for ridge tilled plots (figure 5). In 1995, the majority of total P lost was particulate P and thus, ridge tilled plots had a lower loading of total P than

moldboard plowed plots. It appears, however, that the snowmelt runoff is a critical part of annual P transport. The data from 1995 only includes one snowmelt event from snow that fell after the major snowmelt occurred.

1996, the dominant form of phosphorus loss differed greatly between snowmelt and rainfall induced runoff events. During snowmelt erosion was low, and the majority of P lost was in the soluble form. During rainfall induced runoff, the majority of P lost was associated with eroded sediments. Soluble and total P losses during snowmelt were greatest from ridge tilled plots in 1996, with 80 percent as soluble P (figures 4 and 5). During rainfall, total P loss followed the order of total solids loss and was moldboard>chisel>ridge till. The reduction in loss of total phosphorus in the ridge till system during rainfall was offset by the higher losses of soluble P in snowmelt and the annual total P loss did not differ among tillage (range 3.3 - 3.6 lbs acre^{-1}). Thus, the contribution of soluble P lost during snowmelt must be considered when conservation tillage systems are recommended for control of phosphorus in runoff.

Chemical Oxygen Demand

In 1995, the total loss of COD was 188 lbs/acre for moldboard plowed plots and was 45 lbs/acre for ridge tilled plots, with the majority coming from the June 07 event for both tillage systems (Figure 7). The snowmelt runoff event did not contribute a large amount of COD to the annual total. In 1996, losses runoff of COD were 170, 150, and 120 lbs/acre for chisel plowed plots, moldboard plowed plots, and ridge tilled plots respectively. Although total COD losses were similar for moldboard and chisel plowed plots, they differed in seasonal contribution. Chisel plowed plots lost more COD during the snowmelt period, while moldboard plowed plots lost more from rain induced runoff. The majority of loss from ridge tilled plots was also during the snowmelt events and losses from rain induced runoff were much less than moldboard and chisel plowed plots. Losses of COD from rainfall induced runoff were 100, 71, and 48 lbs/acre for moldboard, chisel, and ridge till respectively. Thus, losses of COD differed seasonally among tillage systems and total loss was lowest for the ridge till system.

Herbicide Loss

oss of herbicides to surface water is of greatest concern when a runoff event occurs within one or two weeks following iemical application. In 1995, herbicide application was made on May 24 and four subsequent runoff events were chosen for herbicide analysis. Light rains that did not induce runoff followed herbicide application and some of the chemical likely moved below the zone susceptible to runoff loss. A small runoff event occurred on June 05 and both herbicides were detected in runoff samples (Tables 3 and 4). For both tillage treatments, banded application significantly reduced the amount of herbicide loss. Loading from moldboard plowed plots was greater than from ridge tilled plots for both application methods due to the greater volume of runoff. Additional herbicide analysis was made for June 23, 25, and 26 events. There was no runoff from ridge till plots for the June 23 and 25 events and only a very small volume for the June 26 event. These events show a significant reduction in herbicide loss due to band application in either tillage method. Banding reduced the mass of herbicide applied to one third that of broadcasting but reduced the runoff losses of herbicide by 5 and 12 times for alachlor and cyanazine respectively. Ridge tillage reduced total herbicide loss by limiting the amount of runoff.

In 1996, herbicide application was made on May 17 and seven runoff events followed. The effect of application method on herbicide concentration is illustrated in figure 7. Concentrations of alachlor and cyanazine were high in the first event following application and decreased exponentially thereafter. Banding significantly reduced the concentration of both herbicides in runoff. Tillage effects on herbicide concentration were generally not significant and were variable with time. However, tillage did affect losses of herbicide because of differences in runoff volumes among the tillage systems. The effects of application method, tillage system, and their interaction on losses of alachlor and cyanazine are shown in figure 8. For broadcast application, runoff losses were in the order of moldboard>chisel>ridge till. Banding reduced total losses for the moldboard and chisel plowed plots. For the ridge till system, losses were low regardless of application method because the volume of runoff was low for these events. Thus, conservation tillage and/or banding may be effective management strategies for reducing herbicide losses to runoff.

The success of band application of herbicides depends on the ability to control weeds in-between the bands by cultivation. For some years, wet soils prevent cultivation and significant weed pressure and yield reductions will result when banding was used rather than broadcast application. For this study, weed density was measured before and after cultivation. Before cultivation, weed cover was 62% between the rows on plots with banded herbicide application and was 27% on plots with broadcast herbicide application. However, following a single cultivation, weed cover was reduced to 1% for both treatments. Weed density did not differ with application method within the 10 inch band.

Yield

Corn yields in 1995 averaged 118 bu/acre for moldboard plowed plots and 107 bu/acre for ridge tilled plots. In 1996 yields were 129, 123, and 116 bu/acre for moldboard plowed, ridge tilled, and chisel plowed plots respectively. Effects of tillage and herbicide application method were not significant for either year.

Table 3. Loading of Alachlor from select runoff events from moldboard plowed plots (MB) and ridge till plots (RT).

	Total Loading of Alachlor (mg/hectare)					
Event Date	Runoff (in)		Banded Application		Broadcast Application	
	MB	RT	MB	RT	MB	RT
June 05-06	0.12	0.06	1761	227	6454	1309
June 23	0.04	0.0	68.1	--	577	--
June 25	0.06	0.0	65.5	--	238	--
June 26	0.08	0.001	94.1	1.65	729	0.83
Total	**0.30**	**0.061**	**1989**	**228**	**7998**	**1310**
% of Applied			0.25	0.03	0.36	0.06

Table 4. Loading of Cyanazine from select runoff events in 1995.

	Total Loading of Cyanazine (mg/hectare)					
Event Date	Runoff (in)		Banded Application		Broadcast Application	
	MB	RT	MB	RT	MB	RT
June 05-06	0.12	0.06	356	496	7780	6801
June 23	0.04	0.0	90.6	--	1271	--
June 25	0.06	0.0	238	--	838	--
June 26	0.08	0.001	366	6.4	1691	3.9
Total	**0.30**	**0.061**	**1051**	**502**	**11580**	**6805**
% of Applied	--	--	0.15	0.07	0.57	0.33

CONCLUSIONS

- Annual runoff was highest from ridge tilled plots because of higher snowmelt runoff. Fall moldboard plowing limited snowmelt runoff, but chisel plowing did not.

- Surface residue associated with the ridge tilled and chisel plowed plots reduced runoff and erosion from spring rains following planting and before canopy closure. Annual soil loss was in the order of moldboard plow>chisel plow>ridge till.

- Phosphorus losses differed seasonally among tillage systems. Ridge tilled plots had higher losses of P in snowmelt runoff than the other tillage systems and soluble P was the dominant form. Phosphorus losses from rain induced runoff followed the order of soil loss and particulate P was the dominant form. On an annual basis, total P losses were similar for all tillage systems.

- Chisel plowed and ridge tilled plots had lower losses of broadcast applied herbicides than moldboard plowed plots.

- Banding reduced herbicide losses from moldboard and chisel plowed plots. Losses from ridge tilled plots were low regardless of application method.

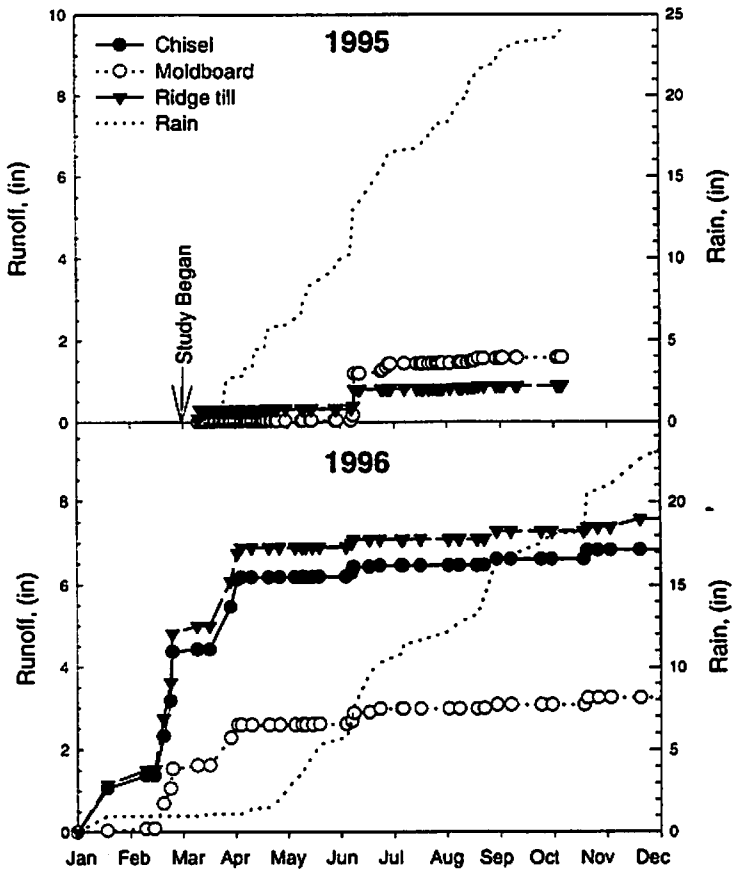


Figure 1. Cumulative Runoff and Precipitation

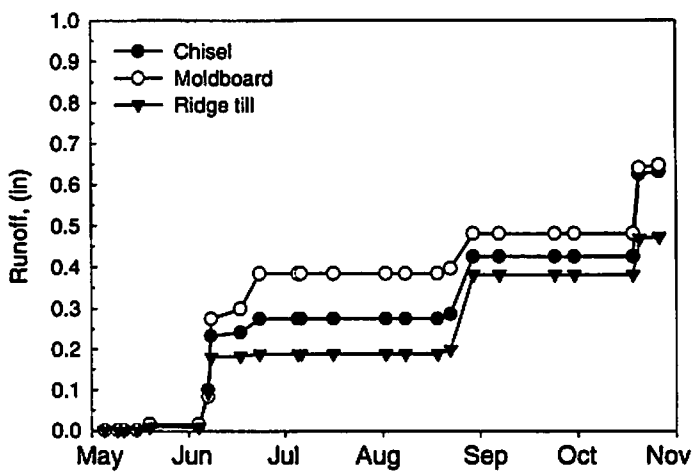


Figure 2. 1996 Runoff following planting

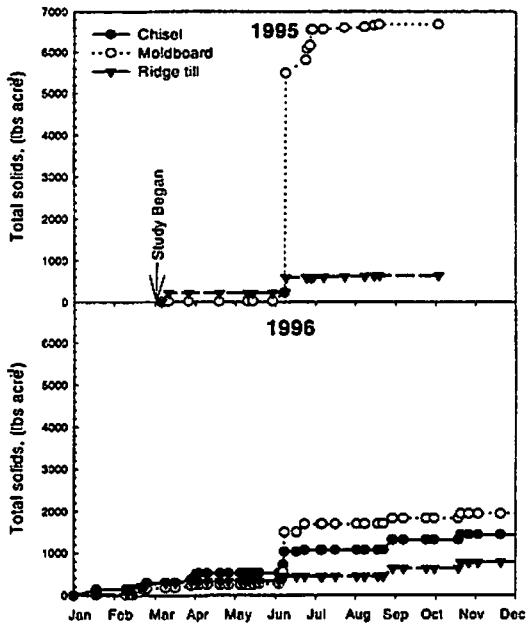


Figure 3. Cumulative Loss of Total Solids

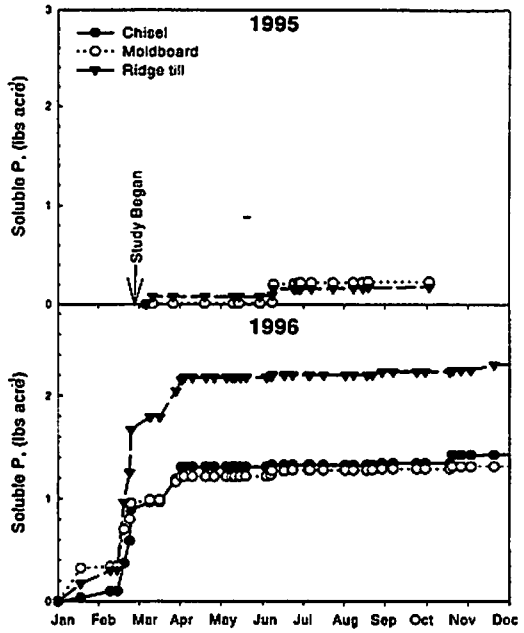


Figure 4. Cumulative Loss of Soluble Phosphorus

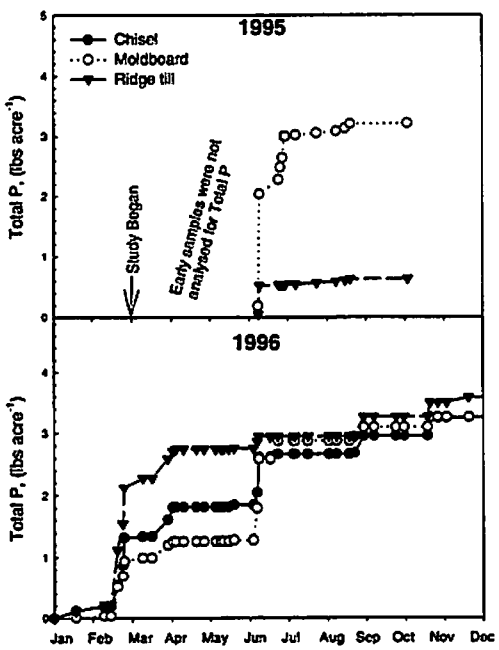


Figure 5. Cumulative Loss of Total Phosphorus.

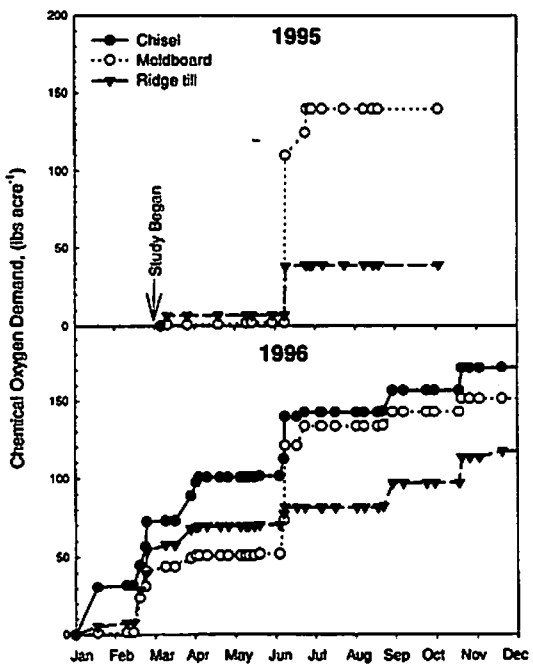


Figure 6. Cumulative Loss of Chemical Oxygen Demand.

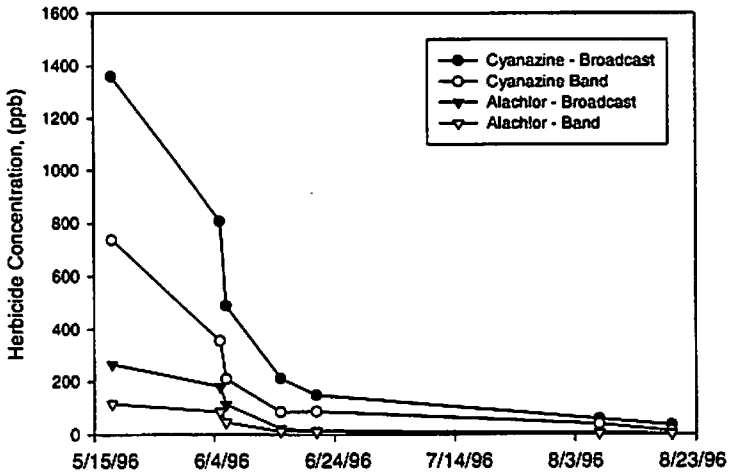


Figure 7. Impact of banding on herbicide concentration in runoff for 1996.

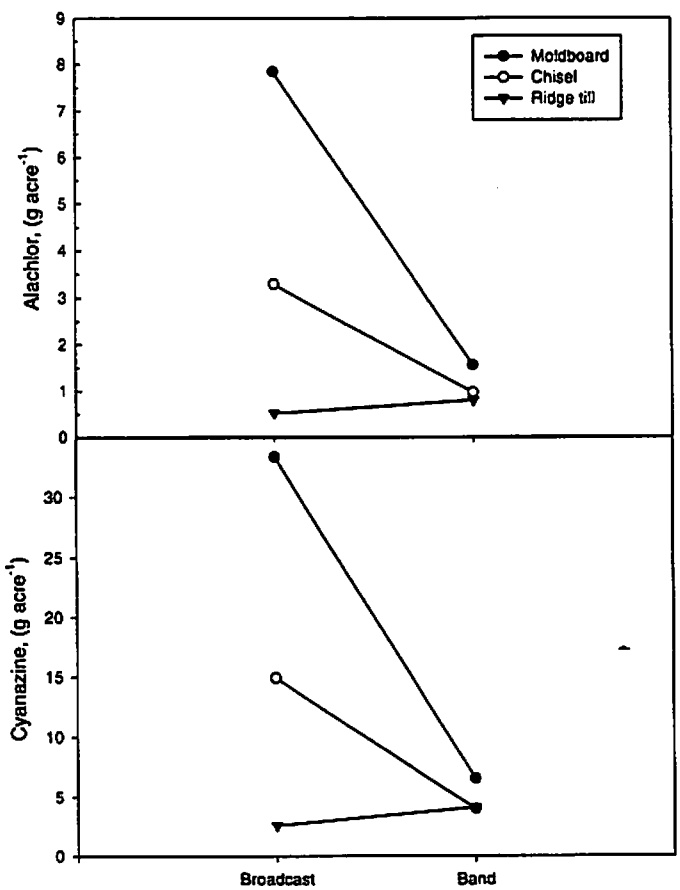


Figure 8. Tillage and herbicide application method impacts on 1996 losses of alachlor and cyanazine.

EFFECT OF NITROGEN AND SULFUR ON CANOLA - 1996

R.K. Severson, C.D. Holen, G.W. Rehm[1/]

Abstract

Specific fertility recommendations for nitrogen and sulfur are currently not available in Minnesota. This study evaluates the effect of three rates of nitrogen and four rates of sulfur applied to canola in a split-plot design on yield, test weight and oil percent. Nitrogen rates had no effect on yield or test weight and significantly decreased oil percentage as nitrogen rates were increased. Sulfur rates statistically did not effect yield, test weight or oil percent however a trend was evident that yield and oil percent increased with the addition of sulfate-sulfur averaged over nitrogen rates.

Introduction

The annual worldwide production of canola is approximately 4 million acres. Canada and the European Economic Community account for about one third of the world production. Minnesota and North Dakota are the major U.S. production states with about 20,000 acres grown annually. Canola is a relatively new alternative crop being produced in northwestern Minnesota. Current fertility recommendations are based solely on research conducted in Canada. Previous research in Canada has shown that canola utilizes about three times the sulfur compared to small grains. The objective of this study was to evaluate four sulfur rates on canola at three nitrogen rate yield goals.

Experimental Procedure

This study was conducted in Polk county near Fosston in 1996. Three nitrogen main effect treatments were established based on yield goals of 2000, 2500 ad 3000 pounds of canola per acre. Sulfur rates of 0, 20, 40 and 60 pounds of sulfate-sulfur were applied in a split-plot design to the main effect treatments. Ammonium sulfate was used as the sulfur source and supplemented with ammonium nitrate to achieve nitrogen rates of 130, 162.5 and 195 pounds per acre. Treatments were randomized and replicated in four blocks. Phosphorus and potassium were broadcast applied to all plots based on soil test results. All fertilizer treatments were applied prior to planting canola. Treflan was applied pre-plant incorporation at a rate of .75 pounds active ingredient per acre. All plots were planted on May 12, 1996 and re-planted on June 12, 1996 due to a severe crusting problem. Pioneer 45-A-71 canola variety was planted at a final population of 15 plants per square foot. At harvest canola yields were measured with a Hege plot combine and corrected to 10% moisture content. Oil percentage was analyzed by Dr. Jim Hanzel at North Dakota State University.

Summary of Results

There was a significant reduction in oil percentage with increased nitrogen rates and no effect on yield or test weight. Averaged across nitrogen rates, no significant differences were found, however, the addition of sulfur showed a trend to increase yield and oil percentage as sulfur rates increased with no effect on test weight.

Status

This research project was started in 1996 and will be conducted in Polk county again in 1997.

[1/] Extension Educator and Professor, Polk County; IPM Specialist, Northwest Minnesota; Professor, Department of Soil, Water, and Climate, respectively.

NITROGEN CONSERVATION IN A LIQUID DAIRY MANURE MANAGEMENT SYSTEM WITH FLUSH WATER RECYCLING[1]

S. M. Braum and J. F. Moncrief[2]

Abstract:

Dairy farms in SE Minnesota often have a strongly positive nitrogen balance. Nitrogen losses to the atmosphere from manure storages are desirable if they occur through denitrification. Such losses reduce the amount of nitrogen that needs to be land applied, thereby reducing possible excess fertilization which could lead to water pollution. The occurrence and amounts of gaseous nitrogen losses from a liquid manure management system with recycled flush water were investigated on a dairy farm in Winona Co. with 150 to 165 cows. The prevailing mode of nitrogen loss was found to be ammonia volatilization. Denitrification losses were negligible. The average daily loss rate varied from 24.1kg N d^{-1} to 43.3kg N d^{-1}.

Introduction

As they do in all across the U.S., dairy herd sizes on many individual farms are increasing in SE Minnesota to maintain or increase profitability. Along with producing more milk to sell, larger herds also generate larger amounts of wastes. When confined to buildings or small outside lots, the large amounts of wastes generated require proper handling to allow continuous operation of the facilities and to prevent hygienic problems. While the economic value of nutrients in manure for crop production is still worth consideration, the potential for environmental damage from excessive amounts of these nutrients, especially N, becomes increasingly important. In cases where the imbalance between nutrient supply from manure and their removal by crops is particularly big due to excess nutrient influxes from bought feed, fertilizer or N-fixation (alfalfa), the costs of compliance may exceed the benefits derived from the wastes. The problems of nitrogen excess and possible surface and groundwater contamination are magnified for dairy farms in SE Minnesota because of the prevailing crop rotation (alfalfa, corn, soybean), the karst geology with rapid groundwater recharge and the topography of an old, highly dissected erosional land surface with steep slopes and rapid runoff.

Constructed earthen storage basins have become a widespread means of storing animal wastes. In this LCMR-funded project, we are investigating the flow and transformations of nitrogen in a waste management system on a dairy farm in Winona Co. in SE Minnesota over the course of two years. The possibility of gaseous nitrogen losses from the system during storage is of particular interest, since such losses reduce the amount of nitrogen that needs to be disposed of by land application.

Manure management systems can lose nitrogen to the atmosphere as ammonia (NH_3), nitrous oxide (N_2O), and dinitrogen (N_2). Ammonia and ammonium (NH_3, NH_4^+) are always present in manure, commonly comprising 33% of the total N in liquid manure. Several factors influence the volatilization of ammonia. Volatilization can occur anywhere liquid manure is exposed to the atmosphere; scum mats and ice covers consequently reduce ammonia volatilization. It increases with increasing pH and temperature of the liquid manure. N-losses from a manure system as nitrous oxide (N_20) and dinitrogen gas (N_2) require the existence of a nitrification-denitrification cycle. Nitrate (NO_3^-) can be generated under aerobic conditions by microbial oxidation of ammonia. If nitrate then enters into an anaerobic environment, it can be microbially reduced to nitrous oxide or dinitrogen, which are then lost from the manure to the atmosphere.

The research site is the Charles Meyer dairy farm in Winona Co. The dairy herd on the Meyer farm was 150 head in 1995, which increased to 165 in 1996. The milk yields (herd average) were 28,000lb or 12,700kg in 1995 and 27,000lb or 12,300kg in 1996. The farm operates an earthen manure storage basin with two cells. The wastes from the dairy barn and the milkhouse enter the first cell through a submerged pipe. Most of the solids are retained in the first cell, either by sinking to the bottom or by forming a floating scum mat on the surface. The liquid under the mat equilibrates with the second cell through a second submerged pipe in the dam separating the two cells. Liquid from the second cell is pumped into a storage tank and used to flush the barn, completing the cycle. The calculated combined maximum volume of the storage cells is 8,400m^3 at the specified depth of 2.44m (8ft). Due to sludge deposition, this depth is no longer available throughout the basins, somewhat reducing the actual storage volume. Twice a year, the contents of cell I are stirred up and pumped out and applied onto cropland with a traveling irrigation gun. This draws down the second basin until its level is below the connecting pipe, leaving approximately 1,054m^3 of liquid in cell II to continue flushing the barn. To avoid an overflow, liquid is pumped occasionally from the second cell for land application.

---

[1]This project was funded by the Legislative Commission on Minnesota Resources

[2]S.M. Braum (postdoctoral research associate) and J.F. Moncrief (professor) are in the Dept. of Soil, Water & Climate, Univ. of Minnesota, St. Paul, MN 55108

Experimental Procedure

Manure composition: Manure samples were taken at regular intervals from both cells over the course of two refill periods from 1995 to 1996. The samples were analyzed for total N, ammonia/ammonium, nitrate, total phosphorus, pH, and total, volatile and ash solids content.

System volume determination: After Meyer farms applied manure pumped from the first cell during the first week of May 1996, 2600g of Li was added to the liquid remaining in cell II. The lithium acted as a chemical tracer. By determining the Li-concentrations in both cells over time, the mixing and turnover of cell liquids could be monitored. If complete mixing occurred, a uniform Li-concentration would establish itself. The time it took to reach uniformity throughout the storage basins was the time required for complete mixing. At that point, the Li-concentration was a direct measure of the total volume of liquid circulating through the system. The volume combined with the concentrations of N, P and K gave us the total amounts present of these nutrients. This allows us to evaluate nitrogen losses to the atmosphere as well as planning for the application of the manure as fertilizer. The Li-tracer was useful for the whole period of 167 days from emptying the cells in the spring until the emptying in the fall of 1996, when the storage was again completely full without any freeboard.

Nitrogen budgeting: For comparison with the amount of nitrogen measured in the manure storage, the amounts of nitrogen excreted over the given refill periods were calculated by subtracting the nitrogen in the milk from the nitrogen supplied by the feed ration. Feed ration amounts and analyses were kindly provided by the Meyers. In 1995, the daily ration per cow contained 677g of N and in 1996 it was 771g of N. The nitrogen content of the milk was assumed to be a constant 0.512%.

Results and Discussion

Convergence of the Li-concentration in the two cells of the storage occurred several weeks before the end of the second refill period, indicating uniform mixing (see Fig. 1). At the end of the second refill period, the lithium tracer added at its beginning minus the amount removed from cell II in August allowed us to calculate the liquid volume of the manure storage when it is completely full. The system volume was determined to be 6,711m^3, 3,229m^3 in cell I and 3,482m^3 in cell II. These values were also used in the calculations for the end of the first refill period, since the storage had been completely full then, too.

The amounts and chemical forms of nitrogen in the storage basins were monitored over the two refill periods. For both periods, comparison of the total nitrogen present in the storage at the end of the refill period to the amount that entered the system through feed indicated that substantial losses of nitrogen had occurred. The losses were calculated as follows:

10/18/1995 to 5/1/1996: 195 days of refill

N added with feed: 150 * 195 * 0.677kg =	19.8t
N removed by milk: (12,712kg / 365) * 150 * 195 * 0.00512 =	5.2t
N excreted by the herd: 19,802kg - 5,216kg =	14.6t
N left in cell II at beginning: 1,054m^3 * 1.149kg m^{-3} =	1.2t
Potential total N in the storage: 14,586kg + 1,211kg =	15.8t
N found in storage at end: 3,229m^3 * 2.014kg m^{-3} + 3,482m^3 * 1.319kg m^{-3} =	11.1t
=> N lost: 15,797kg - 11,096kg =	4.7t

The 4.7t represents a 29.8% loss of nitrogen over the 195 days. This is an average daily loss of 24.11kg N.

5/9/1996 to 10/23/1996: 167 days of refill

N added with feed: 165 * 167 * 0.771kg =	21.2t
N removed by milk: (12,258kg / 365) * 165 * 167 * 0.00512 =	4.7t
N excreted by the herd: 21,245kg - 4,738kg =	16.5t
N left in cell II at beginning: 1,054m^3 * 1.304kg m^{-3} =	1.4t
N removed from cell II by pumping in 8/96: 499m^3 * 2.111kg m^{-3} =	1.1t
Potential total N in the storage: 16,507kg + 1,374kg - 1,053kg =	16.8t
N found in storage at end: 3,229m^3 * 1.547kg m^{-3} + 3,482m^3 * 1.324kg m^{-3} =	9.6t
=> N lost:16,828kg - 9,605kg =	7.2t

The 7.2t represents a 42.9% loss of nitrogen over the 167 days. This is an average daily loss of 43.25kg N.

Most of the nitrogen in the manure was in the organic form. Ammoniacal nitrogen (NH_3 and NH_4^+) represented between 34% to 50% of the total N. Nitrate was detected only sporadically in very small concentrations. Since nitrification is a prerequisite for denitrification, nitrogen losses by denitrification must be assumed to have been negligible also. The pathway for nitrogen loss from the system must therefor be ammonia volatilization. At the beginning of the study it was hoped that substantial losses would occur by denitrification. Such losses are preferable to losses as ammonia because the nitrogen is then lost primarily as dinitrogen which is not available for plant uptake and therefor non-polluting. Larger amounts of nitrous oxide could be problematic because N_2O is a greenhouse gas, however, it constitutes generally only a small fraction of the nitrogen lost in denitrification. Substantial atmospheric losses as ammonia

are a mixed blessing. While they certainly help reduce the amount of environmentally active nitrogen that needs to be disposed of through land application on the farm in question, such losses are actually contributions of available N to the ecosystem. Ammonia in the atmosphere can be taken up directly by plants, or it can enter the soil by precipitation or dry deposition. This leads to increased soil nitrogen and soil acidification, which are especially problematic in poorly buffered and nitrogen-limited natural ecosystems. For these reasons, ammonia in the atmosphere is considered a severe environmental problem in Europe, with emissions from livestock operations being the most important source.

The losses that occurred from the system at the Meyer farm have two possible areas of origin: the livestock buildings and the manure storage cells, because at these two locations, the manure is exposed to the atmosphere. Measurements of the ammonia volatilization from the manure storage will be made in the first half of 1997 to assess its share of the losses. We will also continue to monitor nitrogen in the system to determine if the higher rate of loss for the second refill period was due to climatic factors (summer vs. winter), or if it was caused by the installation of a more efficient aeration system in the spring of 1996in cell II.

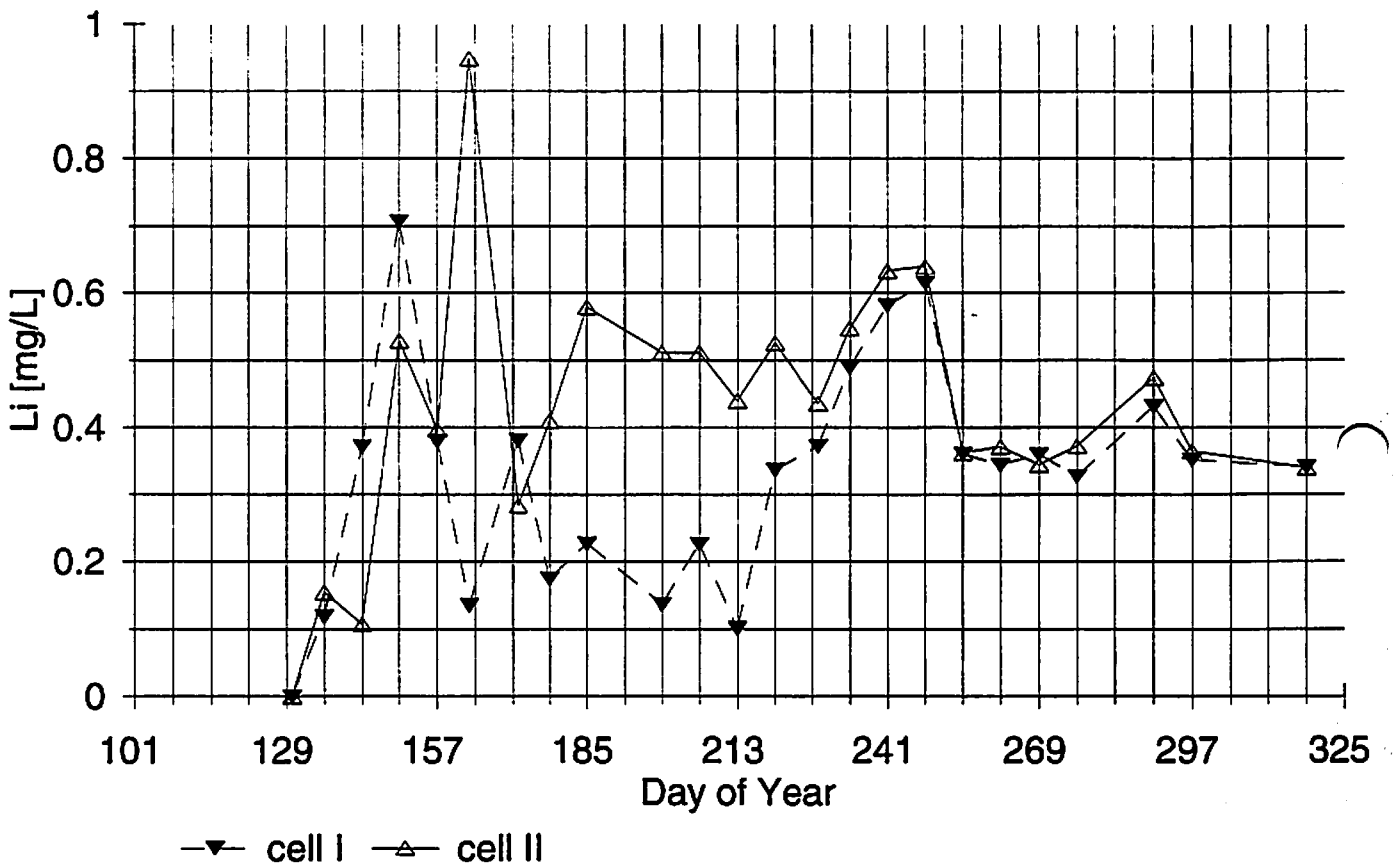



Fig.1: [Li] in Cells I and II