Table 3. The effect of method of establishment used in 1992 on yield of four legumes in 1993.

Legume	Cutting	Method of Establishment A	B	C	D	E
		- - - - - - - - ton dry matter/acre - - - - - - - -				
alfalfa	1	.71	.64	.82	.82	.65
	2	1.70	1.82	1.70	1.80	1.63
	3	1.28	1.36	1.31	1.31	1.39
	Total	3.69	3.83	3.83	3.93	3.67
birdsfoot trefoil	1	2.64	2.94	2.57	2.61	2.52
	2	1.67	1.33	1.64	1.48	1.85
	Total	4.31	3.27	4.21	4.09	4.37
cicer milkvetch	1	2.13	2.33	2.41	1.68	2.15
	2	1.41	1.25	1.50	1.26	1.45
	Total	3.54	3.58	3.91	2.94	3.60
red clover	1	2.32	2.26	2.10	2.53	2.48
	2	1.92	1.86	1.99	1.53	1.73
	Total	4.24	4.12	4.09	4.06	4.21

Table 4. The effect of method of establishment on the number of plants counted in a 3 ft^2 area in September of 1992.

Legume	Year of Establishment	Method of Establishment A	B	C	D	E
		- - - - - - - - - - plants/3 ft^2 - - - - - - - - -				
alfalfa	1991	41	41	43	57	36
	1992	56	55	37	70	89
birdsfoot trefoil	1991	28	27	30	49	37
	1992	30	27	37	28	39
cicer milkvetch	1991	18	15	25	49	46
	1992	35	54	33	63	66
red clover	1991	28	27	30	39	36
	1992	55	55	67	87	82

Evaluation of Best-Management of N on Irrigated Potatoes: Yield and Nitrate Losses[1]

B.M. Carlson, C.F. Reece, and C.J. Rosen

Abstract

Positionally-dependent nitrate leaching from potatoes grown using conventional nitrogen management (banding at planting, emergence, and hilling) were compared to nitrogen management using petiole-nitrate sap-test based fertigation at the Staples Irrigation Center. Time-averaged soil water nitrate concentrations increased with the amount of solid fertilizer applied to the soil. On the other hand, concentrations were insensitive to N applications through irrigation (fertigation) as evidenced by a value of 17 ppm for the Fertigated - Reduced plots, and 25 ppm for the Nonfertigated - Conventional plots which had similar amounts of total applied N. Analysis of yield from the plots showed no significant differences between any Reduced or Conventional treatments. By using fertigation and further lowering N rates there is great potential to maximize yield while lowering costs and reducing groundwater contamination.

Introduction

Various potato management systems which may reduce groundwater contamination have been proposed. One of these is a system which applies N in a liquid form through an irrigation system (called "fertigation"). This system has the potential of reducing contamination by applying fertilizer only when the plants show deficiency and has the advantage of placing the N directly in contact with the roots. This combined with soil bulk density differences and root uptake can lead to differences in water flux and nitrate concentration between rows and furrows. These effects can be taken advantage of to reduce leaching in a fertigated system.

Objectives

Compare nitrate losses under a N-management system involving Conventional fertilization, and one using fertigation. Evaluate relative contribution of row and furrow N-fluxes to total N-loss.

Materials and Methods

As the first year of a two year project plots were established at the Staples Irrigation Center on Verndale sandy loam, growing Russet Burbank potatoes . The plots had 36" row spacing, and 10" seed spacing. Plots consisted of three treatments of solid fertilizer (Control, Reduced and Conventional) duplicated with and without fertigation. Starter fertilizer (urea) was applied at planting at a rate of 9.1Kg for Reduced, and 18.2Kg for Conventional. Urea banded at emergence (24 May) and hilling (17 June) consisted of 31.8Kg for Reduced, and 45.5Kg for Conventional. Three fertigation treatments of 9.1Kg N as a solution of 28% ammonium nitrate were applied in July. Fertigation was scheduled by using petiole sap nitrate tests. Nonfertigated - Reduced and fertigated - Conventional plots were designated for intensive study. Suction cup samplers were installed at 30 and 60 cm depths in the rows and between the rows. Non -intensive study plots received samplers at 60 cm between the rows. Tensiometers were placed at 30 and 60 cm following the same configuration for intensive or non-intensive plots. Tipping bucket rain gages were used to measure irrigation. Water flux was calculated using Darcy's equation. Soil water samples were analyzed for nitrate content on a Wescan analyzer.

Results

Nitrate concentrations were higher in the row at the beginning of the growing season. Concentrations in the furrow became larger as the growing season progressed. Reduced treatment plots had lower concentrations than Conventional regardless of fertigation. Water flux was greater in the furrow (ex. 12.6 cm fert.-Reduced, 26.9 cm nonfert.-Conv.) than the row (ex. 8.6 cm fert.-Reduced, 11.2 cm nonfert.-Conv.).

Nitrate movement was associated with water flux (Fig. 1). Time-averaged soil water nitrate concentrations increased with the amount of solid fertilizer applied to the soil, while N applications through irrigation (fertigation) had little effect on nitrate concentrations (Fig. 1 &3 and Table 1). This was especially evident comparing the fertigated-Reduced treatment (17 ppm) to the nonfertigated-Conventional (25 ppm) since both treatments had similar totals of N applied (100 to 109 Kg-N/A) (Fig 4). Analysis of yield from the plots showed no significant differences between any Reduced or Conventional treatments (Fig. 5 and Table 2).

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[1]Funding for this project was provided by the Legislative Committee for Minnesota Resources.

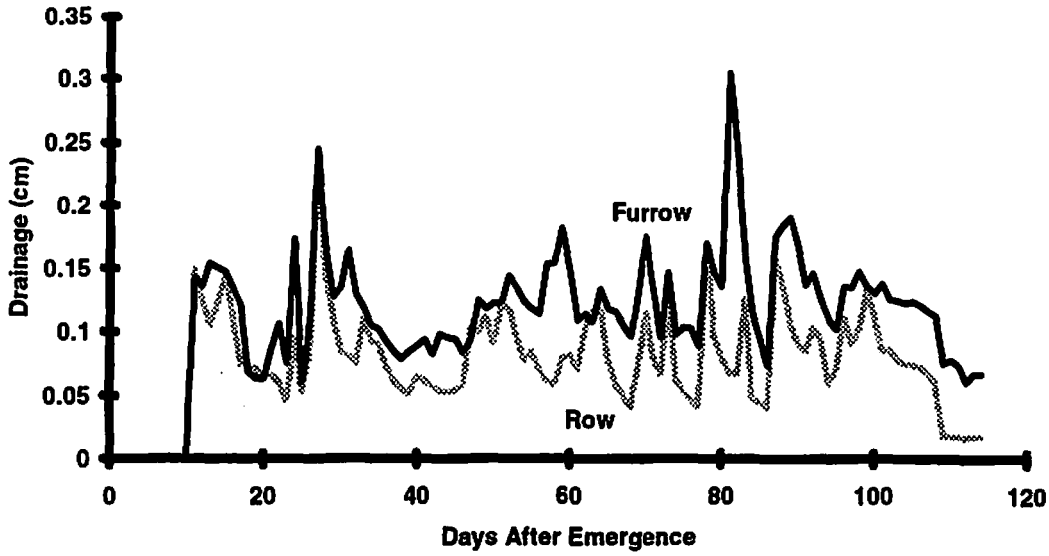

Figure 1. Drainage from a furrow and a row position at 60 cm in fertigated - Reduced plots. Other plots followed a similar pattern.

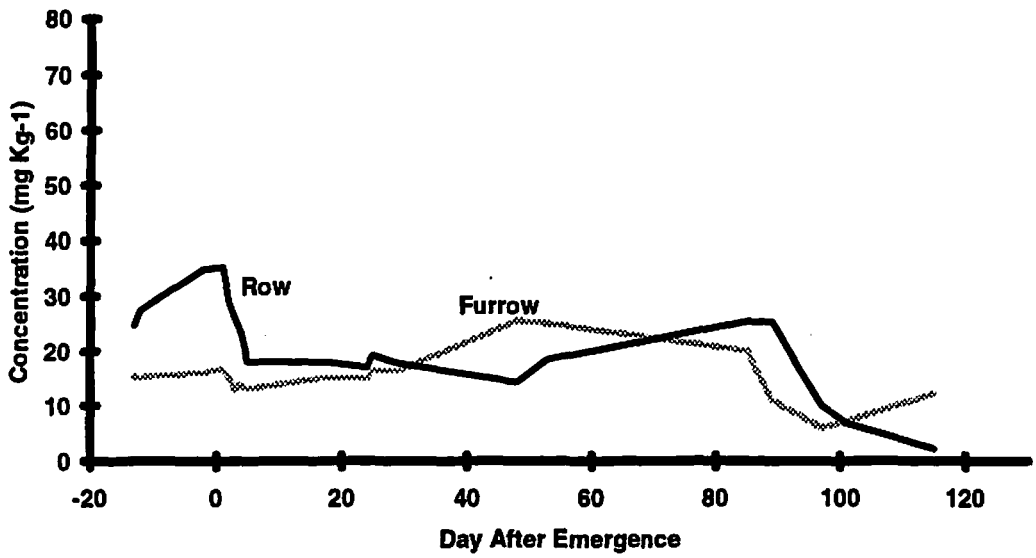

Figure 2. Soil water nitrate concentrations over the growing season for a fertigated plot. 100 Kg/A N applied. Other fertigated plots followed a similar pattern.

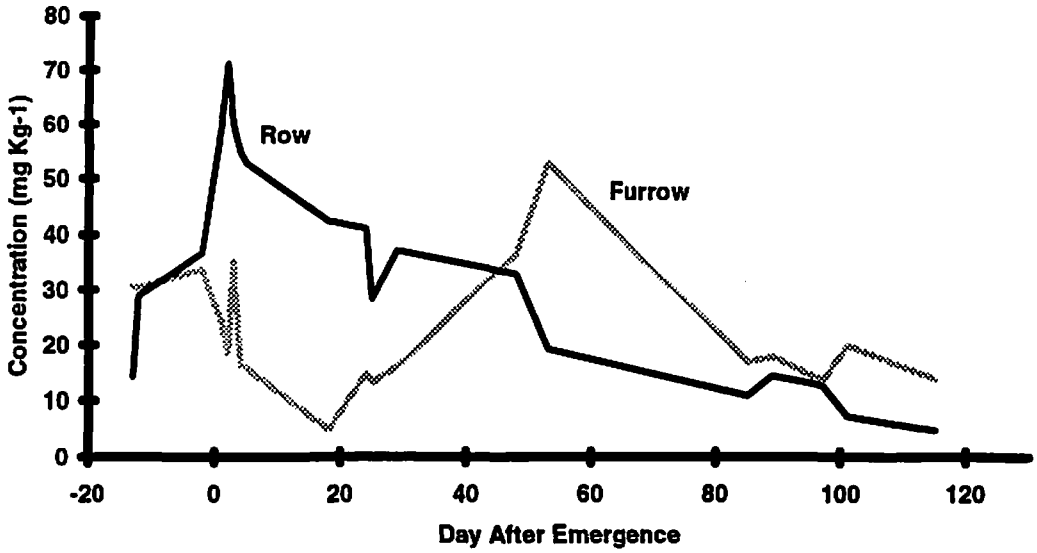

Figure 3. Soil water nitrate concentrations over the growing season for a nonfertigated plot. 109 Kg/A N applied. Other nonfertigated plots followed a similar pattern.

Table 1. Nitrate concentrations in soil water at 60 cm depth, between rows.

date	fertigated			nonfertigatd		
	Control	Reduced	Conventional	Control	Reduced	Conventional
10-May-93	16.3	15.4	30.2	15.4	16.5	30.6
11-May-93	19.4	15.3	23.8	16.8	21.1	30.3
21-May-93	21.6	16.0	39.3	19.2	25.4	33.7
24-May-93	26.8	16.8	24.8		28.3	24.2
25-May-93	17.3	15.3	25.2	17.9	20.5	18.3
26-May-93	13.9	13.1	21.4	15.5	19.0	35.2
27-May-93	12.5	13.9	20.4	14.1	15.2	16.4
28-May-93	13.4	13.2	18.9	11.9	15.7	15.7
10-Jun-93	10.2	15.2	19.8	9.5	12.4	4.9
16-Jun-93	12.2	15.1	16.8	11.5	14.0	14.7
17-Jun-93	11.6	16.5	12.2	11.2	13.8	13.2
21-Jun-93	12.6	16.4	17.0	12.9	15.2	16.1
10-Jul-93	14.7	25.6	19.8	17.4	23.9	36.6
15-Jul-93	14.6	25.1	41.2	26.4	33.8	52.7
16-Aug-93	8.0	20.2	35.8	8.5	20.9	16.9
20-Aug-93	7.7	11.2	42.2	13.2	1.8	17.9
28-Aug-93	3.3	6.0	20.0	9.0	6.2	13.6
1-Sep-93	4.5	7.2	31.4	11.0	2.3	20.0
15-Sep-93	3.0	12.3	12.9	7.9	0.5	13.9

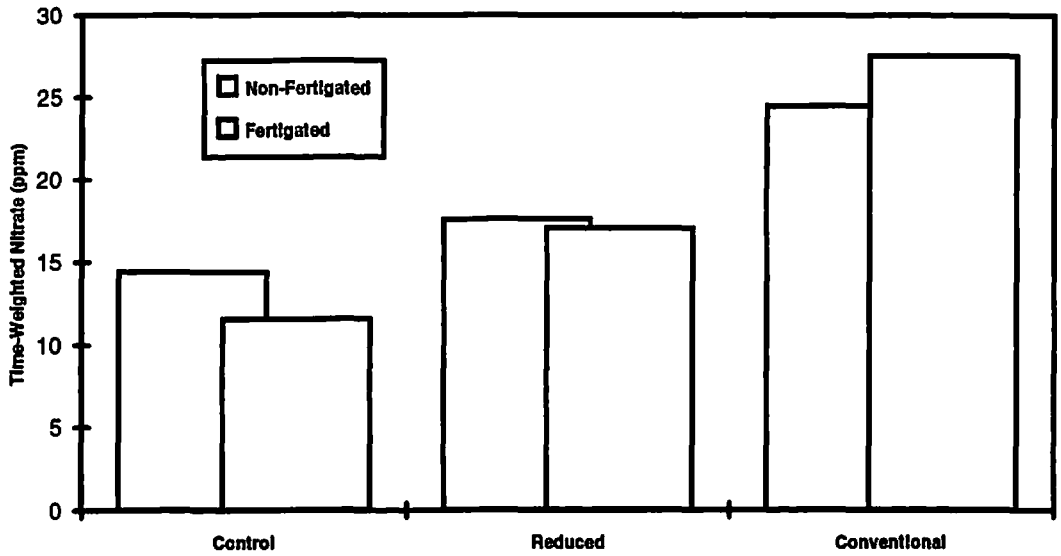

Figure 4. Time-weighted nitrate concentration averages for 1993.

Table 2. Graded yields for 1993.

Treatment		Grade					
water	soil	culls	2's	1's	jumbo	misshapen	total (sd)
		cwt/A					
nonfertigated	Control	20.7	125.1	22.0	15.9	3.1	186.8 (46.4)
nonfertigated	Reduced	38.0	182.2	136.9	16.3	36.1	409.5 (15.3)
nonfertigated	Conventional	32.0	169.4	145.4	34.8	31.6	413.1 (17.1)
fertigated	Control	21.8	140.5	83.7	4.6	7.8	258.4 (21.7)
fertigated	Reduced	36.5	183.7	139.1	21.1	27.7	408.0 (16.4)
fertigated	Conventional	34.0	169.9	175.0	24.6	35.6	439.1 (22.5)

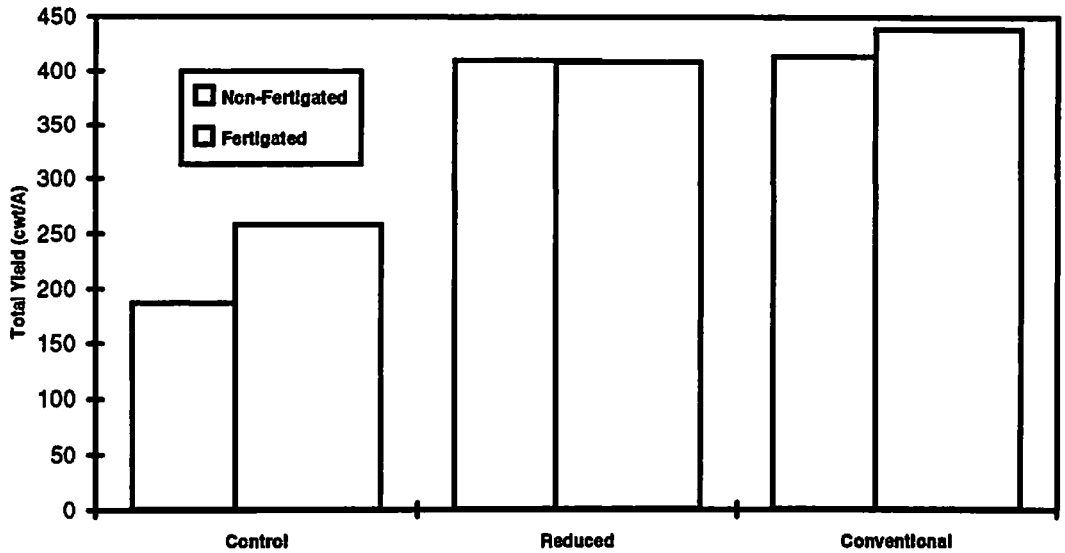

Figure 5. 1993 yield.

Discussion

Due to consistently low nitrate concentrations between plots initially starter N probably did not significantly add to nitrate leaching. On the other hand, the banded applications at emergence and hilling did raise soil solution nitrate concentrations significantly in the row. Higher nitrate concentrations under the Conventional treatments did not translate into higher yields. This tends to indicate that less N could have been applied at emergence and hilling.

Analysis of the water flux data shows a marked increase in water flux in furrow positions compared to rows. This can probably be attributed to lower root density and water uptake in the furrows. It is important to note that nitrate flux followed a pattern very similar to drainage. We conclude that if N can be kept out of the areas of highest water flux - the furrow - groundwater contamination can be Reduced.

Conclusions

Yields were not significantly Reduced when solid fertilizer was substituted with fertigation. Evidence so far indicates that by using fertigation and lowering solid N applied to the soil, there is great potential to maximize yield while lowering costs and lessening groundwater contamination.

Significant differences in soil water nitrate concentration exist between row and furrow positions at both 30 and 60 cm. Water quality studies should account for these differences to obtain an accurate measure of nitrate leaching. Potato management systems utilizing fertigation can reduce N losses to groundwater markedly.

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CARROT RESPONSE TO FERTILIZER ON AN IRRIGATED SANDY SOIL[1]

Carl Rosen, Mel Weins, and Shelly Johnson[2]

Abstract: Fertilizer trials were conducted at the Staples Irrigation Center to refine fertilizer recommendations for carrot production on sandy soils. The previous crop was soybeans. The soil tested high in P, medium in K, and low in B. Carrots responded up to 60 lb N/A. Excessive N application tended to reduce yield and dry matter. A significant yield response to K fertilizer was obtained. Phosphate and B fertilizer did not significantly affect yields. Nutrient concentrations in leaves during the growing season and tops and roots at harvest are presented.

In recent years there has been an increased interest in producing carrots in Minnesota for dehydration. Little is known about the nutrient requirements of carrots under Minnesota conditions, particularly on irrigated sandy soils where an early harvest is desired. The objective of this study was to obtain baseline information related to carrot response to nitrogen, phosphorus, potassium and boron fertilizer amendments.

Materials and Methods: A carrot fertility experiment was conducted at the Irrigation Center at Staples during the 1993 growing season. The soil is a Verndale sandy loam with an organic matter content of 2.3%. The previous crop was soybeans and selected soil chemical properties (0-6") were as follows: pH, 5.9; Bray P, 42 ppm; K, 64 ppm; Mg, 163 ppm; Ca, 1190 ppm; S, 4 ppm; B, 0.2 ppm; and Zn, 1.2 ppm. Eight fertilizer treatments were evaluated:

	Fertilizer Treatment			
#	N	P_2O_5	K_2O	B
	-------- lb N/A -------			
1.	0	0	0	0
2.	120	50	0	2
3.	120	0	150	2
4.	0	50	150	2
5.	60	50	150	2
6.	120	50	150	2
7.	220	50	150	2
8.	120	50	150	0

All phosphorus (0-46-0), potassium (0-0-60), and boron (solubor) applications were broadcast and incorporated on April 21, 1993. Half the nitrogen (urea) was applied on April 21 and the remainder was sidedressed on June 28. Carrots were planted on April 22, 1993. Each main row was 22" on center and consisted of 2 rows 2" apart. The population was originally set to be at 13 plants per foot; however, final plant population was measured at 4 to 5 plants per foot. The planting depth was 0.75". The variety used was 'Legend'. Each treatment was replicated four times. Recently matured leaf samples were collected on July 26 for nutrient analyses. On August 20, 10 feet of row was harvested from each plot. Top and root weight were recorded and subsamples were taken for dry matter determination and nutrient analyses.

Results: Lowest carrot yields were obtained in the control plots where no fertilizer was applied (Table 1). Carrots responded up to 60 lb N/A in this study. Excessive rates of N tended to lower yields and reduce dry matter percentage of the carrot. The previous crop of soybean may have provided some N and lowered the N response. Additionally, the low final stand count may have also reduced the overall yield and N demand. Potassium fertilizer significantly increased yield by 46 cwt/A where as the response to phosphate was not significant. The greater response to K fertilizer compared to P fertilizer is in line with the relatively low soil test level for K and high test for P. Boron fertilizer had no effect on carrot yield or quality.

In the diagnostic leaf sampled July 26, nitrogen fertilizer increased tissue concentrations of nitrate, total N, and Mn, but decreased concentrations of Ca, Cu, and B (Table 2). Potassium fertilizer increased tissue K. Phosphate fertilizer did not significantly affect leaf tissue nutrient concentrations. Boron fertilizer decreased tissue P concentrations.

Nitrogen fertilizer increased concentrations of nitrate, total N, Mg, Mn, and Cu and decreased K and Fe in carrot tops at harvest (Table 3). Phosphate fertilizer decreased concentrations of total N and Zn. Boron and potassium fertilizer did not significantly affect nutrient concentrations in carrot tops at harvest.

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[1]Partial funding for this study was provided by AURI.

[2]Extension Soil Scientist, Dept. Soil Science; Research Plot Coordinator and Research Plot Technician, Staples Irrigation Center.

Nitrogen fertilizer increased concentrations of nitrate, total N, Mg, Mn, Zn, and B in carrot roots at harvest (Table 4). Nitrate concentrations were not at a level that would be of concern for human consumption. Phosphate fertilizer increased concentrations of nitrate and Fe. Potassium fertilizer increased concentrations of K and Fe. Boron fertilizer did not significantly affect nutrient concentrations in carrot tissue.

Additional studies on sandy soils need to be conducted to refine N and K fertilizer recommendations at higher plant populations.

Table 1. Effect of various fertility treatments on carrot yield and quality.

Fertilizer Treatment					Carrot	Root	Root	Dry
#	N	P_2O_5	K_2O	B	Yield	Length	Diameter	Matter
	-------- lb N/A --------				cwt/A	inches	inches	%
1.	0	0	0	0	214	8.6	1.37	11.7
2.	120	50	0	2	236	9.3	1.43	11.8
3.	120	0	150	2	269	9.6	1.50	11.2
4.	0	50	150	2	242	8.7	1.43	11.4
5.	60	50	150	2	281	9.6	1.58	11.4
6.	120	50	150	2	282	10.0	1.55	11.7
7.	220	50	150	2	250	9.6	1.60	10.5
8.	120	50	150	0	293	9.8	1.50	11.9
Significance					*	*	*	NS
BLSD (5%)					49	0.9	0.18	--
Contrasts								
Lin Rate N (4, 5, 6, 7)					NS	*	*	++
Quad Rate N (4, 5, 6, 7)					*	*	NS	NS
Boron (6 vs 8)					NS	NS	NS	NS
K (2 vs 6)					*	++	++	NS
P (3 vs 6)					NS	NS	NS	NS

NS = Not significant, *, ++ = significant at the 5% and 10% level, respectively.

Table 2. Effect of various fertility treatments on nitrate - N and the elemental composition of carrot leaves sampled July 26, 1993.

Fertilizer Treatment					Nutrient										
#	N	P_2O_5	K_2O	B	NO_3-N	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
	-------- lb N/A --------				ppm	---------- % ----------					--------- ppm ----------				
1.	0	0	0	0	361	2.50	0.41	4.59	1.38	0.23	169	72	7	34	45
2.	120	50	0	2	2407	2.85	0.36	4.12	1.33	0.24	163	80	6	32	36
3.	120	0	150	2	2520	3.00	0.36	4.69	1.20	0.23	159	87	7	34	37
4.	0	50	150	2	374	2.31	0.39	4.83	1.52	0.22	175	67	6	32	40
5.	60	50	150	2	1577	2.74	0.38	4.69	1.16	0.23	166	75	6	32	37
6.	120	50	150	2	2318	2.88	0.37	4.55	1.24	0.23	165	86	6	33	37
7.	220	50	150	2	3382	3.09	0.34	4.59	1.24	0.22	149	100	5	32	34
8.	120	50	150	0	2346	2.86	0.40	4.95	1.19	0.23	192	81	6	31	39
Significance					**	**	**	++	*	NS	NS	++	NS	NS	**
BLSD (5%)					843	0.24	0.04	0.61	0.25	--	--	26	--	--	2
Contrasts															
Lin Rate N (4, 5, 6, 7)					**	**	**	NS	++	NS	NS	**	++	NS	**
Quad Rate N (4, 5, 6, 7)					NS	*	NS	NS	*	NS	NS	NS	NS	NS	NS
Boron (6 vs 8)					NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
K (2 vs 6)					NS	NS	NS	++	NS	NS	NS	NS	NS	NS	NS
P (3 vs 6)					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant, *, ++ = significant at the 5% and 10% level, respectively.

Table 3. Effect of various fertility treatments on nutrient composition of carrot tops at harvest.

Fertilizer Treatment					Nutrient										
#	N	P_2O_5	K_2O	B	NO_3-N	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
	lb N/A				ppm	%						ppm			
1.	0	0	0	0	42	1.71	0.32	3.37	1.99	0.26	176	83	6	28	47
2.	120	50	0	2	132	1.60	0.32	2.96	1.48	0.26	108	64	6	28	42
3.	120	0	150	2	198	2.08	0.32	3.45	1.47	0.25	159	84	7	32	40
4.	0	50	150	2	17	1.42	0.32	3.76	1.80	0.23	197	78	5	27	41
5.	60	50	150	2	51	1.65	0.31	3.69	1.50	0.23	186	79	6	29	40
6.	120	50	150	2	60	1.72	0.31	3.33	1.55	0.25	141	75	6	27	40
7.	220	50	150	2	497	2.16	0.32	3.38	1.51	0.26	134	97	7	31	40
8.	120	50	150	0	151	1.81	0.33	3.56	1.50	0.23	129	68	6	26	41
Significance					**	**	NS	++	*	NS	NS	*	*	NS	**
BLSD (5%)					191	0.26	--	0.55	0.36	--	--	20	1	--	2
Contrasts															
Lin Rate N (4, 5, 6, 7)					**	**	NS	++	NS	++	*	*	**	NS	NS
Quad Rate N (4, 5, 6, 7)					*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Boron (6 vs 8)					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K (2 vs 6)					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P (3 vs 6)					NS	*	NS	NS	NS	NS	NS	NS	NS	++	NS

NS = Not significant, *, ++ = significant at the 5% and 10% level, respectively.

Table 4. Effect of various fertility treatments on nutrient composition of carrot roots at harvest.

Fertilizer Treatment					Nutrient										
#	N	P_2O_5	K_2O	B	NO_3-N	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
	lb N/A				ppm	%						ppm			
1.	0	0	0	0	10	0.77	0.33	2.97	0.36	0.12	57	20	5	22	25
2.	120	50	0	2	39	1.05	0.32	2.50	0.34	0.12	48	18	5	23	23
3.	120	0	150	2	56	1.20	0.34	3.03	0.37	0.12	49	23	5	26	23
4.	0	50	150	2	10	0.70	0.33	3.10	0.36	0.12	58	22	4	22	21
5.	60	50	150	2	24	1.15	0.35	3.20	0.34	0.11	53	22	4	23	22
6.	120	50	150	2	25	1.05	0.35	2.89	0.37	0.13	67	21	5	24	24
7.	220	50	150	2	95	1.45	0.36	3.12	0.39	0.14	54	28	4	28	24
8.	120	50	150	0	37	1.13	0.34	2.78	0.35	0.13	58	22	5	22	23
Significance					**	**	NS	*	NS	NS	NS	++	NS	NS	NS
BLSD (5%)					36	0.20	--	0.51	--	--	--	7	--	--	--
Contrasts															
Lin Rate N (4, 5, 6, 7)					**	**	NS	NS	NS	*	NS	*	NS	*	*
Quad Rate N (4, 5, 6, 7)					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Boron (6 vs 8)					NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K (2 vs 6)					NS	NS	NS	++	NS	NS	*	NS	NS	NS	NS
P (3 vs 6)					++	NS	NS	NS	NS	NS	++	NS	NS	NS	NS

NS = Not significant, *, ++ = significant at the 5% and 10% level, respectively.

TILLAGE, N RATE, ROW CULTIVATION, AND INOCULATION EFFECTS ON STAND ESTABLISHMENT, NODULATION, INCIDENCE OF WHITE MOLD, AND YIELD OF RED KIDNEY BEAN[1]

J.F. Moncrief, C.J. Rosen, B.J. Johnson, M.J. Wiens, B. Sheets and P.H. Graham, [2]

This study evaluated the effects of tillage, N rate, row cultivation, and inoculation on the response by Red Kidney Beans. Reduced tillage options reduced yields 200 to 350 pounds per acre. Grain yield responded to 123 pounds per acre of urea applied in two equal applications. The main effects of row cultivation and inoculation were not statistically significant although they interacted with tillage. Row cultivation reduced yields with the moldboard and disc treatments but increased them when grown with no tillage. Inoculation increased yields with the disc system but reduced them with the no till and moldboard systems.

This study was undertaken to evaluate the effect of tillage, N rate, row cultivation, and inoculation on the growth of Red Kidney Beans. The preceding three years corn was grown. Preceding that there was three years of alfalfa. Kidney beans have not been grown on this site.

The experimental design is a randomized complete block with split plots. Main plots are tillage. Subplots are nitrogen rate, row cultivation, and inoculation. Main plots are 16 rows (30") wide and 100 feet long. Nitrogen subplots were four rows wide and 100 feet long. Cultivation subplots are 16 rows wide and 50 feet long. Inoculation subplots are 2 rows wide and 100 feet long. Tillage, N rate, and cultivation history is three years. Two of the four planter hoppers received red kidney beans inoculated with Rhizobium. Kidney beans were treated with Lindane, Captan, and Streptomyicin. Two 10 foot rows in the center of each subplot were monitored for growth and yield. Five plants were removed from each subplots, roots gently washed and nodules counted. Shoot weight was also measured.

The percent soil cover with weeds by species on July 1, 1993 is shown in table 2. There was more foxtail with the no till system. Although foxtail was reduced by one half with cultivation in the no till system, there was still 19 percent cover by this weed. The other two systems evaluated did not have appreciable amounts of grass. An application of Poast was applied one week after these observations and resulted in good grass control the rest of the season. Ragweed was also higher with no tillage at this point in time, although basagran was applied two days after these observations.

The planter used in this study was equipped with row clearing discs. Their effectiveness in clearing the row area of corn residue was influenced by cultivation in previous years. Previous cultivation reduced in row cover with corn residue with the no till system (table 3). Although soil cover in the row was high, it did not affect stands. Less plants showed insect damage with the no till system.

Tillage reduced bean yields with the residue systems. More plants were infected with white mold when grown with moldboard plowing. Nodule numbers were increased with no tillage. The nitrogen rate affected bean yields, number of diseased plants, and shoot weights. Nodule numbers were not affected by N rate. The optimum N rate appeared to be close to 120 pounds per acre and did not interact with tillage. Cultivation reduced plant stands by 5,000 plants per acre. Inoculation reduced nodule numbers but did not affect yield.

Although cultivation and inoculation did not affect average bean yields there were offsetting interactions for both of these treatments with tillage (table 4).

Inoculation did not interact with N rate (table 5). There was an interaction between tillage, N rate, and inoculation (table 7). Kidney beans responded to inoculation consistently over the range of applied N for the disc tillage system. Beans grown with moldboard tillage responded to inoculant but not consistently over N rates. When grown with no tillage there was a consistent decrease due to inoculation.

There was also a four way interaction between tillage, N rate, cultivation, and inoculation (table 8). There was a positive response to inoculation when no till plots were cultivated and a negative response when not cultivated. The opposite trend occurred with the disc system and moldboard plowing resulted in a mixed response.

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Table 1. Cultural practices at Staples Irrigation Center, Wadena County, MN. 1993.

Tillage

No Till
Spring disc
Moldboard plowed with plow packer May 20
Cultivated with a Hiniker 5000 on July 27

Planting and Harvest Date

The planter is a 4 row Deutz-Allis Model 385 with 30 inch row spacing, equipped with 2 inch fluted coulters and disc row cleaners.

	Planting		Harvested
Crop	Date	Rate	Grain
Bean	May 28	122,000seeds/A	September 28 & 29

Soil

The soil is a Verndale sandy loam (coarse-loamy mixed, Udic Argiboroll) with a slope of 0 to 2 percent. The soil is well drained.

Previous Crop

1987-89 Alfalfa
1991-92 Corn - Pioneer
1993 Red Kidney Beans - Montcalm

Weed Control

2 pt/A of Ranger on 5/11/93
2 qt/A of Lasso on 6/2/93
1.5 qt/A of Basagran on 7/2/93
2 pt/A Poast + 2 pt/A crop oil on 7/8/93

Irrigation schedule

Month	inches
July	.50
Aug.	1.80

Disease Control

2 lb/a Benlate 50 DF on 7/20/93

Rainfall

Month	inches
June	3.37
July	4.89
Aug.	6.04
Sept.	1.69

Fertilizer 1991

Material Analysis	Rate[3]	N	P_2O_5	K_2O	S	Zn	Date Applied
	------ lb/A ------						
8-12-28-4-1[1]	150	12	18	11	6	2	5/8/91
46-0-0[2]	0	0	0	0	0	0	5/29/91
46-0-0[2]	65	30	0	0	0	0	5/29/91
46-0-0[2]	152	70	0	0	0	0	5/29/91
46-0-0[2]	239	110	0	0	0	0	5/29/91
46-0-0[2]	0	0	0	0	0	0	6/13/91
46-0-0[2]	65	30	0	0	0	0	6/13/91
46-0-0[2]	152	70	0	0	0	0	6/13/91
46-0-0[2]	239	110	0	0	0	0	6/13/91

1. Planter applied 2" below and 2" beside row.
2. Broadcast as split urea and irrigated in.
3. The resulting N rates are: 12, 72, 152, and 244 lbs/A

Fertilizer 1992

Material Analysis	Rate[3]	N	P_2O_5	K_2O	S	Date applied
	------ lb/A --------					
15-5-30-10[1]	115	17	6	34	12	5/5/92
46-0-0[2]	0	0	0	0	0	6/8/92
46-0-0[2]	65	30	0	0	0	6/8/92
46-0-0[2]	152	70	0	0	0	6/8/92
46-0-0[2]	239	110	0	0	0	6/8/92
46-0-0[2]	0	0	0	0	0	6/30/92
46-0-0[2]	65	30	0	0	0	6/30/92
46-0-0[2]	152	70	0	0	0	6/30/92
46-0-0[2]	239	110	0	0	0	6/30/92

1. Planter applied 2" below and 2" beside row.
2. Broadcast as urea and irrigated in with .24" and .60" for the 6/8 and 6/30 application dates
3. The resulting N rates are: 53, 113, 193 and 273 lbs/A 36 lbs. NO3-N/A from irrigation was added to N rates (refer to table 5.1992)

Fertilizer 1993

Material Analysis	Rate[3]	N	P_2O_5	K_2O	S	Date applied
	------ lb/A --------					
15-5-20-10[1]	154	23	8	31	15	6/1/93
46-0-0[2]	0	0	0	0	0	6/25/93
46-0-0[2]	54	25	0	0	0	6/25/93
46-0-0[2]	109	50	0	0	0	6/25/93
46-0-0[2]	163	75	0	0	0	6/25/93
46-0-0[2]	0	0	0	0	0	7/22/93
46-0-0[2]	54	25	0	0	0	7/22/93
46-0-0[2]	109	50	0	0	0	7/22/93
46-0-0[2]	163	75	0	0	0	7/22/93

1. Planter applied 2" below and 2" beside row.
2. Broadcast as urea by split application.
3. The resulting N rates are: 23, 73, 123 and 176 lbs/A.

Table 2. Effect of tillage and cultivation on weed cover.

7/1/93	No till		Disc		Mldbrd		(Pr>F)		
	--- % weed cover ------								
	C[1]	NC	C	NC	C	NC	Till	Cult	TxC
Alfalfa	.5	3.1	.1	.1	.0	.0	.084	.123	.122
Lambs	3.8	5.5	6.2	7.3	1.4	1.5	.322	.200	.806
Bindweed	3.4	4.0	10.9	15.4	3.1	3.1	.055	.056	.130
Foxtail	19.4	38.5	.6	5.2	.2	.3	.004	.008	.040
Thistle	.7	.8	.2	.0	.1	.0	.003	.872	.798
Ragweed	1.3	4.7	1.1	1.6	.2	.2	.042	.035	.077

1. C=cultivated NC=not cultivated.

Table 3. Effect of tillage on soil cover by corn residue, emergence and plant injury from insects[1].

	Residue[2] (%)				Stand		Injury[3]	
	Date 6/9/93				6/25/93	9/22/93	6/25/93	
Tillage	In Row		Bet Row		Emergence	Final	Cult	No Cult
	C	NC	C	NC	plants/acre x 10^{-3}			
No Till	51.8a	91.6a	73.3a	96.2a	59.2	54.4	36.5a	28.3a
Disc	19.7b	23.8b	30.3b	34.3b	60.8	52.7	53.4b	45.7b
Moldboard	11.1c	10.6c	12.5c	11.2c	61.0	56.6	49.0b	40.3b
Signif. (Pr > F)					.372	.149	.004	.003

1. Means within the same column when followed by the same letter are not significantly different(α=.10).
2. The p values for residue, row position, cultivation, tillage, tillage by row position, and the cultivation by row position interactions are .076, .005, .001, .720, .446, respectively. C=cultivated. NC=no cultivation.
3. Number of plants per acre with "bald head" (the plants are clipped above the cotyledon by insects).

Table 4. Effect of tillage, nitrogen rate, cultivation and inoculation on kidney bean response., 1993[1].

	9/28/93		9/22/93		7/26/93	
Treatment	Bean Moisture	Bean Yield	Stand 1000's	Disease 1000's	Nodule number	Shoot Weight
	--%--	-lbs/A-	-plt/A-	-plt/A-	- /plt-	-gms/plt-
Tillage (n=64)						
No Till	2.34a	2052a	54.7ab	11.1ab	184a	79.0a
Disc	2.24ab	2187a	52.7b	9.6b	112b	89.5ab
Moldboard	2.16b	2409b	56.6a	15.1a	120b	92.9b
Sig. (Pr > F)	.084	.043	.149	.087	<.001	.124
N Rate lb N/A (n=48)						
23	2.21	2045a	54.6	9.1a	142	72.6a
73	2.22	2138a	55.4	12.8b	---	90.4b
123	2.28	2370b	53.6	11.6ab	135	80.6ab
173	2.27	22312b	54.6	14.2b	---	107.7c
Sig. (Pr > F)	.722	<.001	.851	.037	.408	<.001
Cultivation (n=96)						
Cultivation	2.23	2212	52.1a	12.8	---	---
No Cultivation	2.26	2220	57.1b	11.0	---	---
Sig. (Pr > F)	.550	.845	<.001	.176	---	---
Inoculation (n=96)						
Inoculation	2.22	2207	---	---	121a	88.5
No Inoculation	2.27	2225	---	---	156b	85.6
Sig. (Pr > F)	.154	.315	---	---	.039	.766
Interactions						
Tillage X Cultivation (n=32)						
No Till W/	2.27	2127	52.2	12.7	---	---
No Till W/O	2.40	1977	56.5	9.5	---	---
Disc W/	2.22	2163	48.6	9.8	---	---
Disc W/O	2.25	2212	56.8	9.3	---	---
Mldbd W/	2.18	2346	55.4	16.0	---	---
Mldbd W/O	2.14	2471	57.8	14.2	---	---
Sig. (Pr > F)	.554	.018	.220	.707	---	---
Tillage X Inoculation (n=32)						
No Till W/	2.33	1977	---	---	170	74.7
No Till W/O	2.35	2128	---	---	198	83.3
Disc W/	2.17	2249	---	---	98	91.2
Disc W/O	2.31	2126	---	---	126	87.7
Mldbd W/	2.17	2395	---	---	94	99.5
Mldbd W/O	2.15	2422	---	---	145	85.7
Sig. (Pr > F)	.060	<.001	---	---	.799	.254

Table 5. Effect of tillage, nitrogen rate, cultivation, inoculation and their interactions on kidney bean response., 1993[1].

Tillage X N Rate lb N/A (n=16)[1]

Treatment		Bean Moisture	Bean Yield	Stand 1000's	Disease 1000's	Nodule number	Shoot Weight
		--%--	-lbs/A-	-plt/A-	-plt/A	- Avg.-	- gms -
Notill	23	2.31	1984	56.1	7.2	191	56.2
Notill	73	2.16	1869	55.2	14.3	---	80.9
Notill	123	2.51	2309	53.6	10.0	171	79.1
Notill	173	2.37	2047	52.6	12.8	---	100.5
MEAN		2.34	2052	54.4	11.1	184	79.0
Disc	23	2.24	1965	51.2	6.4	120	81.8
Disc	73	2.44	2139	56.0	8.6	---	96.4
Disc	123	2.10	2307	51.3	9.4	104	77.6
Disc	173	2.17	2335	52.5	13.8	---	105.0
MEAN		2.24	2187	52.7	9.6	112	89.0
Mldbd	23	2.08	2185	56.6	13.7	115	81.4
Mldbd	73	2.07	2404	54.9	15.5	---	90.8
Mldbd	123	2.22	2491	56.1	15.5	125	85.1
Mldbd	173	2.27	2553	58.8	15.8	---	122.0
MEAN		2.16	2408	56.6	15.1	120	93.0
Sig. (Pr > F)		.011	.219	.594	.581	.364	.632

1. Means within the same column with the same mean are not significantly different.

N Rate X Cultivation (n=24)

23	W/	2.24	1948	50.4	10.2	---	---
23	W/O	2.18	2142	58.9	8.0	---	---
73	W/	2.26	2194	53.6	14.9	---	---
73	W/O	2.19	2080	57.1	10.7	---	---
123	W/	2.24	2394	51.6	12.6	---	---
123	W/O	2.31	2344	55.7	10.6	---	---
173	W/	2.17	2311	52.7	13.6	---	---
173	W/O	2.37	2312	56.6	14.7	---	---
Sig. (Pr > F)		.436	.047	.529	.558	---	---

N Rate X Inoculation (n=24)

23	W/	2.16	2053	---	---	129	70.0
23	W/O	2.26	2037	---	---	155	75.6
73	W/	2.18	2116	---	---	---	89.6
73	W/O	2.27	2159	---	---	---	91.2
123	W/	2.31	2332	---	---	113	85.6
123	W/O	2.25	2407	---	---	157	75.6
173	W/	2.25	2326	---	---	---	112
173	W/O	2.29	2298	---	---	---	103
Sig. (Pr > F)		.231	.146	---	---	.580	.821

1. Means within the same column with the same mean are not significantly different.

Table 6. Interaction of tillage, nitrogen rate, and cultivation on kidney bean response., 1993[1].

Treatment		Bean Moisture		Bean Yield		Stand 1000's		Disease 1000's		Nodule number		Shoot Weight	
		---%---		-lbs/A-		-plts/A-		-plts/A-		-Avg.-		- gms -	
Till x N Rate(lb/A)x Cult, (n=8)													
		C[2]	NC[2]	C	NC	C	NC	C	NC	C	NC	C	NC
NT	23	2.43	2.19	1988	1980	51.2	61.0	9.1	5.2	---	---	--	--
NT	73	2.16	2.17	1990	1748	50.1	60.3	17.4	11.1	---	---	--	--
NT	123	2.36	2.67	2412	2207	53.8	53.4	9.2	10.9	---	---	--	--
NT	173	2.15	2.59	2121	1973	53.8	51.4	15.0	10.7	---	---	--	--
MEAN		2.27	2.40	2127	1977	52.2	56.5	12.7	9.5	---	---	--	--
DISC	23	2.16	2.32	1805	2126	45.3	57.1	7.6	5.2	---	---	--	--
DISC	73	2.52	2.37	2187	2091	54.0	57.9	10.7	6.5	---	---	--	--
DISC	123	2.15	2.05	2269	2347	45.7	56.8	9.4	9.4	---	---	--	--
DISC	173	2.06	2.28	2390	2282	49.4	55.5	11.5	16.1	---	---	--	--
MEAN		2.22	2.25	2162	2211	48.6	56.8	9.8	9.3	---	---	--	--
MB	23	2.13	2.04	2051	2319	54.7	58.6	13.9	13.5	---	---	--	--
MB	73	2.09	2.04	2407	2401	56.6	53.1	16.6	14.4	---	---	--	--
MB	123	2.21	2.22	2502	2480	55.3	56.8	19.4	11.5	---	---	--	--
MB	173	2.29	2.25	2424	2682	54.9	62.7	14.2	17.4	---	---	--	--
MEAN		2.18	2.14	2346	2470	55.4	57.8	16.0	14.2	---	---	--	--
SIG. (Pr> F)		.568		.690		.214		.595		.---		.---	

1. Means within the same column with the same mean are not significantly different.
2. C = cultivated. NC= not cultivated.

Table 7. Interaction of tillage, nitrogen rate, and inoculation on bean response at Wadena Co.,1993[1].

Treatment		Bean Moisture		Bean Yield		Stand 1000's		Disease 1000's		Nodule number		Shoot Weight	
		---%---		-lbs/A-		-plts/A-		-plts/A-		-Avg.-		- gms -	
Till x N Rate(lb/A)x Inoc, (n=8)													
		W[2]	W/O[2]	W	W/O	W	W/O	W	W/O	W	W/O	W	W/O
NT	23	2.21	2.41	1924	2044	---	---	---	---	188	194	52	60
NT	73	2.21	2.12	1719	2019	---	---	---	---	---	---	72	90
NT	123	2.52	2.50	2237	2382	---	---	---	---	152	201	76	82
NT	173	2.38	2.36	2029	2065	---	---	---	---	---	---	98	103
MEAN		2.33	2.35	1977	2128	---	---	---	---	170	198	75	83
DISC	23	2.29	2.19	2020	1911	---	---	---	---	96	143	73	91
DISC	73	2.22	2.67	2230	2048	---	---	---	---	---	---	105	88
DISC	123	2.12	2.08	2330	2285	---	---	---	---	99	108	84	71
DISC	173	2.05	2.30	2414	2257	---	---	---	---	---	---	103	108
MEAN		2.17	2.31	2249	2126	---	---	---	---	98	126	91	88
MB	23	1.99	2.18	2215	2156	---	---	---	---	101	127	86	75
MB	73	2.12	2.02	2399	2409	---	---	---	---	---	---	86	96
MB	123	2.27	2.16	2428	2554	---	---	---	---	87	161	97	74
MB	173	2.32	2.22	2536	2570	---	---	---	---	---	---	145	99
MEAN		2.17	2.15	2395	2422	---	---	---	---	94	145	103	86
SIG. (Pr> F)		.003		.103		.---		.---		.466		.600	

1. Means within the same column with the same mean are not significantly different.
2. W = with inoculation. W/O= with out inoculation.

Table 8. Interaction of tillage, nitrogen rate, cultivation and inoculation on kidney bean response at Wadena Co.,1993[1].

Treatment		KIDNEY BEAN							
		Moisture				Yield			
		----------%----------				---------lb/A----------			
		Cult.[2]		No Cult.		Cult.		No Cult.	
Till x N Rate(lb/A)x Cult x Inoc,(n=4)									
		W[3]	W/O	W	W/O	W	W/O	W	W/O
NT	23	2.19	2.66	2.23	2.15	2026	1950	1822	2139
NT	73	2.18	2.13	2.24	2.10	1848	2132	1590	1906
NT	123	2.24	2.48	2.81	2.52	2338	2486	2135	2279
NT	173	2.19	2.11	2.57	2.60	2163	2080	1895	2051
MEAN		2.22	2.34	2.46	2.34	2094	2162	1860	2094
DISC	23	2.09	2.23	2.49	2.15	1846	1765	2195	2058
DISC	73	2.19	2.84	2.24	2.50	2315	2059	2145	2037
DISC	123	2.21	2.09	2.03	2.06	2244	2293	2417	2278
DISC	173	2.09	2.04	2.00	2.55	2317	2463	2512	2052
MEAN		2.14	2.30	2.19	2.32	2180	2145	2317	2106
MB	23	1.98	2.27	1.99	2.10	2107	1996	2324	2315
MB	73	2.18	2.01	2.06	2.02	2409	2405	2389	2414
MB	123	2.20	2.23	2.35	2.10	2376	2629	2480	2480
MB	173	2.34	2.24	2.29	2.21	2437	2412	2635	2730
MEAN		2.18	2.13	2.17	2.11	2332	2360	2457	2485
SIG. (Pr> F)		.050				.003			

1. Means within the same column with the same mean are not significantly different.
2. C = cultivated. NC= not cultivated.
3. W = inoculated. W/O = with out inoculation.

Nitrogen Source Effects on Corn/Potato Yields and Nitrate Leaching[1]

J.T. Waddell, J.F. Moncrief, C.J. Rosen, S.C. Gupta and M.J. Weins[2]

Abstract

Plots were established at Staples, MN with the following treatments: Anhydrous ammonia with and without nitrification inhibitor, turkey manure, urea-ammonium nitrate, granular urea and a control. Each treatment (except the control) had fertilizer applied at approximately 200 pounds N per acre. No differences in yield or moisture content occurred in the corn grain supplied with different N sources, however a significant increase in grain yield was observed versus treatment effects on the control. Stover yields were found to be non-significant. Potato tubers and vines did respond to the different N sources. Anhydrous ammonia and turkey manure applied preplant and subject to 10 inches of rainfall in May still resulted in similar marketable and total potato yields to other N sources that were applied in split applications in June and July. There was also a significant potato response to nitrification inhibition. A comparison of vine dry matter yield shows that using urea as an N source enhances vine growth. Nitrogen collected in suction cups was lower for corn than potato. Crude estimations using excess soil moisture coupled with N concentrations sampled at 2 feet indicate that as much as 100 pounds per acre may have been lost.

Introduction

Crop production on the sandy soils in Minnesota has been advanced by the introduction of irrigation systems (Wright and Bergsrud, 1991). Wright and Bergsrud (1991) developed an irrigation schedule termed 'the Checkbook Method' which predicts daily water use for several different crops. It has been shown by Dylla et. al. (1980) that these tables to predict water use are comparable to estimates obtained by more precise methods. While the checkbook method may be a valuable tool for predicting irrigation scheduling, the variability of climate from year to year plays a major role in assessing the risks of loosing nitrogen to sub-surface water reservoirs. It has been shown that varying the source of nitrogen (either Urea or Turkey manure) in corn cropping systems may have an effect on yields and contribute to contamination of groundwater (Nathan et. al., 1992 and Sexton 1993). Nitrogen source studies on potato yield in Minnesota are infrequent.

It was the purpose of this study to discern the effects of nitrogen source on corn/potato yields and to qualitatively describe N movement below the root zone.

Materials and Methods

The test plots were located on a Verndale sandy loam. The site had a maximum slope of 2% with little or no runoff. Soils of the area are unique. An illuvial soil horizon of limiting hydraulic conductivity (0.54 in h^{-1}) exists with a clear upper boundary at approximately 10 inches and a gradual lower boundary at 16 inches below the surface (Sexton, 1993). Visual observations of the soil showed a limited number of preferential flow paths (macropores) due primarily to ant burrows. Earthworms are less common on soils of such a sandy nature.

Individual plots were 20 x 40 square feet. Corn (Pioneer 3921) was planted on 5 May in 30 inch rows at a rate of approximately 32,000 seeds per acre. On 6 May, the herbicides Bladex (cyanozine) and Dual (metalachlor) were applied at rates of 2.5 pounds and 2 pints per acre, respectively. No insect or fungus control procedures were needed in the corn. Weed control was good with a few weeds (quackgrass, lambsquarter and nightshade). Some eyespot was observed in the corn plots.

Potato (Russet Burbank) was planted on 27 April in 36 inch rows with a density of 43560 seed pieces per acre along with 30 pounds N per acre. Pre-plant and post-harvest knock down herbicide Diaquat was applied at rates of 1.5 pints per acre, otherwise weeds were controlled during the growing season by cultivation on 1 and 25 June. Furadan was applied on 27 July after noticing Colorado Potato Beetle infestation. Fungicide (Bravo) was applied on 23 June, 2 and 9 July, and 13 August (with Ridomil) at rates of 1.5 pints per acre. Some Early Blight was detected during the growing season.

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The design for both corn and potato studies was a completely randomized complete block with four replications. This conservative rate for high yields was used in order to discern differences if any in the uptake and loss of nitrogen. Table 1 shows the application rates and schedules of the various treatments. Anhydrous ammonia was placed below the row for potato pre-plant and between the row for corn sidedress on 30 June.

Irrigation scheduling was based on the Checkbook Method (Wright and Bergsrud, 1991), with attempts to apply 0.75 inches (Figure 1). During the corn stages from planting to 12 leaf, irrigation was applied at a deficit of 60% of the available water (1.42 inches); from 12 leaf to first dent, the irrigation trigger was 0.95 inches (40%); and from first dent to maturity, irrigation was initiated at 66% (1.6

Table 1. Nitrogen sources, application rates and dates.

Treatment	Potato			Corn		
	Rate	Date	Total‡	Rate	Date	Total
Anhydrous Ammonia with N-serve	239 (197)† lbs/ac	22 April	227 lbs/ac	347 (286) lbs/ac	30 June	303 lbs/ac
Anhydrous Ammonia	239 (197) lbs/ac	22 April	227 lbs/ac	347 (286) lbs/ac	30 June	303 lbs/ac
Urea	182 (85) lbs/ac	1 & 25 June	200 lbs/ac	182 (85) lbs/ac	1 & 25 June	187 lbs/ac
Urea Ammonium Nitrate (28%)	28 (85) gal/ac	1 & 25 June	187 lbs/ac	28 (85) gal/ac	1 & 25 June	187 lbs/ax
Turkey Manure§	6.8 (211) ton/ac	21 April	211 lbs/ac	6.8 (211) ton/ac	21 April	211 lbs/ac

† Values in parenthesis represent the calculated applied N (pounds per acre) for each source. Note that an additional 30 pounds N per acre was applied to potato and 17 pounds N per acre of corn in starter application.

‡ Represents total nitrogen applied to individual plots including starter fertilizer.

§ Applied value calculated by 100 % of mineral N (24.7 lbs N/ton dry weight) and 30% of organic N (59.1 lbs N/ton). Moisture content was 26.9%.

inches) depletion. For potatoes, an irrigation deficit of 50% was used from planting to tuberization and from tuberization to maturity a 40% deficit was used. Rainfall events which exceeded half of field capacity were followed by two days of cumulative soil water deficits at zero. Whenever the water deficit by the Checkbook Method was less then 10 centibars of tension, suction was applied to suction cup samplers. Also, suction was applied to samplers before irrigation events or when the chance of precipitation was 50% or greater.

Suction samplers were made from high flow (1 bar) porous ceramic cups (2 inch diameter) were glued to poly vinyl chloride (PVC) pipe. Access tubes were inserted through a rubber stopper from which suction was used for collection of soil water percolate. Suction samplers were installed in plots amended with Urea and turkey manure along with the control plot. Suction samplers were installed at the 24 inch depth. Samples collected were quickly frozen and taken to the analytical lab where nitrate and ammonia concentrations were measured.

Corn was harvested by hand on 21 October. Stover and grain moisture content, yield and N uptake were determined. Potatoes were harvested on 16 September with biomass, N accumulation and quality parameters determined.

Results and Discussion

From figure 1, it is evident that rainfall was not limiting during the growing period except for a few instances when irrigation was used. Ample or excess rainfall occurred in all months except June and July which were close to average values determined at the Irrigation Center. Mean temperatures were below normal for the growing season. For this reason, corn yields may have been depressed.

Corn

Table 2 shows the parameters measured for corn. No differences were seen in stover accumulation, likewise for grain yield (except in the case of grain, the control yielded significantly less). The lack of significant differences may be attributed to large variabilities between replications. Average grain yield over all treatments (except control) was 110 bushels per acre and for stover 1330 pounds per acre. Because of the wet and cold growing season, drying time was reduced as seen by moisture content in the grain (> 30%) and stover (50 to 70% water). Again, no differences were observed in grain moisture content and only slight differences in stover water content, due to high variability between replications.

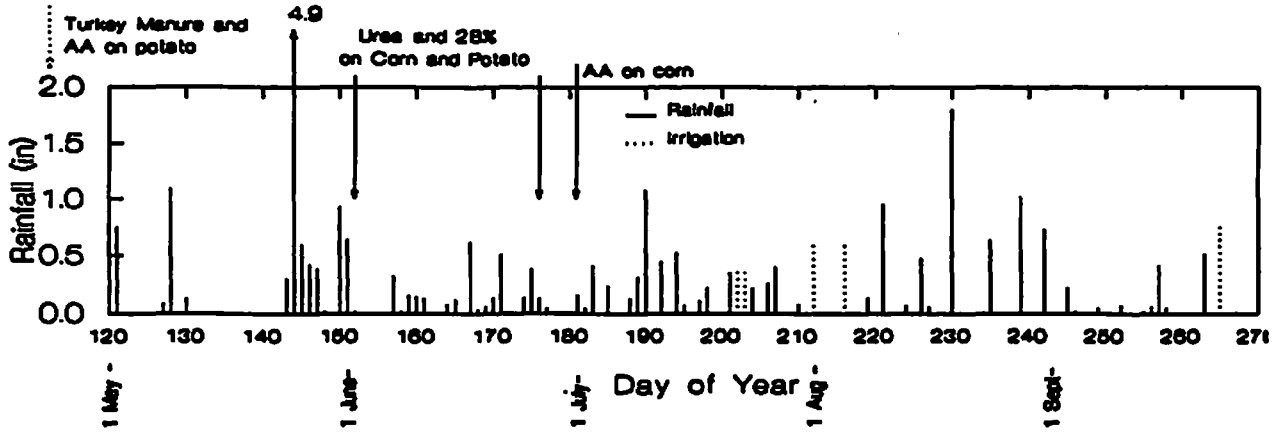

Figure 1. Rainfall and irrigation events for 1993 corn/potato growing season. Also shown is schedule of fertilizer applications.

Table 2. Response of corn to different nitrogen sources.

Nitrogen Source	Grain Yield	Grain Moisture	Stover Yield	Stover Moisture	Nitrogen Uptake		
					Grain	Stover	Total
	bu/ac	%	lbs/ac	%	----------lbs/ac----------		
Anhydrous Ammonia with N serve	106.6a	32.1a	1241a	64.6ab	75.7ab	11.1abc	86.8 b
Anhydrous Ammonia without N serve	107.0a	32.3a	2045a	50.4 b	75.0ab	17.4a	92.4ab
Urea	113.0a	32.6a	1073a	58.0ab	84.7a	17.1ab	101.8a
28%	107.7a	32.3a	1094a	77.7a	74.2ab	9.2abc	83.4 b
Turkey Manure	116.9a	31.7a	1314a	73.9a	73.4 b	8.8 bc	82.2 b
Control	70.1 b	33.4a	1220a	64.4ab	39.6 c	6.6 c	46.2 c

Means within a column followed by the same letter are not significantly different using Duncan's Multiple Range Test (α=0.1).

Nitrogen uptake in corn grain and stover is also shown in table 2. Plots with urea as the nitrogen source had the highest N uptake, although not significantly different then the anhydrous ammonia (with and without N-serve) or the urea ammonium nitrate (28%) sources. Nitrogen uptake in the urea plot was significantly greater than the turkey manure treatment. Figure 2 shows total nitrogen concentrations in soil water collected with suction samplers. From the figure, it can be seen that the N content moving out of the root zone increased steadily over time until mid August after which it dropped off. Increased uptake of nitrogen during the middle of the growing season is evident from the drop in the curve in the check plots, after which the concentration of N in the water increased probably due to mineralization of organic matter.

The first week in July shows the greatest moisture excess of approximately 1.5 inches in a week. Nitrogen lost in the turkey manure treatment increased sharply probably as a result of high mineralization rates which increased the potential for leaching.

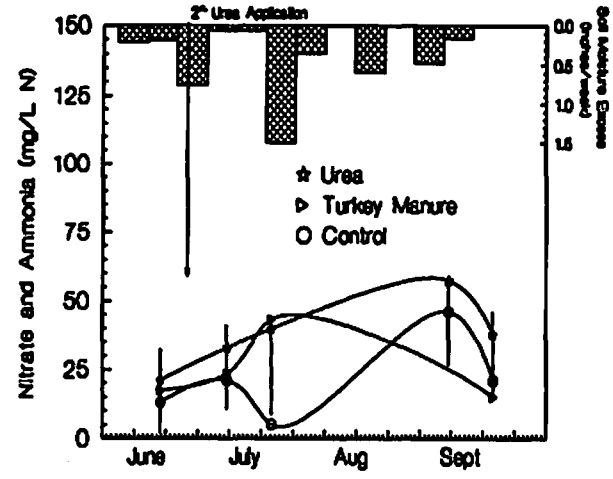

Figure 2. Soil water nitrate concentrations under corn along with soil moisture excess (calculated by checkbook method) and standard errors.

Table 3. Response of potato tubers to different nitrogen sources totalling to 210 (± 5) lbs/ac applied N.

Nitrogen Source	Culls	Ones	Twos	Jumbo	Knobs	Market	Total	Vine Yield
		cwt/ac						lbs/ac
Anhydrous Ammonia with N serve	23.0ab	139.9a	198.7a	9.1ab	11.6b	338a	382ab	1093b
Anhydrous Ammonia without N serve	21.6ab	120.2a	176.1a	15.4a	11.5b	296b	344ab	1070b
Urea	19.0b	161.4a	172.9a	10.0ab	23.9a	334a	387a	1999a
28%	18.6b	129.9a	160.8a	17.9a	14.5ab	290b	341b	1218b
Turkey Manure	24.5ab	122.8a	191.3a	6.7ab	24.3a	314ab	369ab	965b
Control	28.8a	32.9b	162.7a	0.6b	5.4b	195c	230c	318c

Means within a column followed by the same letter are not significantly different using Duncan's Multiple Range Test (α=0.1).

Potato

Table 3 shows the response of potato tubers to the different nitrogen sources. Marketable tuber yield was highest with the anhydrous application with N-serve, however this yield (338 cwt/ac) was not significantly different than the urea or turkey manure sources. The urea and AA (with N-serve) did yield significantly higher than the AA (without) and the 28% treatments. Besides marketable tubers, total tubers harvested followed a similar trend. Vine yield, which may not be economically important to the farmer, is important in accumulating nitrogen and perhaps reducing nitrate concentrations in subsurface water reservoirs. Table 3 shows that N accumulation in the vine was highest for the urea treatment. However, vine yields and N concentrations play only a minor role in the N budget. Nitrogen uptake in tubers was highest for AA with and without N-serve and urea treatments. Turkey manure amended to plots was not as efficient a source in that N uptake was less. As a result of tuber yield in turkey manure amended treatments not being significantly less than other treatments, luxury consumption of nitrogen was not a factor. Instead, as the growing season progressed the organic fraction of N in the turkey manure may have been made more available. Figure 3 shows nitrogen concentrations in soil water peaked for the manure treatments during the final stage of the growing season. A possible explanation would be that as mineralization increased (as can also be seen by the upward trend in the control treatment) plant requirements also increased. As the plants matured, the manure was still mineralized and as a result became susceptible to leaching. Figure 3 also shows the N content in soil water under plots amended with urea. The very high peak in late June after the second urea application may not actually be potentially leached. The samples collected from this treatment at this time contained as much as half the total in the form of ammonium. The lower leaching potential of NH_4^+ leads to questions of its arrival at the 2 foot depth. One explanation is that as a result of significant precipitation after urea application, the urea was solubilized and moved to the lower depth where it hydrolyzed and transformed into nitrate (by nitrification bacteria) and ammonium (hydrolysis product).

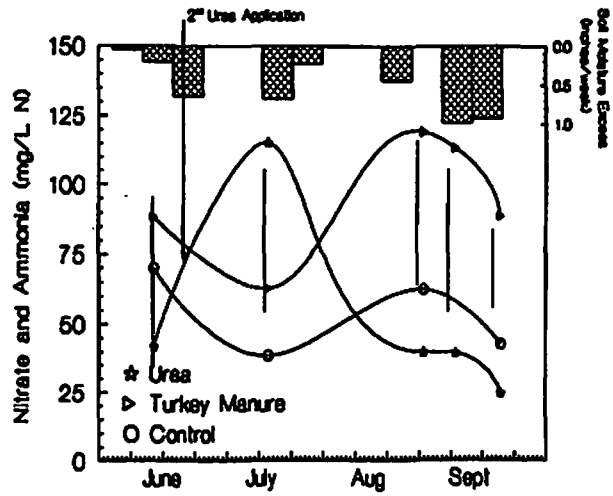

Figure 3. Soil water nitrate concentrations under potato along with soil moisture excess (calculated by checkbook method) standard errors.

Summary

Rainfall during the month of May totalled just under 7 inches (25 year mean rainfall = 3.2 inches), resulting in above average leaching conditions. Grain and stover yields did not differ significantly compared to different N sources at approximately equivalent rates. The response of greatest marketable tuber yield with application of Turkey manure, urea and anhydrous ammonia occurred. However, these results only apply in the case of above average rainfall. In order to determine whether different sources of N plays a role in yields and N losses, further study must occur. This study will be continued next year.

Table 4. Some quality parameters and Nitrogen uptake values along with moisture content of tuber data.

Nitrogen Source	Specific Gravity	Hollow Heart	Tuber N uptake	Tuber Water Content	Vine N Uptake	Vine Water Content
	g cm^{-3}	%	lbs / ac	%	lbs / ac	%
Anhydrous Ammonia with N Serve	1.096a	8.0 b	121a	75.8abc	18.6 bc	86.7a
Anhydrous Ammonia without N serve	1.095a	12.0ab	116ab	75.3 c	20.0 b	85.5a
Urea	1.094a	9.0 b	118ab	76.6a	32.9a	86.6a
28%	1.095a	10.0 b	106 bc	75.6 bc	20.2 b	87.5a
Turkey Manure	1.096a	9.0 b	99 c	76.3a	9.44 cd	87.8a
Control	1.095a	18.0a	52 d	75.6 bc	2.76 d	67.5 b

Means within a column followed by the same letter are not significantly different using Duncan's Multiple Range Test (α=0.1).

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SOUTHERN EXPERIMENT STATION
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WASECA, MINNESOTA 56093-4521

WEATHER DATA - 1993

Month	Period	Precipitation 1993	Precipitation Normal[1]	Avg. Air Temp. 1993	Avg. Air Temp. Normal[1]	Growing Degree Units 1993	Growing Degree Units Normal[1]
		---- inches ----		----- °F -----			
January	1 - 31	1.65	0.98	10.5	10.2		
February	1 - 28	1.21	0.97	13.8	16.1		
March	1 - 31	1.92	2.28	26.1	19.1		
April	1 - 30	5.12	2.97	42.4	43.1		
May	1 - 10	2.64		58.1		93.5	
	11 - 20	1.01		55.0		83.5	
	21 - 31	2.54		56.7		96.5	
	Total	6.19	3.65	56.6	57.7	273.5	327
June	1 - 10	.63		59.9		114.0	
	11 - 20	4.55		66.6		169.5	
	21 - 30	1.64		68.6		181.0	
	Total	6.82	4.11	64.9	67.1	464.5	515
July	1 - 10	2.37		70.2		199.0	
	11 - 20	3.21		69.3		187.0	
	21 - 31	1.58		70.7		226.5	
	Total	7.16	4.21	70.0	71.3	612.5	646
August	1 - 10	0.86		65.9		162.0	
	11 - 20	5.69		73.9		234.0	
	21 - 31	1.76		70.5		223.0	
	Total	8.31	4.20	70.1	68.4	619.0	567
September	1 - 30	3.29	3.56	55.2	59.9	230.0	316
October	1 - 31	0.75	2.45	46.5	47.9	0	31
November	1 - 30	1.73	1.72	29.9	32.3		
December	1 - 31	1.22	1.35	19.9	16.2		
Year	Jan-Dec	45.37	32.45	42.2	43.4	2200.0[2]	2402
Growing Season	May-Sep	31.77	19.73	63.5	64.9	2200.0	2371

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

Notes:
1) Highest April-September precipitation in 79-yr record.
2) Second highest annual precipitation in 79-yr record.
3) Highest 24-hour precipitation on August 15 - - - 4.52"
4) Growing degree units 8% below normal for season, 5th lowest since 1950.
5) Highest temperature on August 11 and 13 - - - 90°F.
6) Last spring frost - - - April 30.
7) First fall frost - - - September 27.
8) Third coldest September on record.
9) First time on record where May - Sept. precipitation exceeded pan evaporation.
10) Solar radiation for May - Sept. was 9% below normal and lowest in 21 yrs of record keeping.

1993 Soil Moisture

0-5' Profile, Webster Clay Loam

Continuous Corn

Southern Experiment Station, Waseca, MN 56093

Depth	4/30	5/14	6/1	6/15	7/3	7/16	8/3	8/20	9/1	9/16	10/1	10/15	11/1
inches	inches available water in zone												
0 - 6[1]	1.08	1.16	0.99	1.17	1.13	0.91	0.87	1.19	1.22	0.90	1.10	0.87	0.94
6 - 12	0.84	0.89	0.71	0.81	0.70	0.35	0.48	1.02	0.89	0.56	0.78	0.64	0.71
12 - 18	0.88	0.89	0.98	0.80	0.86	0.72	0.54	0.94	0.92	0.70	0.74	0.65	0.74
18 - 24	0.76	0.72	0.84	0.61	0.74	0.68	0.51	0.75	0.62	0.56	0.55	0.55	0.64
24 - 36	2.10	2.03	1.81	1.74	1.97	1.64	1.22	1.89	1.50	1.78	1.45	1.79	1.68
36 - 48	2.93	2.88	2.36	2.71	3.09	2.06	2.08	2.43	2.41	2.49	2.16	2.59	2.76
48 - 60	2.60	2.24	1.66	2.11	1.87	1.70	1.61	1.74	2.07	1.99	1.80	1.91	2.05
Total available water in 0-5' profile (inches)	11.19	10.82	9.36	9.95	10.36	8.06	7.30	9.96	9.64	8.98	8.58	9.01	9.51
% of Capacity[2]	101	98	85	90	94	73	66	90	87	81	78	82	86

[1] All values obtained by gravimetric sampling using Waseca D_b and WP constants.

[2] Assuming 11.05" field moist capacity.

Above average rainfall resulted in plentiful soil moisture in the five-foot profile throughout the 1993 growing season. Lowest soil moisture levels occurred in late July and early August during peak use. With soil moisture conditions at 86% of maximum in November soil moisture entering the 1994 growing season will likely be at field capacity.

NITROGEN LOSS TO TILE LINES AS AFFECTED BY PREVIOUS TILLAGE SYSTEMS[1]

Waseca, 1993

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

ABSTRACT: No tillage (NT) is thought to increase infiltration and, therefore, should increase the amount of water percolating through the soil compared to conventional tillage. An 11-year study was conducted to determine if greater amounts of NO_3-N and pesticides were being lost to tile drainage water with NT compared to moldboard plow (MP) tillage. In November 1992, all plots were moldboard plowed; thus results in 1993 are the residual effects of these two tillage systems. Rainfall during 1993 was 12.9" above normal and tile flow was plentiful. In this residual year, plots with NT history for the past eleven years had slightly higher tile flow compared to the MP tillage plots; however, the NO_3-N concentrations in the tile water were higher for the MP compared to NT. Nitrate-N losses to the tile lines were 20% higher for the MP system. Grain yield and N removal in the grain were not different between the two tillage systems. Silage yield,nitrogen uptake in the silage, and grain N concentration were higher for NT compared to the MP system. Under the stress conditions of 1993 these data indicate somewhat greater availability of N in the system following eleven years of NT; perhaps due to mineralization of higher amounts of immobilized N in the surface soil. The two tillage systems did not differ greatly in the amounts of NO_3-N in the 8-foot soil profile in November.

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. To some degree the time of application and crop grown have been shown to influence NO_3-N loss to tile lines. The purpose of this one-year study was to determine if previous long-term tillage has a residual effect on N utilization, accumulation of NO_3-N in the soil profile, and the subsequent loss of NO_3-N to tile lines.

EXPERIMENTAL PROCEDURES

A study was initiated in 1975 on a Webster clay loam at Waseca to monitor the movement of N into a tile line installed in each of 12 plots measuring 45' x 50'. Each plot is enclosed with plastic sheeting to a 6'depth. Annual N rates of 0, 100, 200, and 300 lb N/A were applied from 1975-1979. No N was applied for the 1980 and 1981 crops. Residual N from N applied over the 5-year period (75-79) was utilized by the 1980 and 1981 corn crops. Soil samples to 10' and tile water samples taken in late 1981 showed little remaining evidence of the previous treatments.

In the fall of 1981, eight plots with the most uniform tile flow rates over the 1975-81 period were selected. Two tillage treatments (fall moldboard plow and no tillage) were replicated four times and randomized over the previous plot histories. Beginning in 1990, three replications and 6 plots were used. Corn was grown on these plots from 1982 through 1992. In the fall of 1992, the stalks were chopped and all 8 plots were moldboard plowed.

On April, 23, 180 lb N/A as urea was applied with an air-flow applicator before field cultivation. Corn (Pioneer 3578) was planted on May 6 at a population of 32000 plants/A with a 6-row planter. 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 Lasso (3.5 lb ai/A) and Bladex (3 lb ai/A) applied May 13. Weed and insect control were excellent.

Silage yields were taken at physiological maturity. Grain yields were taken by combine from 2-45' rows. Tile line flow began on March 29 and continued to flow each month until September 30. When tile lines were flowing, flow rates were measured daily and samples taken on a daily basis for the first week and then on a M-W-F basis thereafter for NO_3 analysis. All analyses were done by the Research Analytical Lab.

Soil NO_3-N in the 0-8' profile was determined from two cores/plot taken in 1-foot increments on November 16, 1993.

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[1] Funding provided by the North Central Regional Research Committee (NC-201) and the Southern Experiment Station
[2] Professor and Post-Doctoral Research Associate, Univ. of Minnesota

RESULTS

Moldboard plowing the plots that had a 11-year NT history increased silage yield, total N uptake by the whole plant, and grain N concentration over the long-term MP tillage plots (P=90% level) (Table 1). In addition, trends toward increased grain yield and higher grain N removal after plowing the NT plots suggests greater N availability probably due to the mineralization of the organic N that accumulated in the top 6" of the NT plots over the 11-year period. Grain moisture was not affected by the previous tillage systems.

Precipitation during the growing season and for the year was 12.49 and 12.92" above normal, respectively. Consequently, tile flow was higher than usual for both the tillage systems (Table 2). Highest tile flow occurred in April followed by June. Flow-weighted NO_3-N concentration for the season averaged 23% higher with MP tillage. Thus, NO_3-N losses via the drainage water were 20% higher for MP tillage. On an annual basis these NO_3-N losses were the equivalent of 28% and 33% of the fertilizer added for NT and MP, respectively, in this very wet year.

Table 1. Influence of previous tillage systems on corn production and N utilization at Waseca in the residual year.

Tillage System	Final Population	Silage Yield	Silage N uptake	Grain Yield	Grain N	Grain N removal	Grain H_2O
	x10³	T DM/A	lb N/A	bu/A	%	lb N/A	%
Moldboard Plow	26.5	4.96	75.7	104.6	1.09	54.1	29.6
No Tillage	27.0	5.47	93.5	112.0	1.20	63.5	29.2
Signif.Level (%)[1]	98	92	94	60	94	88	37
CV (%)	0.4	3.6	6.4	8.1	2.9	7.4	3.0

[1] Probability level of significance.

Table 2. Influence of previous tillage systems on tile flow, flow-weighted NO_3-N concentration and NO_3-N loss in 1993.

Month	Tile Flow	NO_3-N Concentration	NO_3-N Loss
	acre-in	ppm	lb/A
		Moldboard Plow	
March	0.74	7.0	1.23
April	6.53	9.1	12.74
May	4.33	9.2	8.45
June	6.18	16.4	22.35
July	1.64	18.2	5.83
August	2.45	14.9	7.74
September	0.59	14.2	1.57
Total	22.46	Avg = 12.7	59.91
		No Tillage	
March	1.26	6.7	1.87
April	7.28	6.8	11.02
May	4.57	6.3	6.39
June	5.67	11.8	14.72
July	1.81	13.8	5.77
August	2.46	14.6	8.05
September	0.72	12.0	2.14
Total	23.77	Avg = 10.3	49.96

Residual NO_3-N in the soil profile at the end of 1993 growing season showed little difference between the two tillage systems. These results are different from the previous years where MP tillage contained consistently higher amounts of residual NO_3-N. The increased amounts of NO_3-N in the 0-8' profile of the former NT plots indicates that greater amounts of mineralized N became available after plowing in this system compared to the long-term MP tillage.

Table 3. Influence of previous tillage systems on residual NO_3-N in the soil profile in November, 1993.

Profile Depth	Tillage System	
	Mb.Plow	No Tillage
feet	----------NO_3-N (lb/A)----------	
0-1	13.1	18.1
1-2	4.4	5.6
2-3	5.1	6.0
3-4	13.6	18.4
4-5	12.3	15.2
5-6	10.7	10.9
6-7	10.8	12.0
7-8	10.1	9.4
Total (0-8')	80.1	95.6

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

Waseca, 1993

Gyles W. Randall, Gary L. Malzer and Jeffrey A. Vetsch[2/]

ABSTRACT: A study to determine the influence of time of N application and N-Serve on the uptake of N by corn and the loss of NO_3 to tile drainage was continued in 1993. Results from this seventh year showed significant yield improvement over the control with all N treatments. Fall application of N without N-Serve gave the lowest yields and N use efficiency of the N treatments. Yields and N use efficiency were not different among the fall + N-Serve, spring, and split N treatments. Tile lines flowed from late March through late September. Tile flow averaged 11.16" for corn and 10.55" for soybean. Highest NO_3-N concentration and losses in the corn plots occurred with the fall application of N without N-Serve while the highest concentration and losses under soybean occurred with spring and split application of N to the previous corn crop. Nitrate-N concentrations and losses from continuous fallow plots that did not receive fertilizer N or a planted crop for seven years were 60% higher than from the fertilized corn. This was due to soil mineralization and no crop uptake over this period.

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

EXPERIMENTAL PROCEDURES

Thirty-six individual tile line plots were installed on a poorly drained Webster clay loam at the Southern Experiment Station in 1976. Each 20 x 30' plot is completely surrounded by plastic sheeting to a depth of 6' to prevent lateral flow and contains a tile line (4' deep) 5 feet from one end. All tiles drain to collection pits where flow rates can be measured and water samples collected for analyses. After completing a research project in 1983 using this tile facility, the plots were cropped to corn with a blanket N rate in 1984 and 1985 to establish uniformity.

Beginning in 1986 corn was planted on one-half of the experimental site while soybean was planted on the other half. Thirty two plots (16 with corn and 16 with soybean) with the most uniform drainage were selected from the 36 for the primary study. The experimental design consists of a 4 x 4 Latin square where the rows and columns were based on the previous (1977-83) tile flow rates from each plot. The four primary N treatments (see Table 1) are applied to the corn phase each year with the residual effects measured in the soybean phase. Three additional N treatments were replicated four times around the edge of the core 16-tile-plot area and were planted to corn. These three treatments were analyzed along with the other four as a completely randomized design.

Anhydrous ammonia was applied at a rate of 135 lb/A for all N treatments while N-Serve was applied at 0.5 lb/A. Fall treatments were applied on October 28, 1992. Average soil temperature at the 4" depth on that date was 50°F with an average of 40°F over the following 10-day period. Spring preplant treatments were applied on May 5. The sidedress portion (60%) of the split treatments was applied at the V-8 stage on July 12.

The corn area (1992 soybean area) was field cultivated once before planting, while the soybean area (1992 corn area) was fall chiseled and field cultivated once prior to planting. Surface residue accumulation was estimated by the line-transect method in both the corn and soybean area before and after planting. Surface residues averaged 61, 64, 17, and 34% in the corn and soybean (1992) plots before and after planting, respectively. Because of high soil P and K tests, no broadcast nor starter fertilizer was used.

Corn (Pioneer 3578) was planted at 32,200 seeds/acre on May 17 with a JD Max-Emerge planter equipped with waffle coulters. A corn rootworm insecticide was not used. Weeds were chemically controlled with a preemergence application of Lasso (3.5 lb/A) plus Bladex (3 lb/A) on May 22. Soybeans (Sturdy) were planted in 30" rows at 9 beans per foot of row on May 17. Weeds were chemically controlled with 3.0 lb/A Lasso preemergence (June 1) plus a post emergence application of Pursuit (4 oz/A) at the 1st trifoliate stage (July 7).

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-4 stage and plots were thinned to 29,040 plants/acre. Stover and grain samples were taken at physiological maturity by hand harvesting 30' of row for stover yields and 60' of row for grain yields and moisture. Tile line flow rates were determined daily and were recorded when flow exceeded 10 ml/minute (0.01"/day). Samples were collected for NO_3-N analysis on an every-other-day basis. Soil samples for NO_3-N analysis were taken in 1-foot increments to a depth of 8 feet from the fallow plots and selected soybean plots on May 5. Chemical analyses of whole plant stover, grain, water, and soil samples were performed by the Research Analytical Laboratory, University of Minnesota.

1/ Partial funding provided by Dow Chemical U.S.A., Minnesota Agric. Exp. Stn., and the Southern Experiment Station.

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

Plant

Stover N concentration at physiological maturity was significantly affected by fertilizer N and its time of application (Table 1). Stover N was incresed over the control by all N treatments except when applied in the fall without N-Serve. Split application of N resulted in higher stover N concentration (0.82%) than the fall treatment without N-Serve (0.63%). Stover N for the fall with N-Serve and spring treatments (0.72%) was not different (P = 95% level) than the fall without N-Serve and split treatments.

Stover yield was increased over the control by all of the fertilizer N treatments (Table 1). However, statistical differences among the four primary treatments were not significant (P = 90% level). When all seven treatments were analyzed as a completely randomized design, it is clear that highest stover yields (average of 1.84 tons) were obtained with the spring preplant N treatments while the lowest yields (average of 1.55 tons) were consistently obtained with the split treatments. Fall application of N did not increase stover yield above that obtained with the split application of N.

Similar to stover yield, N uptake in the stover was incresed above the control by all fertilizer N treatments (Table 1). Differences in stover N uptake among the four primary treatments occurred only at the P = 84% level. Analyses of all seven treatments indicated significantly (P = 95% level) lower N uptake with the fall application without N-Serve compared to all spring and split N treatments.

Table 1. Influence of time of N application and N-Serve on whole plant N, stover yield, N uptake, and final population of corn following soy soy soybeans.

N Application		Stover			Final
Time	N-Serve	N	Yield	N uptake	Population
		%	TDM/A	lb/A	ppA x 10^3
Primary trts					
Fall (Oct.)	No	0.63	1.61	20.3	28.8
Fall (Oct.)	Yes	0.72	1.68	24.3	28.8
Spring (April)	No	0.72	1.78	25.7	28.9
Split[1]	No	0.82	1.54	25.6	28.8
Additional trts					
Check	–	0.54	1.08	11.6	28.7
Spring (April)	Yes	0.80	1.90	30.2	28.8
Split[1/]	Yes	0.83	1.56	26.1	28.6
		Statistical Analysis			
Latin square (Primary trts)					
Significance Level (%) :		97	80	84	8
BLSD (.05) :		0.12	–	–	–
CV (%) :		8.9	8.4	13.6	0.9
Completely randomized (7 trts)					
Significance Level (%) :		99	99	99	6
BLSD (.05) :		0.09	0.19	4.6	–
CV (%) :		8.7	8.6	14.2	1.3

[1/] 40% preplant + 60% sidedress.

Grain and silage yields were increased significantly over the control (0 lb N/A) by all of the N treatments (Table 2). Fall application of N without N-Serve gave consistently lower grain and stover yields than the three other primary treatments. Yields among the fall with N-Serve, spring, and split N treatments were not different. Grain moisture at harvest was significantly higher for the 0-lb N treatment compared to the rest, but differences in moisture among the four primary treatments did not exist.

Grain N concentration was higher for all fertilizer N treatments compared to the control (Table 2). Among the four jprimary treatments, significantly higher grain N was found with the split treatment. Grain N concentrations tended to be higher with the spring N + N-Serve and split treatments compared to the fall and spring without N-Serve treatments. Nitrogen removed in the harvested grain was lowest with the fall-applied N treatment without N-Serve and highest for the split and spring N + N-Serve treatments (Table 2). Total N uptake was increased over the control by 35.9 lb/A (90%) for the fall without N-Serve, 47.5 lb/A (120%) for the fall + N-Serve, 45.3 lb/A (114%) for the spring preplant treatment, and an average of 56.1 lb/A (141%) for the spring with N-Serve and split N treatments.

The General Linear Model program in SAS was used to "contrast" the four primary treatments and determine if significant differences existed. The significance levels shown in Table 3 show an improvement in stover N concentration, grain yield, silage yield, grain N removal, and silage N uptake (P = 90% level) with N-Serve added to the fall-applied N. Spring application of N showed significant advantages over fall-applied N for stover N concentration, grain moisture, and silage N utake. Split application of N resulted in higher stover and grain N concentrations, lower stover yield, higher grain N removal, and lower silage N uptake compared to the spring preplant application.

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

N application		Grain					Total N
Time	N-Serve	Yield	H_2O	N	N removal	Silage	uptake
		bu/A	%	%	lb/A	TDM/A	lb/A
Primary trts							
Fall (Oct.)	No	103.9	41.1	1.12	55.2	4.06	75.6
Fall (Oct.)	Yes	114.2	40.7	1.16	63.0	4.35	87.2
Spring (April)	No	112.6	40.6	1.11	59.3	4.45	85.0
Split[1]	No	116.7	39.4	1.23	68.1	4.30	93.7
Additional trts							
Check	–	57.5	43.8	1.03	28.1	2.44	39.7
Spring (April)	Yes	124.0	41.8	1.24	72.4	4.83	102.8
Split[1/]	Yes	114.8	42.1	1.20	65.0	4.28	91.0
Latin square (Primary trts)		Statistical Analysis					
Significance Level (%):		90	85	98	94	88	98
BLSD (.05)	:	11.6	1.8	0.07	9.5	0.36	9.7
CV (%)	:	5.5	2.3	3.3	8.4	4.5	6.4
Completely randomized (7 trts)							
Significance Level (%):		99	99	99	99	99	99
BLSD (.05)	:	9.2	1.6	0.07	7.0	0.30	9.7
CV (%)	:	6.5	2.6	4.3	8.9	5.5	8.8

[1/] 40% preplant + 60% sidedress.

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

	Contrast		
Parameter	Fall w/o N-Serve vs Fall w/N-Serve	Fall vs Spring	Spring preplant vs Split
	Significance Level (%)		
Stover N Concentration	91	98	94
Grain N Concentration	82	82	99
Grain Moisture	41	90	89
Grain Yield	94	88	62
Stover Yield	47	23	95
Silage Yield	92	87	67
Final Population	10	14	47
Grain N Removal	92	88	95
Silage N Uptake	98	97	94

Water

Weather conditions during the 1993 growing season were colder than normal and were 12.0" wetter than normal. This resulted in tile flow from March 31 through September 27. Tile drainage volumes shown in Table 4 indicate highest flows in Appril, May, and June. Drainage from the 16 corn plots averaged 11.76" with a 1.59" range among the four time/method treatments. Soybeans showed slightly less tile drainage compared to corn with an average of 10.55" from the 16 plots and a range of 4.63" among the four time/methods. Ideally, drainage should be uniform among the time/method treatments; however, normal soil and drainage variability exists in these plots and results in these unfortunate differences.

Monthly flow-weighted NO_3-N concentrations in the corn plots showed greater temporal variation than in previous years. Very low NO_3-N concentrations were found in the very first samples collected (March) (Table 5). In April, NO_3-N concentrations were 2X to 3X higher than in March with the highest concentration found in the fall treatment without N-Serve. In May the flow-weighted NO_3-N concentratijons were 2.6, 1.6, and 0.9 mg/L higher than in April for the fall, fall + N-Serve, and spring treatments, respectively, while the split treatment showed no change in concentration. High flow rates in June apparently were responsible for the high NO_3-N concentrations being leached to the drainage water. Flow-weighted NO_3-N concentrations in June were 7.3, 5.4, 3.9, and 2.8 mg/L higher than in May for the fall, fall + N-Serve, spring, and split applications, respectively. In July, highest concentrations continued with the fall treatment; however, NO_3-N concentrations escalated more quickly (3.0, 4.9, and 1.6 mg/L) with the fall + N-Serve, spring, and split applicatijons, respectively. Nitrate-N concentrations began to decline in August with all N treatments. In September, highest NO_3-N concentrations were found with the fall + N-Serve and spring treatments. Flow-weighted NO_3-N concentrations for the year were highest for the fall treatment, intermediate for the fall + N-Serve and spring treatments, and lowest for the split treatment. These concentrations were lower than in previous years, probably due to the high rainfall over the last 3 years. These data clearly show the susceptibility of fall-applied N without N-Serve to loss of NO_3 in tile drainage water when spring rainfall is excessive.

Table 4. Tile water discharge from the corn, soybean, and fallow plots in 1993.

N application		Month							Year
Time	N-Serve	March	April	May	June	July	August	Sept.	Total
		acre -inches							
		CORN							
Fall (Oct.)	No	0.00	3.10	2.59	3.58	0.46	1.26	0.07	11.06
Fall (Oct.)	Yes	0.00	3.24	2.76	3.87	0.67	1.29	0.08	11.90
Spr. (April)	No	0.12	2.76	2.37	3.93	0.67	1.40	0.12	11.36
Split	No	0.28	3.32	2.69	3.94	0.78	1.59	0.05	12.65
		SOYBEANS							
Fall (Oct.)[1/]	No	0.04	3.06	2.10	3.33	0.73	1.22	0.04	10.52
Fall (Oct.)[1/]	Yes	0.23	3.59	2.89	4.00	0.78	1.24	0.01	12.74
Spr. (April)[1/]	No	0.00	3.16	2.32	3.41	0.83	1.09	0.03	10.84
Split[1/]	No	0.00	2.16	1.33	3.42	0.27	0.92	0.01	8.11
		FALLOW							
NONE		0.00	2.35	1.16	2.87	0.62	1.10	0.17	8.28

[1/] N applied for the 1992 corn crop.

Table 5. Flow-weighted NO_3-N concentrations for each month from the corn, soybean, and fallow plots in 1993.

N application		Month							Year
Time	N-Serve	March	April	May	June	July	August	Sept.	Total
		mg NO_3-N/L							
		CORN							
Fall (Oct.)	No	—	8.6	11.2	18.5	18.9	12.7	9.1	12.5
Fall (Oct.)	Yes	—	6.9	8.5	13.9	16.9	13.0	13.0	10.5
Spr. (April)	No	2.0	6.4	7.3	11.2	16.1	9.7	16.9	9.9
Split	No	3.7	6.6	6.4	9.2	10.8	8.8	8.1	7.6
		SOYBEANS							
Fall (Oct.)[1/]	No	—	10.8	10.2	8.7	9.2	8.7	—	8.3
Fall (Oct.)[1/]	Yes	2.2	6.6	6.2	6.2	6.4	6.2	5.5	5.9
Spr. (April)[1/]	No	—	10.7	10.1	8.5	7.8	6.9	—	9.1
Split[1/]	No	—	11.4	10.5	10.1	9.0	8.7	—	11.0
		FALLOW							
NONE		—	27.0	28.6	24.6	23.4	22.4	15.6	22.7

[1/] N applied for the 1992 corn crop.

Table 6. Nitrate-N loss for each month from the corn, soybean, and fallow plots in 1993.

N application		Month							Year
Time	N-Serve	March	April	May	June	July	August	Sept.	Total
		lb NO_3-N/A							
		CORN							
Fall (Oct.)	No	0.00	5.61	6.07	14.30	1.94	3.15	0.14	31.21
Fall (Oct.)	Yes	0.00	4.74	5.13	11.98	2.66	3.53	0.23	28.27
Spr. (April)	No	0.05	4.59	4.62	10.23	2.43	3.22	0.45	25.59
Split	No	0.23	4.72	3.94	7.91	1.90	2.94	0.10	21.74
		SOYBEANS							
Fall (Oct.)[1/]	No	0.05	6.54	4.04	5.83	1.19	2.14	0.04	19.83
Fall (Oct.)[1/]	Yes	0.12	5.10	3.70	5.41	1.03	1.68	0.01	17.05
Spr. (April)[1/]	No	0.00	7.57	5.22	6.46	1.48	1.68	0.03	22.44
Split[1/]	No	0.00	6.39	3.59	7.68	0.61	1.89	0.01	20.17
		FALLOW							
NONE		0.00	13.54	6.50	13.84	3.00	5.00	0.60	42.49

[1/] N applied for the 1992 corn crop.

In the soybean plots, where N had been applied either in the fall of 1991 or spring of 1992, NO_3-N concentrations were consistently lower throughout the season and seldom averaged greater than 10 mg/L (Table 5). Highest flow-weighted NO_3-N concentrations were found with the split treatment, especially early in the season. Lowest annual flow-weighted concentration occurred with the fall + N-Serve treatment. Nitrate-N concentrations under a 7-year continuous fallow system (no fertilizer N applied) were approximately 2 to 3X higher than from the fertilized corn and soybean plots. Again, the monthly flow-weighted NO_3-N concentrations appeared to decline over the season; probably a reflection of the high amounts of rainfall which flushed mineralized NO_3 from the soil profile.

Nitrate-N losses in the drainage water were slightly higher for corn than for soybeans (Table 6). Under corn greatest loss of NO_3 occurred with the fall applications, especially when N-Serve was not applied. Losses were least with the split application of N. This would be expected because most of the percolation occurred in May and June prior to application of 60% of the N in this treatment. Nitrate-N losses under soybean were highest for the spring treatment, intermediate for the split and fall treatments, and lowest for the fall + N-Serve treatment. Nitrate-N losses in the fallow system, where mineralization of the soil organic matter was the NO_3 source, was 30 to 150% higher than from the fertilized corn-soybean rotation. This emphasizes the importance of growing a crop to absorb N released from these high organic matter soils.

Nitrate-N losses to the tile drainage water were normalized to tile water flow to minimize the influence of water flow volume among the N treatments on the interpretation of the data (Table 7). Normalized values for corn were highest for the fall w/o N-Serve, intermediate for fall + N-Serve and spring, and lowest for the split treatment. In the year following corn and its associated treatments, normalized losses ranked in the order split > spring preplant > fall w/o N-Serve > fall w/N-Serve. Apparently, sufficient N was not utilized by the corn and remained in the soil profile following the split and spring applications; thus, higher NO_3 losses in the succeeding year. Normalized NO_3-N losses for the corn-soybean system were highest for the fall treatment, intermediate for the spring and split treatments, and lowest for the fall + N-Serve treatment. Additional years with adequate drainge losses are necessary to determine if these findings are consistent over time.

Table 7. "Flow-normalized" NO_3-N losses to tile drainage in a corn-soybean sequence in 1993.

	Time/Method of N Application			
Crop System[1/]	Fall No N-Serve	Fall + N-Serve	Spring No N-Serve	Split No N-Serve
	NO_3-N lost (lb/A/inch of drainage)			
Corn	2.82	2.38	2.25	1.72
Soybean	1.88	1.34	2.07	2.49
Corn Soybean System	2.36	1.84	2.16	2.02

[1/] Continuous fallow (7 years without fertilizer N) = 5.13.

Soil

Nitrate-N remaining in the 0-8' soil profile in late-April was considerably lower for both crop systems compared to previous years (Table 8). This was especially true for the fallow system. Slightly more NO_3 accumulted below the tile depth in the fallow system compared to the soybeans. The above-normal rainfall conditions in 1990, 1991, and 1992 undoubtedly affected residual soil NO_3 levels at the start of this year. Because of this and the fact that record amounts of growing season rainfall were received in 1993, no soil samples were taken for residual NO_3 after harvest.

Table 8. Nitrate-N in the soil profile in April, 1993 as influenced by previous crop in 1992.

	1992 Crop	
Profile depth	Fallow	Soybean
feet	lb/A	
0 - 1	9.4	19.2
1 - 2	.5	8.8
2 - 3	10.1	6.1
3 - 4	10.8	3.3
4 - 5	9.3	3.7
5 - 6	9.2	4.4
6 - 7	11.6	4.2
7 - 8	12.8	5.0
Total in		
0 - 5' profile	47.1	41.1
0 - 8' profile	80.7	54.7

CONCLUSIONS

The cold and wet conditions resulted in fair corn production and plentiful tile drainage. Corn production was greatly improved by the various N treatments over the control. Corn grain and silage production was influenced by time of application with fall application generally resulting in lowest yields and N use efficiency. Corn production and N uptake were quite similar for the fall N + N-Serve, spring, and split treatments; however, split-applied N did result in lower stover yields and higher grain N concentrations. Tile flow data indicated only small differences among the four N treatments with respect to amount of drainage but did show elevated NO_3-N concentrations and losses with the fall application of N w/o N-Serve. Flow-weighted, monthly average NO_3-N concentrations closely reflected the time of N application. Nitrate-N concentrations from the fall treatment w/o N-Serve began to excalate in May and quickly rose in June to 18.5 mg/L. Adding N-Serve to the fall-applied N delayed the escalation of NO_3 in the drainage with the peak reaching 16.9 mg/L in July. Spring and split applications delayed NO_3 escalation until June with peak concentrations of 16.1 and 10.8 mg/L, respectively, occurring in July. Nitrate-N concentrations and losses in the drainage water in the "residual" year with soybeans were much lower but were highest with the previous spring and split application treatments. Residual soil NO_3 at the beaginning of the season was very low due to the wet conditions of the past three years.

NITROGEN FERTILIZATION OF ESTABLISHED REED CANARYGRASS

Waseca, 1993

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

ABSTRACT: Recently developed low-alkaloid varieties of reed canarygrass are being considered as an alternative forage for dairy enterprises. The objectives of this study were to determine the effect of single early-season and split applications of fertilizer N on the yield and quality of reed canarygrass. Forage yields were optimized at the 300 lb N/A rate. Total N uptake and N concentration increased with increasing N rate (both April and June) except the second harvest where they were maximized at 150-lb N rate applied in June. Single early-season applications of N were as effective as split applications for yield and forage quality. Residual soil NO_3-N in the 0-3' profile after the third cutting significantly increased when N applications exceeded 400 lb N/A. Continued research will be needed to accurately determine the environmental effects of high N rates applied to reed canarygrass.

Research conducted in Iowa in the early 70's indicated that reed canarygrass contained high concentrations of N and utilized fertilizer N very efficiently when fertilized with ample N. The objectives of this study were to determine the effect of single early-season and split applications of fertilizer N on the yield and quality of reed canarygrass.

EXPERIMENTAL PROCEDURES

Twenty plots, each measuring 20' x 40', were laid out on established reed canarygrass (var. Palaton) in April 1993 on a Webster clay loam soil. Plots were fertilized with varying rates of N as ammonium nitrate on April 23. After the first cutting the main plots were split into subplots and again were fertilized with varying rates of N as ammonium nitrate on June 14 (Table 1). A randomized complete block design with four replicates was used in the analysis of the first harvest (June 3). An unbalanced split-plot design was used for the second (July 15) and third (Sept. 1) harvests. Yields were taken by harvesting a 3' x 40' swath (first cut) and a 3' x 20' swath (second and third cuts) from each plot. Forage subsamples were taken for moisture and total Kjeldahl N analyses. The analyses were conducted by the Research Analytical Laboratory in St. Paul. Soil samples, three cores per plot to a depth of 3 feet in 1 foot increments, were taken from selected treatments on November 23. All soil samples were immediately forced-air dried at 125° F, ground, and analyzed for NO_3-N by the Research Analytical Laboratory.

RESULTS AND DISCUSSION

Yield

First harvest dry matter yields were increased significantly over the control by the early (April 23) application of N fertilizer. Yields were not increased further at rates greater than 150 lb N/A (Table 1). Second harvest yields were increased significantly over the control by both the April and June applications. A significant April x June interaction was found for the second harvest. This interaction is explained by the 1.29 TDM/A yield increase with the 150 lb N/A rate applied in June when no N was applied in April, compared to a 0.44 T/A yield increase with the same June rate applied to plots receiving 150 lb N/A in April. Moreover, the highest second cut yield (1.51 TDM/A) occurred with the 0 + 150 lb N/A (April + June) application rates, compared to 1.34 TDM/A when 150 lb N/A was applied in both April and June. Third cut yields responded significantly up to 300 lb N/A for early application and 200 lb N/A for the late application. The April x June interaction was not significant. The 200 lb (April) + 200 lb (June) treatment produced the highest yield.

Total dry matter yield was optimized at a combined total of 300 lb N/A. An April application of 300 lb N/A produced yields equal to the split application of 150 + 150 lb N/A. The significant April x June interaction for total dry matter yield is shown by the 2.10 TDM/A yield increase when 150 lb N/A was applied in June to plots that received no N in April, compared to only a 0.98 TDM/A increase when the same June rate was applied to plots receiving 150 lb N/A in April. In addition, no yield increase was found when 300 lb N/A was added in June to plots receiving 300 lb N/A in April. More N (300 compared to 250 lb N/A) was required to obtain optimum yield of reed canarygrass in 1993 as compared to 1992. Higher rainfall in 1993 could explain the differences in N required between the two years.

N Concentration

Total N concentration in the forage increased significantly with N application for all three harvests (Table 2). However, N concentration in the second harvest did not increase with June N rates above 150 lb N/A. Nitrogen concentration was very high for the 0 (April) + 150 lb N/A (June) application indicating rapid uptake of N in the 30-day period between application and harvest. Generally, June N affected N concentration more than April N for the second harvest. The treatment effects on N concentration are consistent with the observed significant yield interaction between April and June applications. No N concentration interaction was found for the third harvest; thus N concentration increased with increasing N rate for both April and June application.

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Table 1. Dry matter yield of Reed Canarygrass as influenced by N fertilization at Waseca in 1993.

Rate/Time of N Applc'n		Cutting Number & Date			
		1st	2nd	3rd	
April 23	June 14	6/3	7/15	9/1	Total
lb N/A		TDM/A			
0	0	1.26	0.22	0.39	1.87
0	50		1.05	0.59	2.90
0	100		1.45	0.76	3.47
0	150		1.51	1.19	3.97
50	0	1.88	0.38	0.45	2.70
50	50		1.02	0.57	3.47
50	100		1.31	0.81	4.00
50	150		1.43	1.23	4.53
100	0	2.21	0.70	0.57	3.49
100	50		1.12	0.78	4.11
100	100		1.37	0.95	4.52
100	150		1.39	1.27	4.87
150	0	2.49	0.90	0.74	4.12
150	50		1.26	0.95	4.70
150	100		1.26	1.14	4.89
150	150		1.34	1.28	5.10
200	0	2.37	1.20	0.96	4.53
200	200		1.38	1.41	5.16
300	0	2.53	1.34	1.29	5.16
300	300		1.32	1.35	5.20
Individual Factors					
April N Rate					
0		1.26	1.06	0.73	3.05
50		1.88	1.03	0.76	3.67
100		2.21	1.14	0.89	4.25
150		2.49	1.19	1.03	4.70
200		2.37	1.29	1.18	4.85
300		2.53	1.33	1.32	5.18
Signif. Level (%):		99	99	99	99
BLSD (.05):		0.28	0.10	0.13	0.36
June N Rate					
0			0.79	0.73	3.65
50			1.11	0.72	3.96
100			1.35	0.91	4.38
150			1.42	1.24	4.78
200			1.38	1.41	4.92
300			1.32	1.35	4.79
Signif. Level (%):			99	99	99
BLSD (.05):			0.10	0.14	0.21
Interaction April x June Application					
Signif. Level (%):			99	34	99
CV (%):		9.5	9.7	9.8	5.7

N Uptake

Total N uptake for the first harvest was significantly increased above the control by each April N rate (Table 2). Highest uptake values with the early application were obtained at 300 lb N/A for all harvests. A significant interaction between April and June application was observed for the second harvest. The highest uptake values for the second harvest were obtained with the late 150 lb N/A rate following zero early N. No significant interaction occurred in the third harvest as uptake rates increased at each rate for both application times. Total N uptake, sum of all three harvests, increased with increasing N supply (Table 3). Apparent N recovery was high (80% or more) for all application rates except 400 and 600 lb N/A. Highest percent recovery was generally obtained with a single April application of ≥100 lb N/A, unlike 1992, where split applications were better.

Table 2. Nitrogen concentration in and N uptake by Reed Canarygrass as influenced by N fertilization in 1993.

Rate/time of N application		N Concentration			N Uptake		
April 23	June 14	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
lb N/A		%			lb N/A		
0	0	2.35	2.68	2.45	59.6	11.7	19.4
0	50		2.86	2.51		59.8	30.0
0	100		2.62	2.47		105.0	37.3
0	150		4.25	2.66		128.7	63.4
50	0	2.26	2.70	2.33	84.7	20.7	20.8
50	50		3.12	2.31		63.2	26.4
50	100		3.84	2.31		100.7	37.0
50	150		3.98	2.53		113.5	62.2
100	0	3.04	2.86	2.42	134.8	40.6	27.6
100	50		3.00	2.34		67.4	36.6
100	100		3.97	2.34		108.6	44.2
100	150		4.28	2.85		118.6	72.3
150	0	3.48	3.35	2.32	173.7	61.2	34.6
150	50		3.69	2.56		93.3	49.4
150	100		3.26	2.66		81.7	60.9
150	150		4.35	3.08		116.6	79.0
200	0	3.45	3.67	3.02	163.2	90.1	63.8
200	200		4.14	3.14		114.5	89.2
300	0	3.99	4.10	3.20	200.6	109.6	83.4
300	300		4.47	4.25		118.1	114.0
Individual Factors							
April N Rate							
0		2.35	3.35	2.52	59.6	76.3	37.5
50		2.26	3.41	2.37	84.7	74.5	36.6
100		3.04	3.53	2.49	134.8	83.8	45.2
150		3.48	3.66	2.65	163.2	88.2	56.0
200		3.45	3.90	3.08	173.7	102.3	76.5
300		3.99	4.28	3.72	200.6	113.9	98.7
Signif. Level (%):		99	99	93	99	99	99
BLSD (.05):		0.35	0.34	0.53	21.6	13.4	17.9
June N Rate							
0			3.22	2.62		55.6	41.6
50			3.17	2.43		70.9	35.6
100			3.67	2.44		99.0	44.9
150			4.21	2.78		119.4	69.2
200			4.14	3.14		114.8	89.2
300			4.47	4.25		118.1	113.9
Signif. Level (%)			99	99		99	99
BLSD (.05):			0.45	0.31		13.3	12.1
Interaction April x June Application							
Signif. Level (%):			99	20		99	1
CV (%):		8.0	13.7	12.1	11.4	17.3	25.5

Root N uptake

Immobilization of N in the roots of reed canarygrass was measured by sampling the root mass in late fall. Three inch diameter cores, 4 inches deep, were taken from selected treatments. Roots were separated from soil, dried, and analyzed for total N at the Research Analytical Laboratory in St. Paul. Because of high variability among the root mass weights, they were averaged and a mean of 5.5 TDM/A-4 inch was obtained. Total N concentration ranged from 0.77% with the 50 lb N/A rate to 0.96% with the 300 lb N/A rate. Total N uptake ranged from 85 lb N/A-4 inch with the 50 lb N/A rate to 106 lb N/A-4 inch with the 300 lb N/A rate. These data suggest that reed canarygrass has a great potential for immobilizing large amounts of N in its root system.

Table 3. Total N uptake and nitrogen use efficiency of Reed canarygrass as affected by N treatments in 1993.

Rate/Time of N Application		Total N	Apparent N[1/]
April 23	June 14	Uptake	Recovery
---------- lb N/A ----------		lb N/A	%
0	0	90.7	—
0	50	149.5	118
0	100	202.0	111
0	150	251.7	107
50	0	126.2	71
50	50	174.4	84
50	100	222.5	88
50	150	260.5	85
100	0	203.0	112
100	50	238.9	99
100	100	287.6	98
100	150	325.8	94
150	0	269.4	119
150	50	316.4	113
150	100	316.3	90
150	150	369.3	93
200	0	317.1	113
200	200	366.9	69
300	0	393.7	101
300	300	432.6	57

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

Soil Residual Nitrate-N

Soil samples taken in late-November showed a significant increase in soil NO_3-N remaining in the 0-3' profile when N rates for reed canarygrass exceeded 400 lb N/A (Table 4). At application rates of 300 and 400 lb N/A slightly higher soil NO_3-N levels existed at the 1-2' and 2-3' depths compared to the 250 lb N/A rate. Nitrate-N accumulation in the 0-5' profile was minimal with N rates of 0, 150, and 400 lb N/A, but high levels of residual NO_3 remained when 600 lb N/A was applied. Fertilizing reed canarygrass at N rates greater than 400 lb N/A could result in considerable build up of soil NO_3-N, which could later be lost to ground or surface waters.

Table 4. Nitrate-N remaining in the 0-3' soil profile on Nov. 23 as influenced by N rates applied to Reed canarygrass.

N rate applied on:		Soil Profile Depth						
April 23	June 14	0 - 1'	1 - 2'	2 - 3'	3 - 4'	4 - 5'	0 - 3'	0 - 5'
------- lb N/A -------		---------- lb NO_3-N/A ----------						
0	0	6.0	3.3	2.4	3.8	3.5	11.7	19.0
50	50	4.9	2.5	2.7			10.1	
100	100	6.8	2.3	2.4			11.5	
100	150	5.8	1.9	2.2			9.9	
150	0	8.5	3.5	2.9	2.6	4.3	14.9	21.8
200	0	7.4	2.6	2.6			12.6	
200	200	9.1	14.3	11.4	8.3	5.7	34.8	48.8
300	0	13.6	8.6	12.3			34.5	
300	300	31.2	53.3	65.9	46.0	17.6	150.4	214.0

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

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

ABSTRACT: Four single crop production components (ridge tillage; 3-crop wheat-corn-soybean rotation; narrow, alternate strips (15' wide); and legume interseeding) were integrated into a complete cropping system. Studies were started in 1991 at two locations in southern Minnesota on Webster clay loam soil. The rotations compared were: a) continuous corn; b) corn-soybean; c)corn-soybean-wheat with and without interseeded legumes (Nitro alfalfa and hairy vetch). Each corn strip following wheat and soybeans was fertilized at four N rates (0, 40, 80, and 120 lb N/A) to determine N contribution of legumes. Results from the last 3 years suggest that the narrow-alternate strips of corn, soybean, and wheat in a ridge-till system provide excellent surface residue coverage and satisfy erosion control goals. While corn yields were enhanced (3 and 12% in E-W and N-S row orientation, respectively) and soybean yields decreased slightly (5 and 3% in E-W and N-S row orientation, respectively), wheat yields were unaffected in the narrow strips compared to conventional systems. Wheat introduced into the traditional corn-soybean strip system not only reduced border effects on soybeans but also reduced soybean cyst nematode (SCN) egg populations.

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

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

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

PROCEDURE

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

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

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

RESULTS

The yield advantage of the narrow strips for corn in the 3-crop (wheat-corn-soybean) rotation was 4.6 bu/A in the E-W system and 16.9 bu/A in the N-S row orientation compared to the whole-field averages (Table 1). In the E-W rows, row 1 (next to wheat) and row 6 (next to soybeans) yielded 6 and 19% higher, respectively, compared to the average of the center two rows, which were assumed to represent the whole field situation. When the rows were oriented N-S, the yield advantage was 32 and 34% for rows 1 and 6, respectively, compared to the center two rows.

[1/] Funding provided by USDA-LISA and Minnesota Department of Agriculture.
[2/] Post-doctoral Research Associate, Professor, and Professor, respectively, Univ. of Minnesota.

Soybean yields were depressed 6.1 bu/A (16%) for row 1 (next to corn) and 2.1 bu/A (6%) for row 6 (next to wheat) compared to the center two rows in the E-W row orientation (Table 2). In N-S rows, row 6 (next to wheat) yielded only 0.2 bu/A less compared to the center two rows while the row bordering corn (row 1) suffered 6.1 bu/A (19%) yield loss compared to the center two rows. The strip yields were 1.9 and 1.0 bu/A less for the E-W and N-S systems, respectively, compared to the whole-field averages.

Soybean yields were decreased much more severely in narrow strips alternated with corn (Table 3). Outside rows (rows 1 & 6) bordering corn yielded 23% less (8.4 bu/A) than the center two rows in the E-W system and 18% less (5.8 bu/A) in the N-S system. The soybean row on the N side of corn (E-W system) and E side of corn (N-S system) yielded 33 and 26% less, respectively, than the center two rows. Seed yields for the 6-row alternate strips were decreased by 3.6 bu/A in the E-W system and 2.3 bu/A in the N-S system compared to the whole-field averages. Averaged over the three years, wheat yields were not affected greatly either by the corn or soybean borders (Table 4).

Surface residue coverage prior to planting was ideal for all crops (Table 5). After planting, residue coverage was still > 30% following corn and wheat. Residue coverage after soybean was only 24%, but this was offset by mid-May with a well-established stand of wheat capable of providing erosion control in this 3-crop system.

Nitro alfalfa and hairy vetch interseeded into wheat in 1991 reduced corn yields the following year. Neither the alfalfa nor the vetch winter-killed; thus, spring regrowth was abundant in 1992. Scalping the ridges about 1/2" before planting corn was not sufficient to kill either the alfalfa or vetch. As a result, soil water in the seed zone was lower, seed germination and emergence were somewhat slower, and the regrowth provided too much competition for the small corn. In 1993, the ridges were scalped more deeply (2-3") followed by treating the spring regrowth with a herbicide. This suppressed the spring regrowth of alfalfa and hairy vetch and provided a more favorable early plant growth environment in 1993. Therefore, the N contribution from the legumes (approximately 40 lb N/A) was seen only in 1993 (Table 6).

Soybean cyst nematode egg counts were taken in November, 1992. Considerably lower SCN population was recorded in all the cropping systems where either wheat or corn were grown in the last two years compared to those systems that included soybean in either 1991 or 1992 (Table 7).

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

Row Direction	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip‡
	bu/A					
E-W Rows	158.7	141.9	149.1	146.1	177.4	4.6
N-S Rows	178.9	143.6	135.7	139.5	182.3	16.9

† 3-yr (1991-1993) averages at the 120-lb N/A rate.
‡ Yield advantage of 6-row strip compared to the center two rows, which are assumed to represent the whole-field situation.

Table 2. Soybean seed yield in a C-Sb-W rotation as influenced by row position and direction†.

Row Direction	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip‡
	bu/A					
E-W Rows	31.2	33.8	37.3	37.6	35.2	-1.9
N-S Rows	25.8	31.0	31.9	33.1	31.7	-1.0

† 3-yr (1991-1993) averages
‡ Yield advantage of 6-row strip compared to the center two rows, which are assumed to represent the whole-field situation.

Table 3. Soybean seed yield in a C-Sb rotation as influenced by row position and direction†.

Row Direction	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip‡
	bu/A					
E-W Rows	31.1	33.3	36.0	33.7	24.1	-3.6
N-S Rows	24.2	30.9	32.8	32.3	29.8	-2.3

† 3-yr (1991-1993) averages
‡ Yield advantage of 6-row strip compared to the center two rows, which are assumed to represent the whole-field situation.

Table 4. Border effects on wheat yields as influenced by row direction†.

Row Direction	N⅓ or E⅓	Center⅓	S⅓ or W⅓	Yield Adv. of 15' strip‡
	bu/A			
East-West	42.9	42.3	40.9	-0.3
North-South	42.6	42.1	37.9	-1.2

† 3-yr (1991-1993) averages
‡ Relative yield advantage of the 15'strip compared to the center 5', which is assumed to represent the whole-field situation.

Table 5. Surface residue coverage (2-year average)† as influenced by previous crop at Freeborn Co.

Previous crop	Before planting	After planting
	%	
Corn	72	41
Soybean	59	24
Wheat	82	35
Wheat + Alf.	87	54
Wheat + Vetch	90	49

† 1992-1993 averages

Table 6. Nitrogen fertilizer response of corn following wheat in a C-Sb-W rotation at Freeborn Co. in 1993.

N rate	Previous crop: Wheat	Wheat + Alf.	Wheat + Vetch
lb/A	bu/A		
0	47	73	65
40	73	86	76
80	78	92	100
120	101	101	106

Table 7. SCN population as influenced by cropping system at Freeborn Co.

Previous crop		Eggs/100 cc
1991	1992	of soil
Soybean	Corn	5120
Soybean	Wheat	7366
Soybean	Wheat + Alf.	3419
Corn	Soybean	6376
Corn	Corn	2317
Wheat	Corn	2117
Wheat + Alf.	Corn	1190

Soybean was the crop in 1990 in all the plots

CONCLUSIONS

1. Narrow alternate strips of corn, soybean, and wheat satisfy erosion control goals.
2. Corn yields are enhanced in both the 2- and 3-crop systems, but soybean yields are decreased significantly, especially in the 2-crop system.
3. Wheat yields were not affected either by corn or soybean borders.
4. Introducing wheat into the 2-crop system reduced border effects on soybeans and SCN egg populations.
5. Economic analyses of all inputs and outputs from these cropping systems is needed before we can compare the profitability of these narrow strip systems to conventional systems.

DECLINE RATES OF SOIL TEST P AND K IN A CORN-SOYBEAN ROTATION[1/]

1993

G. W. Randall and S. D. Evans[2/]

ABSTRACT: Decline rates of soil test P and K are being measured following 12 years of various application rates of P and K at two locations. Soil test P declined by about 20% at both Waseca and Morris in 1993. Soil test K decreased by 10% at Waseca and increased by about 20% at Morris. Corn yields at Waseca were increased by 36 to 50 bu/A at soil P tests from 16 to 90 lb Bray P_1/A compared to yields when the test was 7 lb/A. At Morris, corn yields were increased 13 to 14 bu/A when Bray P_1 tested >29 lb/A compared to yields from plots that tested 16 lb Bray P_1/A. Although soil test K ranged from 200 to 320 lb K/A at Waseca, corn yields were not affected by soil test K. Over the 7-yr period (1986 - 1993) soil test P declined by 1.3, 4.4 and 6.1 lb/A/yr when no fertilizer was added to soils initially testing 16, 49 and 90 lb Bray P_1/A, respectively, at Waseca. Soil test K varied considerably from year to year and did not allow consistent decline rate calculations. At Morris, soil P declined by 2.6 and 5.1 lb/A/yr when no fertilizer was added to soils initially testing 37 and 67 lb Bray P_1/A.

With good fertilization practices over the last 20 to 30 years, many farmers throughout the Cornbelt have built their P and K soil tests to high and very high levels. Studies conducted over the last 12 years have not shown corn and soybean yield increases from additional broadcast P and K at these high to very high test levels. Consequently, a number of farmers have curtailed P and K fertilization on these high testing soils. Two commonly asked questions in this scenario are: (1) How fast will my soil test drop if I don't continue to add fertilizer P and K and (2) At what test level should I begin to add P and K to maintain fertility at an optimum level for efficient and economical production? The purposes of this study are to determine (1) the decline rates of soil test P and K and (2) the optimum soil test level which should be maintained for economical corn and soybean production.

EXPERIMENTAL PROCEDURES

High rates of P and K were applied over a 12-year period (1973-84) in studies at the Southern Experiment Station at Waseca (Table 2) and the West Central Experiment Station at Morris (Table 3). These rates created a wide range of soil test values upon which we can evaluate the decline rates of soil test P and K when no additional fertilizer is added. Treatments 2, 3, and 4 have not received additional P since 1984 while treatments 6 and 7 at Waseca have not received K. The K treatments were not included at Morris because of very high native soil test K levels. Treatment 5, which had a moderately high level of fertilization prior to 1985, continues to receive P and K, and thus, serves as the high fertility control. The P and K materials (0-46-0 and 0-0-60) were broadcast on the soil surface and incorporated by chisel plowing the soybean residue in the fall of 1992. Specific experimental procedures used for corn at the two locations are presented in Table 1. Management practices providing for optimum yields were employed at each location. Starter fertilizer was not used.

Table 1. Experimental procedures for corn on the high P and K rate study at the two branch stations in 1993.

	Location	
Variable	Morris	Waseca
Planting date	4/26	5/6
Row spacing	30"	30"
Planting rate (plants/A)	29,600	32,000
Hybrid	Pioneer 3788	Pioneer 3578
Herbicide	3# Lasso + 2.2# Bladex (Bdct.)	3# Lasso + 3# Bladex (Bdct.)
Harvest date	10/11	11/10
Soil type	Aastad clay loam	Webster clay loam

RESULTS AND DISCUSSION

Total phosphate (P_2O_5) and potash (K_2O) applied over the 12-year period ranged from 0 to 1200 lb/A (Tables 2 and 3). These application rates plus the 1985-91 rates resulted in highly significant differences in soil test P at both locations and soil test K at Waseca. At Waseca soil test P ranged from 7 to 90 lb/A (Table 2). Soil test P declined about 20% in the fertilized plots compared to 1992, while soil test K decreased by 10%. Corn yields were increased significantly by P but plateaued at soil P levels higher than 16 lb/A. Corn yield was not influenced by soil test K in this wet and cool year, which limited yields.

1/ Funding provided by the TVA-National Fertilizer Development Center.

2/ Soil scientists and professors at the Southern Experiment Station (Waseca) and West Central Experiment Station (Morris), respectively.

At Morris, Bray P_1 ranged from 7 to 64 lb/A while Olsen's $NaHCO_3$ test ranged from 8 to 57 lb P/A (Table 3). Soil test P values declined about 20% at Morris, while soil K values increased about 20%. Corn yields at Bray P_1 levels of 7 and 16 lb/A were significantly lower than those from the plots testing 29 lb/A and above.

Table 2. Soil test values, seed moisture, and seed yield as influenced by 20 years' application of P and K at Waseca.

	P and K Treatments		Soil Test[2/]			Grain	
No.	Total 1973-84	1985-92[1/]	pH	P	K	Moisture	Yield
	----- lb P_2O_5 + K_2O/A ------			----- lb/A ----		%	bu/A
2	0 + 1200	0 + 100	6.5	7	320	26.9	79.3
3	600 + 1200	0 + 100	6.3	16	300	28.7	121.6
4	1200 + 1200	0 + 100	6.5	42	294	28.1	115.8
5	600 + 1200	100 + 100	6.5	90	272	29.0	129.2
6	1200 + 0	100 + 0	6.6	74	202	28.2	134.4
7	1200 + 600	100 + 0	6.5	68	200	27.4	130.7
Signif. Level (%):			17	99	99	28	99
BLSD (.05) :				13	51	-	18.0
CV (%) :			4.5	15.	11.	8.3	8.6

[1/] Treatments applied each fall. P was discontinued for treatments 6 & 7 in 1988.
[2/] Samples were taken in October before 1993 treatments were applied.

Table 3. Soil test values, seed moisture, and seed yield as influenced by 20 years' application of P and K at Morris.

	P and K Treatments		Soil Test[2/]				Grain	
No.	Total 1973-84	1985-92[1/]	pH	P_1	P	K	Moisture	Yield
	------ lb P_2O_5 + K_2O/A -----			------- lb/A -------			%	bu/A
2	0 + 1200	0 + 100	8.0	7	8	606	30.0	74.8
3	600 + 1200	0 + 100	7.9	16	16	572	29.8	84.0
4	1200 + 1200	0 + 100	8.0	29	23	516	30.8	98.4
5	600 + 1200	100 + 100	7.9	64	57	543	31.5	96.8
Signif. Level (%):			44	99	99	94	66	94
BLSD (.05) :			-	18	16	-	-	-
CV (%) :			1.0	39.	40.	7.3	5.0	13.6

[1/] Treatments applied each fall.
[2/] Samples were taken in October before 1993 treatments were applied.

SIX-YEAR SOIL TEST DECLINE RATES

Regression analysis was used to assess the average decline rates for Bray P_1 and exchangeable soil test K at Waseca and Bray P_1 at Morris. Soil test data from each of the plots in treatments 2, 3 and 4, which have not received fertilizer P since 1984, were included for the 7-year period (1986-1993) for both sites. Similarly, soil test data for each of the plots in treatments 6 and 7, which have not received fertilizer K since 1984, were included for the 7-year period at Waseca. Both soil test P and K were included from all plots in treatment 5, which received 100 lb P_2O_5/A + 100 lb K_2O/A annually.

Soil Bray P_1 change over the 7-year period at Waseca is shown by each of the lines in Fig.1. Average soil P test for each of the treatments in any particular year is shown by the appropriate symbol. Coefficients of determination (R^2) indicate highly significant relationships (99% level) for the treatments where fertilizer P was not applied and a significant (95% level) relationship where P was applied (Table 4). Soil test P was shown to decline by 1.3 lb/A/yr when the initial soil test was 16 lb/A. At initial soil test values of 49 and 90 lb/A, soil Bray P_1 declined by 4.4 and 6.1 lb/A/yr, respectively, in this corn-soybean rotation. Annual additions of 100 lb P_2O_5/A increased the soil test an average of 4.1 lb/A/yr when the initial test was 62 lb/A.

No relationship was found between the exchangeable soil K test and time (years after 1986) when 100 lb K_2O/A was applied annually (trt 5) or with treatments 6 and 7 (Fig. 2). Soil test K was extremely variable over this period as shown by the symbols in Fig. 2. Very high K levels were found in 1988, 1991 and 1992 while K tests were lower in 1987, 1990 and 1993.

At Morris, soil test P variability was high and decline rates could not be calculated from the regression equations which were not significant (treatment 2). However, soil P did decline by 2.6 and 5.1 lb/A/yr when P was not added to the plots that initially tested 37 and 67 lb P/A, respectively. This decline rate was slightly less than at Waseca where soil P test was also very high.

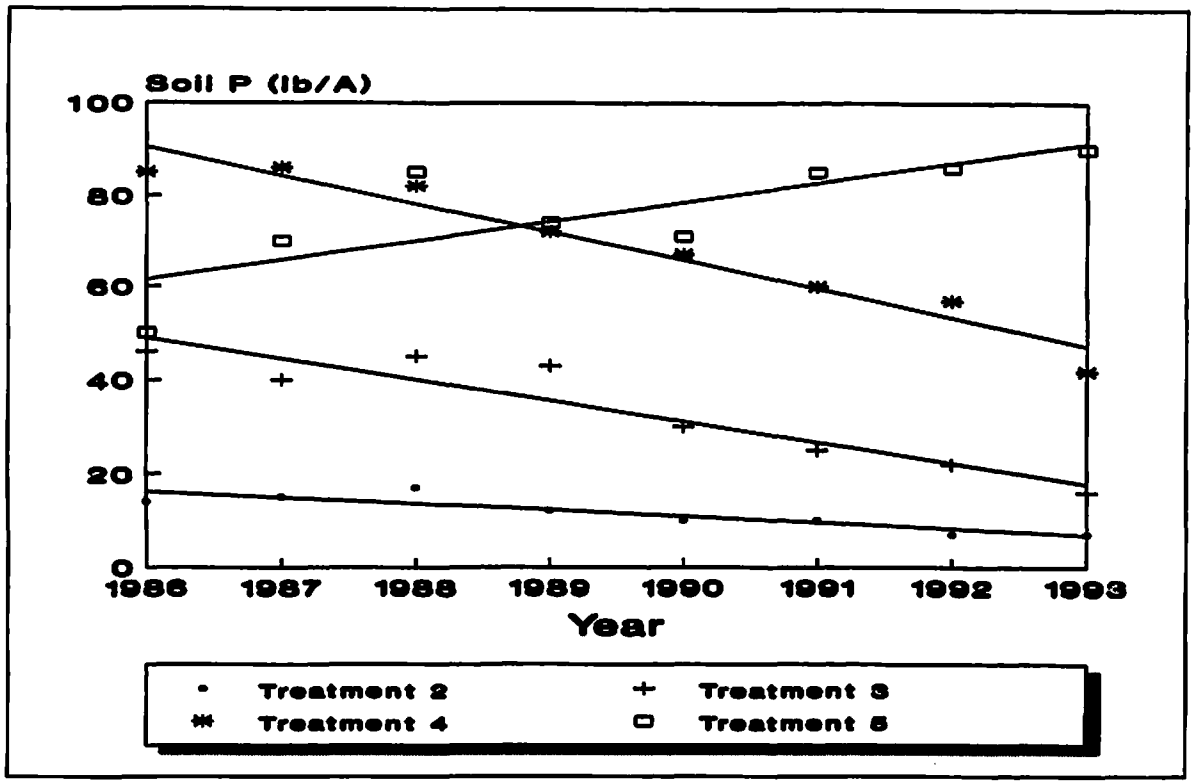

Figure 1 Decline rate of soil P over a 7-year period as influenced by P treatment at Waseca.

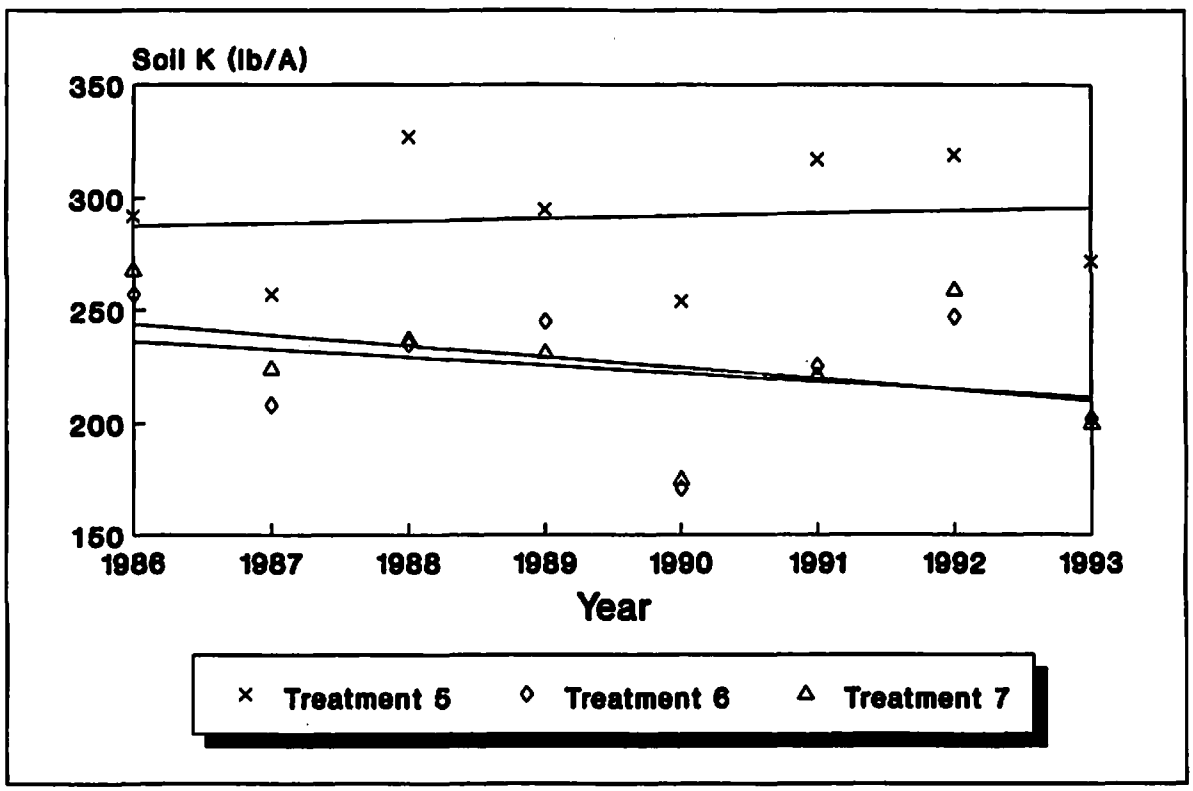

Figure 2 Decline rate of soil K over a 7-year period as influenced by K treatment at Waseca.

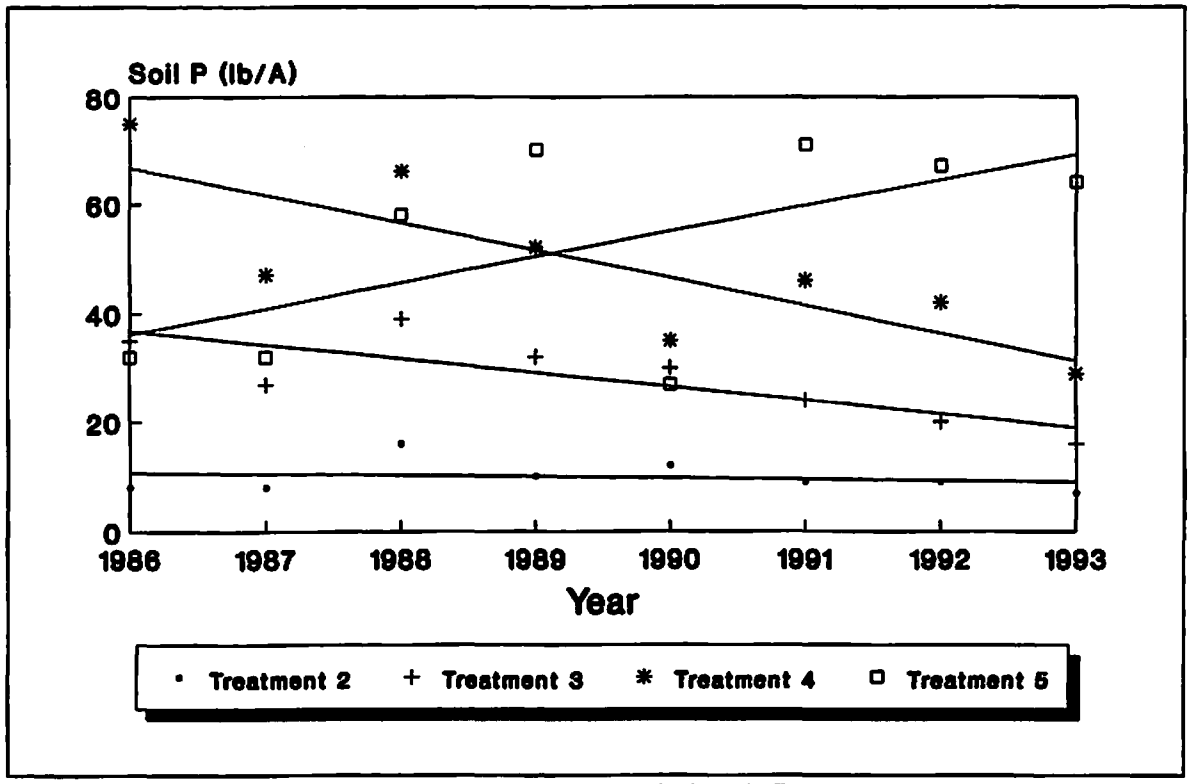

Figure 3 Decline rate of soil P over a 7-year period as influenced by P treatment at Morris.

Table 4. Linear regression equation and coefficient of determination (R^2) for the various P and K treatments at Waseca and Morris.

Location	Nutrient	Treatment	Regression Equation[1/]	R^2
Waseca	P	2	ST + 16.1 - 1.33 X	66.3 **
"	P	3	ST = 48.7 - 4.41 X	75.2 **
"	P	4	ST = 90.2 - 6.13 X	88.2 **
"	P	5	ST = 62.1 + 4.14 X	34.3 *
"	K	5	ST = 287.1 + 1.26 X	5.0 NS
"	K	6	ST = 235.7 - 3.40 X	5.7 NS
"	K	7	ST = 243.8 - 4.88 X	8.9 NS
Morris	P	2	ST = 10.3 - 0.23 X	3.1 NS
"	P	3	ST = 36.7 - 2.59 X	14.4 *
"	P	4	ST = 66.6 - 5.06 X	46.7 **
"	P	5	ST = 35.9 + 4.73 X	20.9 **

[1/] ST = Soil Test (lb/A), X = Years

CONCLUSIONS

Long term (12-yr) additions to these two soils created a wide range in soil test P levels. Corn yields were optimized over the no P treatments at soil test P levels of 16 lb/A or higher at Waseca. Yields were not affected by the K soil tests. At Morris, corn yields were improved about 14 bu/A with soil test P levels of 29 lb P/A and higher. Soil test P declined by about 20% at both Waseca and Morris. Soil test K was decreased by about 10% at Waseca and increased by about 20% at Morris in 1993. Over the 7-year period (1986-93), soil Bray P_1 tests declined by 1.3, 4.4 and 6.1 lb/A/yr when no fertilizer P was applied to these soils initially testing 16, 49 and 90 lb/A, respectively, at Waseca. When 100 lb P_2O_5/A was added annually, soil Bray P_1 increased by 4.1 lb/A/yr when the initial test was 62 lb/A. At Morris, soil test P was more variable, but soil P declined by 2.6 and 5.1 lb/A/yr when the initial Bray P_1 was 37 and 67 lb/A, respectively. Soil test P was increased by 4.7 lb Bray P_1/A/yr when 100 lb P_2O_5/A was added annually at Morris. Because of extremely high soil test K variability from year to year, it was difficult to show a consistent soil test change over time. This information on soil test decline rates when fertilizer is not applied should be very helpful to farmers who are considering omitting fertilizer P for a few years when their soils test high in P.

DEVELOPMENT OF A SOIL N TEST IN ANIMAL-BASED SYSTEMS[1/]

1993

G. W. Randall and M. A. Schmitt[2/]

ABSTRACT: Field studies were conducted at eight sites to build a data base for the development of a soil N test for animal-based crop production systems. Wet conditions since 1990 resulted in very low soil nitrate values at all sites. Preplant soil nitrate-N at all sites was below the minimum critical concentration of 6 ppm used in the present soil N test for south-central and eastern Minnesota. Thus, no N credits would have been given. Corn yields were lower than expected at all sites but did respond to N. Optimum N rate at each site was similar to the rate recommended without the use of a soil N test. These data suggest that a soil nitrate-N test is not helpful in determining N credits in soil systems that have received abundant rainfall in previous seasons.

A soil N test was developed for Minnesota corn producers in 1993 based on research conducted at over 50 sites from 1989-1992. Because most of these sites did not have a manure or alfalfa history, we focused our 1993 soil N test investigations on animal-based crop production systems with alfalfa and/or manure histories. The purpose of this investigation was to obtain corn yield response data to fertilizer N as a function of various soil N indices. This information will be used to develop a data base for validation of our present N test and/or development of a N test specific for soils amended with organic sources of N.

Experimental Procedures

Site characteristics of each of the eight locations in south central and southeastern Minnesota are given in Table 1. Seven of the sites have a manure and/or alfalfa history. The NT-1 site did not but was amended in 1992 with 250 lb N/A for corn after soybean to theoretically provide a high level of residual N. Four replications of the treatments shown in Table 2 were established. Nitrogen was broadcast-applied as urea prior to planting. Sidedress N treatments were band-applied about 4" deep midway between the rows at the V6 stage at four sites. Corn management practices (hybrid, planting date and rate, weed control, etc.) were conducted by the farmer-cooperator at all off-Station locations. These practices were optimum for excellent production; however, rainfall amounts exceeded normal at all locations. Due to very wet conditions, yields were only taken from three replications at four sites.

Results and Discussion

The yields shown in Table 2 are below the yield goal at all locations. This was due to the very wet and cold conditions that limited corn growth. These wet conditions coupled with above-normal precipitation the three previous years also resulted in very low soil residual NO_3-N concentrations at all sites. The present Minnesota-N recommendations based on a 0-2' preplant NO_3 test give no N credit when NO_3-N concentrations are ≤ 6.0 ppm. None of the sites exceeded this level with a range of 2.4 - 4.6 ppm. In addition, 21 ppm is often cited as a threshold NO_3-N concentration for 0-1' samples taken at the V4 stage. None of these sites contained NO_3-N concentrations even close to this level – even the NT-1 site which had received excessive N in 1992. Therefore, it is unfortunate, but a realty, that this year's results were more affected by weather than soil N indices.

Corn responded to N at all sites although the variability was high and the response marginal at some sites (Table 2). Optimum N rates were close to those that would have been recommended without a soil N test, i.e., previous crop, soil OM level, and yield goal. This was encouraging given the poor growing conditions during the season. Split applications of N were superior to equal N rates applied preplant at two of four locations. This was expected given the wet conditions between the preplant and sidedress applications. Yields with the split applications at the NT-1 site were lower than when applied preplant. Apparently, the 30-lb preplant rate did not provide sufficient N early in the season at this site. Corn that received the 30-lb preplant N rate had started to show some yellowing and N deficiency at the time the sidedress applications were made. As a result, the plants were not able to recover satisfactorily from this temporary N deficiency condition and yields suffered.

Conclusions

Residual soil NO_3 concentrations were below current minimum critical levels for preplant and early sidedress soil sampling times at all eight sites. This was likely due to above-normal precipitation from 1990-1992. Corn yields were lower than expected but were optimized at N rates close to those that would have been recommended without the aid of a soil N test. In summary, 1993 was a poor year in which to develop a soil N test because credit for "available" N in these animal-based systems was not apparent.

1/ Funding provided by the USDA-CSRS Special Research Grants; Water Quality Program (Nitrogen Testing) and the Legislative Commission on Minnesota Resources.

2/ Professor, Southern Experiment Station and Asst. Professor, Dept. of Soil Science, Univ. of Minnesota

Table 1. Site characteristics at the eight locations used in 1993 to develop and/or validate a soil N test.

Parameters	Location							
	MC-1	MC-2	MC-3	MC-4	MC-5	MC-6	NT-1	NT-2
County:	Waseca	Olmsted	Olmsted	Nicollet	Martin	Martin	Waseca	Waseca
Location:	SES	Lawler	Griffin	Peters	Gronewald	Kosbab	SES	SES
Soil type	Webster cl	Port Byron sil	Port Byron sil	Nicollet cl	Nicollet cl	Canisteo cl	Nicollet cl	Webster cl
Prev. Crops								
1992	Corn	Corn	Corn	Corn	Corn	Corn	Corn	Corn
1991	Alfalfa	Corn	Corn	Soybean	Soybean	Corn	Soybean	Alfalfa
1990	Alfalfa	Corn	Corn	Corn	Corn	Corn	Corn	Alfalfa
1989	Alfalfa	Corn	Alfalfa	Soybean	Sw. Corn	Soybean	Corn	Alfalfa
Manure history	10,000 gal/A Liq. Dairy 10/91	6200 gal/A Liq. Dairy 5/92	30 T/A Dairy annually	5000 gal/A Liquid Hog 11/91 & 10/89	3400 gal/A Liquid Hog 4/92 & 4/89	4000 gal/A Liquid Hog 4/92 & 4/90	None	None
N Fert. History (lb/A)								
1992	0	120	120	0	25	100	250	0
1991	0	180	120	0	0	130	0	0
1990	0	180	0	150	130	100	180	0

Table 2. Corn yield as influenced by N rate at each of the sites used for soil N test development/validation in 1993.

N rate & time		Location							
Preplant	Sidedress	MC-1	MC-2	MC-3	MC-4	MC-5	MC-6	NT-1	NT-2
------ lb/A -----		---------- bu/A ----------							
0	0	70.0	85.6	65.0	56.9	66.7	47.2	65.2	49.8
30	0	87.5	98.3	71.4	80.5	68.3	48.0	79.3	60.8
60	0	86.9	107.2	84.3	96.3	67.6	46.2	87.9	73.8
90	0	100.2	109.8	88.0	127.8	83.9	54.1	109.1	79.4
120	0	100.5	118.3	89.5	134.7	73.3	58.6	116.7	90.4
150	0	100.7	117.3	89.6	116.2	96.3	69.4	120.7	97.6
180	0	119.1	117.2	97.2	143.3	93.5	68.6	125.3	94.8
30	30	92.5	-	-	-	95.0	-	88.5	74.1
30	60	113.9	-	-	-	106.0	-	104.1	88.0
30	90	111.9	-	-	-	97.9	-	111.1	90.8
Soil NO_3-N test									
preplant, 0-2' (ppm)		2.7	4.6	2.5	3.8	2.4	2.4	3.8	3.4
V4 stage, 0-1' (ppm)		1.6	5.4	2.5	1.1	3.0	2.9	1.4	1.4

Impact of Turkey Manure Application on Corn Production and Potential Water Quality Concerns-Westport MN 1993.[1]

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

Abstract

A field study was continued at Westport, MN (begun in 1991) to study the impact of turkey manure application on irrigated corn and soybean production and nitrate-N movement below an Estherville sandy loam soil. Treatments included two rates of commercial fertilizer (70 and 140 lb N/A), two rates of turkey manure (4 and 8 tons/A--wet weight basis) and an untreated check. Manure rates were computed to provide an estimated equivalent amount of available N per acre as the fertilizer treatments. Treatments were planted to corn in 1993 following a previous crop of soybeans. Plant samples were collected at 8 leaf, silking, and physiological maturity. Plant samples obtained at physiological maturity were separated into grain and stover. Total dry matter production, N concentration and total N uptake were determined for each sampling. Water percolation, and movement of nitrate-N below the root zone was monitored utilizing 30 closed bottom non-weighing drainage lysimeters. Excess percolation was removed from the bottom of each lysimeter after each leaching event. Soil samples were collected from the soil profile prior to planting and at harvest. Soil samples were analyzed for nitrate and ammonium N. Grain yields and N uptake were significantly higher with turkey manure application than with fertilizer. Residual effects of manure application (1992) increase grain yields and N availability during the 1993 season. Fertilizer N application and low rates of turkey manure applied in 1993 had relatively little influence on the concentration of nitrate-N in leaching water. High application rates of turkey manure in 1992 (residual) produced elevated concentrations of nitrate-N in 1993.

Introduction

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

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

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

Materials and Methods

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

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

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1. Appreciation is expressed to the University of Minnesota Agricultural Experiment Station, Wes-Min RCD, Pope Co. SWCD, and Pioneer Hi-Bred International for supplying seed.
2. Professor, and Assistant Scientist respectively, Dept. of Soil Science, University of Minnesota.

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

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

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

The experimental design included three replications of nine treatments in a randomized complete block design. Treatments in 1993 consisted of a zero N control, two rates of turkey manure (4 and 8 T/A, wet weight basis) and two rates of commercial fertilizer N (70 and 140 lb N/A as urea) which were applied to the same plots as in 1991 (the five original 1991 treatments), two rates of manure (4 and 8 T/A) added to new plots in 1993, and the two residual (turkey manure applied in 1992) manure treatments. Turkey manure treatments were incorporated, immediately after application. The nutrient composition of the turkey manure is presented in table 2. Estimate of manure N availability was based on the assumption that 80% of the inorganic N and 30% of the organic N will be available during the first year of application. The manure rates applied were expected to provide approximately 70 and 140 lb. of available N/A. The entire study area was planted to corn (Pioneer 3787 - 95 day R.M.) on May 5th at a seeding rate of 29,600 seeds/A. A tank mix of Lasso (1.75 #/A) + Bladex (1.75 #/A) was applied on May 11th for weed control.

Table 2.Turkey Manure Composition

Nutrients	lb/T
Total N	45
Inorg. NH_4^+-N	13
NO_3^--N	1
Organic N	32
P_2O_5	---
K_2O	---
Moisture %	51

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

Dry Matter production and N uptake were determined July 6th (8-leaf), August 8th (silking) and September 24th. Due to a cool summer and early killing frost, grain yields were lower than expected. Grain yields were determined by harvesting two 20 foot rows. Corn grain yields were reported at 15.5% moisture.

Soil water percolate was collected through the growing season from the bottom of the lysimeters following rainfall events. The amount percolated and the NO_3^--N in the leachate was measured to quantitate concentration, flow rate and total N lost by leaching.

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

Results and Discussion

Significant differences in dry matter and N uptake between treatments were observed at both sampling dates (Table 3). In all cases but one, turkey manure application was more responsive than comparable urea fertilizer treatments. The N concentration in the whole plant at silking when 4 T/A of turkey manure was applied resulted in significantly higher concentrations than the comparable urea treatments, while the 8 T/A treatments did not reflect the higher concentration.

Turkey manure treatments produced higher corn grain yields than comparable urea-N applications. (Table 4). Turkey manure applied in 1992 increased grain yield in 1993 compared with either the control or urea treatments. Turkey manure applied in 1993 significantly increased corn grain yields over the use of commercial fertilizer.