probably because of the dry conditions in 1988. It should be cautioned that these 5-foot NO_3-N concentrations may not represent the concentrations entering the aquifer because of dilution; however, they do provide an indication as to the environmental sensitivity of the treatments.

Corn yields in the pesticide study were not influenced statistically at the P = 90% level by tillage system because of the high variability (CV = 13%) (Table 2). The apparent 10 to 18 bu/A reduction with the ridge-till and no tillage (NT) systems could have been due to the ridging operation which may have pruned some roots and to some weeds in the NT system.

Table 2. Effect of tillage treatments on the 1988 corn yields in Olmsted Co.

Tillage	Grain Yield 1988	Grain Yield 1987-88 Avg.
	bu/A	
Moldboard plow	158.0	171.0
Chisel plow	158.0	170.6
"Ridge till"[1/]	147.8	162.8
No tillage	140.4	156.7
Significance Level (%):	47	
BLSD (.05) :	-	
CV (%) :	13.	

[1/] First ridged in June, 1987.

Corn was planted on a 1½ acre area which is being saved for "future" investigations. Neither fertilizer N nor pesticides were applied. The corn was cultivated twice to control weeds as best possible. Corn yields averaged only 8 bu/A primarily due to weed pressure (early season moisture stress) and insufficient N. It is interesting to note the 72 bu/A difference between this site and the 0-lb N plots that were kept weed-free by herbicides.

Goodhue Co.

Grain yields were increased significantly over the control (both chisel and no tillage) by all of the N treatments (Table 3). Yields were optimized with the 100-lb spring PP treatment. The highest yield, although not statistically speaking, was obtained with the 150-lb PP treatment containing N-Serve. There was no difference between the two tillage systems. None of the split and sidedress treatments enhanced yields over the spring PP anhydrous applications.

Two-year average grain yields also show: (1) optimum N rate to be 100 lb/A, (2) no improvement in yield with either split or sidedress N application, and no difference between the two tillage systems except at the 0-lb N rate where there was a slight advantage for chisel plowing.

Nitrate-N concentrations in the soil water extracted from the 5-foot depth on Sept. 30 varied considerably and did not appear to relate well to N treatment (Table 3). This was probably due to the dry conditions and the incomplete number of samples obtained.

Table 3. Corn yield and NO_3-N concentation in the soil water at 5' as affected by N treatments in Goodhue Co. in 1988.

Treatment				Grain Yield		Nitrate-N[3/] Conc.in water at 5'
No.	N rate	Application time	Tillage[1/]	1988	1987-88 Avg.	
	lb/A			----- (bu/A) -----		mg/L
1	0	-----	Chisel	68.3	103.0	8
2	50	Spr. preplant (PP)	"	106.8	138.6	-
3	100	"	"	113.8	149.9	12*
4	150	"	"	114.5	149.4	12
5	200	"	"	118.6	154.0	-
6	0	-----	No Tillage	67.5	91.6	-
7	100	Spr. preplant (PP)	" "	112.4	150.0	7
8	150	"	" "	115.5	152.8	15
9	200	"	" "	115.2	153.4	-
10	50 + 50	Spr. PP + SD 9-1f	Chisel	111.4	145.6	-
11	50 + 100	" "	"	116.5	149.4	-
12	100 + 50	" "	"	117.3	151.6	-
13	100	SD 6-1f	"	106.4	143.4	-
14	150	"	"	116.6	152.1	38*
15	150 + NI[2/]	Spr. PP	"	123.7	159.1	-
16	150 + NI	SD 6-1f	"	120.1	150.0	-
	Significance Level (%):			99		
	BLSD (.05) :			14.0		
	CV (%) :			9.6		

1/ Chiseling was done in April, 1987.
2/ NI = N-Serve
3/ Sept. 30, 1988
* Avg. of only 2 samples

Winona County

Corn grain yields were very poor at this site due to the dry and hot weather (Table 4). Yield responses to the applied N were inconsistent and highly variable. There did not appear to be an advantage for the split or sidedress N treatments over the spring preplant treatment. No difference was observed between tillage systems.

Two-year average yields show: (1) no difference between the two tillage systems, (2) no advantage for the split and sidedress applications, and (3) a very slight but inconsistent response to fertilizer N at this site which was in alfalfa from 1983-85. Nitrate-N concentrations in the soil water at 5' after two years of experimentation still are at 14 mg/L where no N has been used. Concentrations ranged between 26 and 46 mg NO_3-N/L for the treatments that received fertilizer N, but there was no relationship to N rate. These high values must be a result of the previous alfalfa crop which received manure in 1985.

Table 4. Effect of N treatments on the corn grain yield and NO_3-N concentrations in the soil water at 5' in Winona County in 1988.

Treatment No.	N Rate	Time	Tillage[1/]	Grain Yield 1988	Grain Yield 1987-88 Avg.	Nitrate-N[2/] Conc. in water at 5'
	lb N/A			------- bu/A ------		mg/L
1	0	-----	Chisel	72.1	128.9	14
2	50	Spr. preplant (PP)	"	73.9	131.8	-
3	100	" "	"	81.8	135.2	36
4	150	" "	"	84.9	137.8	37
5	200	" "	"	97.7	144.6	27
6	0	-----	No Tillage	68.0	129.0	-
7	100	Spr. preplant (PP)	" "	80.3	135.0	46
8	150	" "	" "	69.9	126.9	-
9	200	" "	" "	86.8	135.5	26
10	50 + 50	Spr. PP + SD 9-1f	Chisel	86.8	138.4	-
11	50 + 100	" " "	"	85.4	139.4	36
12	150	SD 6-1f	"	76.4	132.6	42
	Significance Level (%):			95		
	BLSD (.05)	:		21.5		
	CV (%)	:		15.		

1/ Chiseling was done in October, 1987.
2/ Oct. 5, 1988

SUMMARY

The following summarizes the yield results from the second year of these studies:

1) N rate was optimized at 150 lb/A for third year corn while at a second site 100 lb N/A was optimum.
2) Yields were slightly but not significantly higher with the manure treatments.
3) No apparent yield advantages were found with split or sidedress applications of N at any of the three sites.
4) There was no yield difference between the no tillage and chisel tillage systems at any of the three sites.
5) Previous crop and manure history apparently impacts corn yield and N management at the Winona Co. site.
6) The role of alfalfa and manure contributions to available N for succeeding corn crops needs to be carefully examined and understood before improved N management is a reality on these soils.
7) Nitrate-N concentrations in the soil water at 5' (below the root zone) provide a good basis upon which to compare the environmental risks associated with various N management systems.

ACKNOWLEDGEMENT

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TILLAGE SYSTEMS FOR CORN AND SOYBEAN CROP SEQUENCES

Waseca, 1988

G. W. Randall, B. W. Anderson and R. R. Allmaras[1/]

ABSTRACT: A study was started in 1986 to determine the effect of tillage on corn and soybean production when grown in rotation compared to a continuous monoculture. Yield results in 1988 were highly variable due to the heat and moisture stress. Although both corn and soybean yields were substantially higher with NT compared to MP and CP tillage, these differences were not statistically significant at the 90% level. Corn and soybeans in rotation yielded 16 and 20% higher, respectively, than did the continuous monoculture systems. Tillage x crop sequence interactions were not significant for either crop.

Corn-soybean rotations have often been compared to continuous corn and soybean monocultures using a particular tillage system. Seldomly, however, have these comparisons been made over a range of primary tillage systems. The purpose of this study is to determine the effect of tillage on corn and soybean production when grown in a monoculture compared to a rotation.

Experimental Procedures

A study had been established on this Webster clay loam site in the fall of 1980 to determine the relationship between primary tillage and the incidence of corn and soybean diseases in continuous corn, continuous soybeans and a corn-soybean rotation. The tillage systems were fall moldboard plow (MP), fall chisel plow (CP), and no tillage (NT). After this 5-yr study was completed in 1985, the initial tillage plots and some of the monoculture plots were kept intact to take advantage of the past tillage and cropping history. Some of the monoculture plots were changed to a corn-soybean sequence so that there are now four cropping systems over each tillage system. The cropping systems are continuous corn (C-C), corn-soybean (C-Sb), soybean-corn (Sb-C), and continuous soybeans (Sb-Sb). Each treatment is replicated four times in a split-plot design with tillage as the main plot and crop system as the subplot.

Fall tillage was performed in October, 1987 after stalk chopping all corn plots. Spring secondary tillage consisted of disking the CP plots and field cultivating the MP and CP plots on April 21.

Nitrogen was broadcast applied as ammonium nitrate prior to secondary tillage to all 1988 corn plots at a rate of 200 lb N/A regardless of previous crop. Broadcast P and K were not applied because of high soil test P and K levels. Starter fertilizer was not used.

Corn (Pioneer 3737) was planted on May 4 at a rate of 28,400 ppA with a John Deere Max-Emerge II 4-row planter equipped with bubble coulters. Counter (1 lb ai/A) was applied to all corn plots at the time of planting. Weeds were chemically controlled with a combination of 3½ qts. Lasso and 3 qts Bladex/A applied preemergence on May 11. Row cultivation was performed on May 31 in the MP and CP corn plots.

Soybeans (Hardin) were planted in 30" rows with the aforementioned planter at a rate of 9 beans/foot on May 16. Weeds were controlled with a preemergence application of Lasso (3½ qts/A) + Amiben (6 qts/A) on May 20. The MP and CP soybean plots were cultivated on June 10.

A modified JD 3300 plot combine was used to harvest both the corn and soybeans. Corn and soybean yields are expressed at 15.5 and 13.5% moisture, respectively.

All wheel traffic during the season was confined to the same inter-row areas that were trafficked at the time of planting. This resulted in wheel traffic on one side of each row with the other side non-compacted by machinery operations.

1/ Soil scientist and assistant scientist, Southern Experiment Station and Professor, Department of Soil Science.

Results and Discussion

Corn yields were quite poor and highly variable due to the extreme heat and dry conditions throughout most of the growing season (Table 1). When averaged over crop sequence, NT yields were 38% and 17% higher than with CP or MP tillage, respectively. These yield differences, however, were not statistically significant at the 90% level due to the high CV (16%) and the highly significant tillage x rep interaction. This interaction is demonstrated by CP yields ranging from 38 bu/A in rep 1 to 107 bu/A in rep 2 while NT yields ranged from 78 bu/A in rep 3 to 136 bu/A in rep 4. Yield variation with MP tillage was much smaller, ranging from 75 bu/A in rep 1 to 108 bu/A in rep 3. These extreme differences were largely due to small changes in microrelief which affected stored soil moisture within the experimental site and because the CP tillage blocks in reps 1 and 3 were on the south edge of the study. Since there was no crop for over 1/2 mile to the south, the hot and dry south winds appeared to have influenced these plots to a greater degree than the rest of the study. Crop sequence significantly influenced corn yield. Corn following soybeans yielded 16% higher than continuous corn. The tillage x sequence interaction was not significant.

Grain moisture was significantly higher with NT compared to the MP and CP systems and for continuous corn (Table 1). Final population was not influenced by either tillage or crop sequence.

Table 1. Corn grain yield and moisture content and final population as affected by tillage and crop sequence.

Tillage	Crop Sequence	Grain Yield	Grain Moisture	Final population
		bu/A	%	x 10^3
MP	C-C	77.0	17.6	28.4
"	C-Sb	96.9	16.6	28.7
CP	C-C	71.4	18.4	28.3
"	C-Sb	75.8	16.9	27.9
NT	C-C	94.4	20.2	28.2
"	C-Sb	109.2	18.0	29.2
FACTORIAL COMPARISONS				
Tillage				
MP		86.9	17.1	28.6
CP		73.6	17.7	28.1
NT		101.8	19.1	28.7
Signif. Level (%): 1/		72	98	90
BLSD (.05) :			1.4	
Crop Sequence				
C-C		80.9	18.8	28.3
C-Sb		93.9	17.2	28.6
Signif. Level (%): 1/		95	99	82
Tillage x Replication Interaction				
Signif. Level (%): 1/		98	99	96
Tillage x Sequence Interaction				
Signif. Level (%): 1/		43	92	51
CV (%) :		16.	2.5	1.8

1/ Probability level of significance.

Soybean yields were relatively better than corn but were also highly variable (Table 2). When averaged over crop sequence, the NT yields were 20% and 14% higher than CP and MP tillage, respectively. Similar to corn, these yield differences were not statistically significant due to the high CV (10%) and the significant tillage x rep interaction. Soybeans following corn yielded 20% more than did continuous soybeans. There was no significant tillage x sequence interaction. Soybean seed moisture at harvest was unaffected by tillage and crop sequence.

Table 2. Soybean seed yield and moisture content as affected by tillage and crop sequence.

Tillage	Crop Sequence	Yield	Moisture
		bu/A	%
MP	Sb-Sb	29.8	11.2
"	Sb-C	36.5	11.5
CP	Sb-Sb	27.8	11.4
"	Sb-C	35.0	11.3
NT	Sb-Sb	35.6	11.5
"	Sb-C	40.0	10.9
FACTORIAL COMPARISONS			
Tillage			
MP		33.1	11.4
CP		31.4	11.4
NT		37.8	11.2
Signif. Level (%):		72	86
Crop Sequence			
Sb-Sb		31.0	11.4
Sb-C		37.2	11.2
Signif. Level (%):		99	74
Tillage x Replication Interaction			
Signif. Level (%):		96	13
Tillage x Sequence Interaction			
Signif. Level (%):		29	97
CV (%)	:	10.	2.6

THREE-YEAR SUMMARY

Corn yields from this completely weed-free site were approximately 15 bu/A higher for NT compared to either MP or CP regardless of crop sequence (Table 3). Corn yields following soybeans averaged approximately 10% higher than continuous corn regardless of tillage system. Soybean yields were not affected by tillage system. Soybeans following corn yielded approximately 16% higher than continuous soybeans when averaged over tillage systems.

Table 3. Three-year corn and soybean yield averages as influenced by tillage and crop sequence.

Tillage	Crop Sequence	Yield	
		Corn	Soybean
		bu/A	
MP	Cont. Corn	131.0	-
"	Corn-Soybean	146.5	48.9
"	Cont. Soybean	-	44.2
CP	Cont. Corn	132.5	-
"	Corn-Soybean	142.5	50.8
"	Cont. Soybean	-	42.5
NT	Cont. Corn	147.4	-
"	Corn-Soybean	161.5	51.7
"	Cont. Soybean	-	44.1

CONSERVATION TILLAGE FOR CORN AND SOYBEAN PRODUCTION[1/]

Waseca, 1988

G. W. Randall and J. B. Swan[2/]

ABSTRACT: This was the 14th year in a study to evaluate five primary tillage systems for corn and soybean production on a Nicollet-Webster soil complex. Corn grain yields were significantly higher with moldboard plow tillage compared to chisel plow, spring disk, or no tillage. Although yields from ridge tillage were 16.7 bu/A less than from moldboard plowing, they were not statistically different. No tillage yields were considerably less than the other tillage treatments primarily because of high grass pressure. Yields from the no tillage, chisel plow and spring disk systems were improved markedly where Poast herbicide had been applied previously to soybeans. Weed pressure was very low with the ridge plant and moldboard plow systems. Under the hot and dry conditions the lesser yields obtained with the conservation tillage (CT) systems were partially due to poor weed control (especially with no tillage) but may also have been due to poor, early season root development in the CT systems in this 14-year study.

With increasing emphasis on controlling erosion and minimizing energy requirements (time, labor, and fuel), tillage practices have changed markedly over the last decade. Many of tillage practices have come to be known as "conservation tillage". To fit this definition, a tillage practice must leave 30% of the soil surface covered with residue after planting. The primary purpose of this study is to evaluate five conservation tillage (CT) systems in a long-term corn-soybean sequence. A secondary objective is to determine the value of starter fertilizers in CT systems.

EXPERIMENTAL PROCEDURES

To evaluate some of these conservation tillage practices an experiment was started in 1975 with continuous corn grown on a Webster clay loam at the Southern Experiment Station. Five tillage treatments (no tillage, fall moldboard plow, fall chisel plow, ridge-plant and till-plant [flat]) were replicated four times. Each plot was 20' wide by 125' long. Tile lines spaced 75' apart run perpendicular to the rows in all plots. Beginning in 1979 all plots were split into two, 4-row plots -- one with starter fertilizer and the other without.

After 8 years of continuous corn, soybeans were planted in 1983 to begin a long-term corn-soybean rotation. Tillage and starter fertilizer treatments remained the same except the till-plant (flat) treatment was changed to a spring-disk (20" disk blade) treatment (Table 1). Because of increased pressure of the grass weeds in the no tillage treatment, all plots were split so that either the front or rear half received a postemergence application of Poast at a rate of ¼ lb/A with 1 qt of oil concentrate in the years that soybeans were grown.

Ridges for the ridge plant treatment in 1988 were built in June, 1987. After the 1987 soybean harvest, the moldboard and chisel plow treatments were performed. On April 21 the moldboard and chisel plow treatments were field cultivated once and the spring disk treatment was disked twice. Ammonium nitrate was broadcast-applied at a rate of 150 lb N/A immediately before the secondary tillage. Ridges for 1989 soybeans were prepared on June 20.

Corn (Pioneer 3732) was planted in 30" rows at a rate of 29,900 plants/A on May 4. All treatments were planted with a John Deere 7100 planter equipped with 2" fluted coulters. B&H ridge cleaners were attached to the planter for the ridge-plant treatment. Ten gallons/A of 7-21-7 was used as the starter treatment.

Broadcast P and K were not applied for the 1988 soybean crop because of very high soil tests. Soil tests on this site in 1984 averaged: pH = 6.7, Bray$_1$ extractable P = 60 lb/A and exchangeable K = 424 lb/A. Chemical weed control consisted of 3 lb Bladex and 3½ lb Lasso/A applied preemergence (May 14). In order to evaluate the effectiveness of the preemergence herbicide application on weed control, a plastic sheet 18" wide and 6' long was placed between the 4th and 5th rows of each plot during herbicide spraying to prevent the application of herbicide onto the soil surface. Weed counts (grass and broadleaf) were taken on May 23 from sprayed and unsprayed areas and poast and non-poast

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1/ Funding provided by the Southern Experiment Station, Waseca.
2/ Professors, Southern Experiment Station and Department of Soil Science, respectively.

areas. Treatments 2, 3, 4, and 5 were cultivated on June 1. Weed control was quite good on all cultivated plots.

Surface residue coverage was measured by the line-transect method on April 18 prior to spring tillage and on May 16 after planting. Planting depth was determined by cutting off the coleoptile at the soil surface from all the plants in a 10-foot length of row in each tillage plot 27 days after planting. The seeds were then excavated and the length of the coleoptile to the seed was measured. Early plant growth (EPG) was determined by harvesting the above ground portion of 10 random plants per starter and non-starter plot 41 days after planting.

Corn leaf samples were taken on July 14 from all treatments except NT, which was sampled on July 21, by randomly sampling the leaf opposite and below the ear from the starter treatment within each tillage treatment. Yields were taken by combine harvesting the center two rows from each plot with a modified JD 3300 combine. Grain moisture and N concentrations were determined on each of these samples.

RESULTS

Grain yield and moisture differences among the tillage treatments were highly significant when averaged over starter fertilizer and previous Poast treatments (Table 1). Moldboard plow (MP) tillage resulted in significantly higher yields than the chisel plow (CP), spring disk (SD), and no tillage (NT) systems. Grain yield was significantly lower and grain moisture higher for NT compared to all other tillage systems. The highly significant interaction between tillage and Poast treatment for yield indicated that yields from the NT, CP and SD systems were increased significantly by the Poast treatments applied to soybeans in previous years (1983, 1985 and 1987). Yields with the MP and ridge-plant (RP) systems were not affected by the Poast treatments primarily because of excellent weed control with these tillage systems regardless of Poast application.

Starter fertilizer increased yields by 16% when averaged across all tillage and Poast treatments (Table 1). Even though a statistically significant interaction between tillage system and starter fertilizer did not exist (23% level), the 15% yield response for the MP system was considerably higher than the 2% for the RP system. This was in contrast to previous years when greatest response to starter fertilizer was with the RP, CP and NT systems. Grain moisture was decreased significantly (0.6 points) by the starter fertilizer but was unaffected by the previous Poast treatments.

Early plant growth was affected significantly by the tillage systems (Table 2). Plants were largest with the MP and RP systems, were intermediate in size with the CP and SD systems and were significantly smaller with NT. Starter fertilizer increased early plant weight when averaged across tillage systems. The interaction between tillage and starter fertilizer was not significant (33% level). Final population was not affected by tillage or starter fertilizer.

Grain N was not influenced by tillage or starter fertilizer (Table 2). However, N removal in the grain (product of grain N concentration and grain yield) was affected significantly by both tillage and starter fertilizer. This effect was due largely to the yield differences among the treatments, which resulted in lowest N removal with the NT system and the plots without starter fertilizer.

Residue measurements taken prior to planting showed significant differences among the treatments for percent of the soil surface covered with residue from the previous crops (Table 3). The treatments ranked NT >SD > RP = CP> MP. After planting, surface residue measurements were taken both within the row and randomly across the plot area. All tillage treatments showed significantly more residue than the MP treatment. However, only the NT system exceeded 30% and therefore met the definition of "conservation tillage". Within the row measurements showed similar residue amounts compared to random across-the-plot measurements for all tillage systems.

Planting depth was affected significantly by the tillage systems (Table 3). This was consistent with most previous years. The variability in the seeding depth as measured by standard deviation and range in depths indicates least variability with the CP and SD systems and greatest variability with the NT system. Seed placement average between 2.2" and 2.5" for the MP, CP, RP and SD tillage systems compared to 1.6" for the NT system. These differences point out the need for careful adjustments of the planter even when following soybeans.

Table 1. Influence of tillage methods, starter fertilizer and previous Poast herbicide treatment on corn production at Waseca in 1988.

Treatment			Grain	
Tillage	Starter[1/] fertilizer	Poast[2/] herbicide	Moisture	Yield
			%	bu/A
No tillage	S	P	22.9	50.1
"	S	NP	22.7	36.5
"	NS	P	24.5	31.9
"	NS	NP	24.2	27.4
Fall plow, f. cult.	S	P	19.5	119.5
" "	S	NP	18.6	117.0
" "	NS	P	19.7	95.8
" "	NS	NP	19.4	109.2
Fall chisel, d., f. cult.	S	P	19.5	109.2
" "	S	NP	20.0	82.0
" "	NS	P	20.2	88.5
" "	NS	NP	21.1	65.4
Ridge plant	S	P	19.4	93.0
" "	S	NP	19.2	96.8
" "	NS	P	19.2	95.2
" "	NS	NP	19.3	89.9
Spring disk (2x)	S	P	19.9	109.3
" "	S	NP	21.0	76.0
" "	NS	P	20.2	105.2
" "	NS	NP	21.3	55.6
Individual Factors				
Tillage				
No tillage			23.6	36.5
Fall plow			19.4	110.4
Fall chisel			20.2	86.3
Ridge plant			19.2	93.7
Spring disk (2x)			20.6	86.5
Significance Level (%):[3/]			99	99
BLSD (.05) :			1.0	22.2
Starter Fertilizer				
Starter			20.3	89.0
No starter			20.9	76.4
Significance Level (%):[3/]			99	99
Poast Herbicide				
Poast			20.5	89.8
No Poast			20.7	75.6
Significance Level (%):[3/]			62	99
Interactions			Significance Levels (%)	
Tillage x SF			82	23
Tillage x Poast			93	99
SF x Poast			41	7
Tillage x SF x Poast			2	27
CV (%)			4.6	22.

1/ S = starter fertilizer used and NS = no starter fertilizer used.
2/ P = Poast herbicide used and NP = no Poast herbicide used in 1987.
3/ Probability level of significant difference between means.

Table 2. Influence of tillage methods and starter fertilizer on corn production at Waseca in 1988.

Treatment				Grain	
Tillage	Starter fert.[1/]	Early plant growth	Final population	N	N Removal
		g/plant	x10^9	%	lb/A
No tillage	S	6.1	26.1	1.66	38.8
No tillage	NS	4.7	28.0	1.67	25.4
Fall plow, f. cult.	S	16.2	29.0	1.62	91.1
Fall plow, f. cult.	NS	14.7	28.6	1.70	77.1
Fall chisel, f. cult.	S	11.5	28.8	1.66	84.8
Fall chisel, f. cult.	NS	9.2	29.5	1.70	70.1
Ridge plant	S	12.2	28.5	1.67	72.1
Ridge plant	NS	11.8	28.9	1.67	74.2
Spr. disk	S	9.3	28.8	1.65	85.2
Spr. disk	NS	8.1	28.9	1.60	79.2
INDIVIDUAL FACTORS					
Tillage					
No tillage		5.4	27.0	1.66	32.1
Fall plow		15.5	28.8	1.66	84.1
Fall chisel		10.4	29.2	1.68	77.5
Ridge plant		12.0	28.7	1.67	73.2
Spr. disk		8.7	28.9	1.63	82.2
Signif. Level (%):		99	59	15	99
BLSD (.05)		2.0			18.8
Starter fertilizer					
Starter		11.1	28.3	1.62	74.4
No starter		9.7	28.8	1.68	65.2
Signif. Level (%):		99	79	67	99
Till x SF IA					
Signif. Level (%):		33	47	87	69
CV (%) :		12.	4.4	2.8	13.

1/ S = starter fertilizer used and NS = no starter fertilizer

Table 3. Influence of tillage methods for corn following soybeans on surface residue, seeding depth and leaf N at Waseca in 1988.

Treatment	Surface Residue			Planting Depth			Leaf nitrogen
	Before planting	After Planting: Across plot	After Planting: Within row	Average	S	Range	
	%			mm			%
No tillage	90	88	90	42	7.6	28-54	2.32
Fall plow	4	1	1	62	7.2	51-76	2.49
Fall chisel	18	7	7	64	5.8	55-78	2.44
Ridge plant	22	14	10	55	7.1	43-67	2.55
Spr. disk	60	14	9	59	5.9	47-69	2.38
Signif. Level (%):	99	99	99	99			48
BLSD (.05) :	9	6	4	12			-
CV (%) :	17.	18.	14.	13.			7.8

Nitrogen concentration of the earleaf at silking was not influenced significantly by tillage (Table 3).

The rate of seedling emergence was determined by counting the number of plants that had spiked thru in 100-feet of row/plot from the 10th to the 19th day after planting. Emergence, as a percent of final stand, shown in Table 4 indicates most rapid emergence with the RP system. Emergence was delayed about 1 to 2 days with the MP, CP and SD systems and about 3 days with the NT systems. These differences continued through about the 6 to 8-leaf stage, but by silking phenological differences among the RP, MP, CP and SD were not evident. The NT system, however, continued to be about 7 days behind at silking and reached physiological maturity a few days after the other tillage systems.

Table 4. Influence of tillage methods on the emergence progress of corn following soybeans at Waseca in 1988.

	Days Post Planting								
Treatment	10	11	12	13	14	15	16	17	19
	% emerged								
No tillage	0	0	8	22	44	74	89	97	100
Fall plow	0	15	55	76	86	90	94	96	100
Fall chisel	0	6	46	73	89	94	98	99	100
Ridge plant	2	38	82	90	96	99	100	100	100
Spring disk	0	8	44	69	84	94	96	98	100

Weed counts (broadleaf and grass) were taken between the 4th and 5th rows from 1 ft^2 sections/plot from both the previous (1987) Poast and non-Poast sections 12 days after preemergence herbicide application (Table 5). Weed pressure from broadleaf weeds was not great, as broadleaf weed counts were low from both herbicide treated and untreated areas. Grasses were controlled extremely well in the MP and RP systems and to a lesser degree with CP tillage. Grass weed control was least adequate with the NT tillage system. Under these dry conditions, the Lasso + Bladex combination had little overall effect on grass weed control at this time.

Table 5. Weed populations on May 23 as affected by tillage and herbicide for corn following soybeans at Waseca in 1988.

	Herbicide[1/]		No Herbicide	
Treatment	Grasses	Broadleaves	Grasses	Broadleaves
	plants/10 sq. ft.[2/]			
No tillage	1400	0	1427	10
Fall plow	20	10	30	0
Fall chisel	250	0	81	10
Ridge plant	50	0	40	0
Spring disk	620	0	719	0

1/ 3½ lb Lasso and 3 lb Bladex/A, preemergence
2/ Average over 4 replications and 2 counts/rep.

Grass counts from these 1 ft^2 areas were also taken for both the Poast and non-Poast areas that had been treated in 1983, 1985 and 1987. The purpose of these measurements was to evaluate the effect of these previous Poast applications on the grass pressure. Data shown in Table 6 indicate: (1) a tremendous affect of tillage on grass density, (2) some improvement in weed control with the preemergence herbicide, and (3) a marked decrease in weed pressure resulting from the previous applications of Poast. This resulted in the highly significant tillage x Poast interaction for corn yield shown in Table 1. Even though most farmers would use a herbicide program for general weed control somewhat similar to the Lasso + Bladex program, it is quite apparent that post emergence applications of materials such as Poast in the soybean phase of this crop sequence would be especially helpful for long-term grass management in the NT and SD tillage systems.

Table 6. Grass populations on May 23 as affected by previous Poast applications and tillage.

Treatment	Poast[1/]		No Poast	
	Preemerg	No Preemerg	Preemerg	No Preemerg
	Grasses/10 sq. ft.[2/]			
No Tillage	670	800	1130	2060
Fall Plow	10	20	30	40
Fall Chisel	30	80	460	1540
Ridge Plant	0	10	100	70
Spr. Disk (2 X)	130	140	1110	1290

1/ Applied in 1983, 1985 and 1987.
2/ Avg. of 4 replications and 2 counts/rep.

SUMMARY - 1987

This was the third crop of corn grown after soybeans in this long-term study with continuous corn from 1975 through 1982, soybeans in 1983, 1985 and 1987 and corn in 1984 and 1986. Surface residues prior to planting were greater than 50% with the NT and SD systems and remained above 30% after planting with the NT system. Plant emergence was fastest with RP, delayed by about 1 to 2 days with the MP, CP and SD systems, and by about 3 days with NT. Weed pressure was reduced some with the Lasso + Bladex preemergence application. Lowest weed pressure was noted with the RP and MP systems. Highest weed counts, primarily grasses, were found with the NT and SD systems. Previous applications of Poast to soybeans greatly reduced grass pressure in the CP, SD and NT systems. Early plant growth was greatest for the MP system and least for NT. Phenological plant development throughout the season continued to be a couple of days behind for the NT plants compared to plants grown on the other tillage systems. Leaf N was not affected by tillage or starter fertilizer. Yields were highest for MP, intermediate for RP, CP and SD, and lowest for the NT system. Soil profile investigations in mid-July indicated very limited soil water throughout the top 36" with all tillage systems and particularly poor rooting systems for the RP and NT tillage systems. Starter fertilizer increased yields by 16% when averaged over tillage systems. However, yield increases due to starter were greatest with the NT, CP and MP systems.

FOURTEEN-YEAR YIELD SUMMARY

Grain yields from the five tillage systems where starter fertilizer was used from 1975-1982 are shown in Table 7. The 8-year average yield shows a 5.3 bu/A yield advantage for the moldboard plow over the ridge-plant system. Some of this difference can be attributed to the 17 bushel advantage in 1980 for moldboard plowing. The chisel plow and till-plant (flat) systems showed intermediate yields while lowest yields were obtained with no tillage. Weed control was excellent in all treatments except no tillage. Postemergence herbicides were applied to no tillage in 1979 and 1980 and did provide better weed control.

Four-year data (1979-82) indicate some advantage for the use of starter fertilizer with the chisel plow (6 bu/A), ridge-plant (5 bu/A) and no tillage systems (5 bu/A). No reason can be given for the obvious difference in response to starter fertilizer between the no tillage and till-plant (flat) systems when both treatments represent the most severely reduced tillage systems.

Yields with no tillage continue to be significantly below the other tillage systems since converting to a corn/soybean sequence (Table 7). Corn yields in this sequence have not been different among the MP, CP, RP and SD systems when starter fertilizer has been used. Without starter fertilizer, yields from the CP, RP and SD systems have averaged about 9% less than from the MP system. Soybean yields in this sequence averaged about 6% higher with the moldboard plow system compared to the CP, RP, or SD systems with virtually no difference among the latter three systems.

Table 7. Influence of tillage methods and starter fertilizer on long-term corn and soybean yields at Waseca.

Treatment		Cont. Corn Yield		Soybeans	Corn
Tillage	Starter	1975-82	1979-82	1983,85 & 87	1984,86 & 88
		bu/A			
No tillage	Yes	129.2	140.6	34.5	111.5
"	No		136.0	34.3	98.8
Fall plow	Yes	154.5	170.9	51.0	145.6
"	No		170.8	50.2	141.2
Fall chisel	Yes	144.4	161.8	47.7	136.0
"	No		155.5	45.5	124.5
Ridge plant	Yes	149.2	161.5	46.9	137.4
"	No		156.4	47.2	129.4
Till plant (flat) 1/	Yes	144.9	154.8	46.8	139.7
"	No		157.4	47.1	132.1

1/ This treatment was converted to a spring disk (2x) beginning with the 1983 crop.

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

1988

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 and K did not decline in 1988, probably because of low crop demand due to the hot and dry conditions. Soybean yields were increased about 10% by increasing P up to a soil test of 40 lb P/A at Waseca but did not increase with higher P levels. Soil test K, ranging from 235 to 325 lb K/A at Waseca, did not influence yield. Soybean yields were very low at Morris and were not affected by soil test P level.

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 moldboard plowing the corn residue in the fall of 1987. Specific experimental procedures used for soybean 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 soybean on the high P and K rate study at the two branch stations in 1988.

Variable	Location: Morris	Location: Waseca
Planting date	5/3	5/19
Row spacing	30"	13"
Planting rate (plants/A)	10 beans/ft	3-4 beans/ft
Variety	Evans	Hardin
Herbicide	3# Lasso + 2.5# Amiben/A (Bdct)	3.5# Lasso + 3# Amiben/A (Bdct)
Harvest date	9/9	10/5
Soil type	Aastad clay loam	Webster clay loam

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.

RESULTS AND DISCUSSION

Total phosphate (P_2O_5) and potash (K_2O) applied over the 12-yr period ranged from 0 to 1200 lb/A (Tables 2 and 3). These application rates plus the 1985-86 rates resulted in highly significant differences in soil test P at both locations and in soil test K at Waseca. At Waseca soil test P ranged from 17 to 121 lb P/A (Table 2). Soil test P did not change compared to 1987, but soil test K was generally 10 to 20% higher. This may have been due to the very dry conditions or to the fact that soybeans were grown in 1988 compared to corn in 1987. Soybean yields were increased significantly by P but plateaued at soil P levels higher than 40 lb/A. No reason can be given for the slightly lower yield of treatment 7.

At Morris, Bray P_1 ranged from 17 to 66 lb/A while Olsen's $NaHCO_3$ test ranged from 8 to 45 lb P/A (Table 3). Due to the extremely dry conditions, yields were very low and soil test P and K levels remained similar to those found in 1987.

Table 2. Soil test values, soybean moisture, and soybean yield as influenced by 15 years' application of P and K at Waseca.

	P and K Treatments		Soil Test 2/			Soybean	
	Total						
No.	1973-84	1985-87 1/	pH	P	K	Moisture	Yield
	----- lb P_2O_5 + K_2O/A -----			--- lb/A ---		%	bu/A
2	0 + 1200	0 + 100	6.7	17	316	11.8	35.8
3	600 + 1200	0 + 100	6.4	45	309	11.3	40.1
4	1200 + 1200	0 + 100	6.7	82	278	11.2	39.7
5	600 + 1200	100 + 100	6.7	85	327	11.4	41.4
6	1200 + 0	100 + 0	6.7	121	235	11.3	40.5
7	1200 + 600	100 + 0	6.6	120	237	10.7	37.1
	Signif. Level (%):		53	99	99	93	96
	BLSD (.05) :		-	11	32	-	4.0
	CV (%) :		3.1	8.3	6.4	3.3	5.1

1/ Treatments applied each Fall.
2/ Samples were taken in October before 1988 treatments were applied.

Table 3. Soil test values, soybean moisture, and soybean yield as influenced by 15' years' application of P and K at Morris.

	P and K Treatments		Soil Test 2/				Soybean	
	Total							
No.	1973-84	1985-87 1/	pH	P_1	P_{OL}	K	Moisture	Yield
	---- lb P_2O_5 + K_2O/A -----			------ lb/A -------			%	bu/A
2	0 + 1200	0 + 100	7.7	17	8	406	11.1	8.0
3	600 + 1200	0 + 100	7.6	38	24	380	10.3	8.3
4	1200 + 1200	0 + 100	7.7	66	45	369	10.4	9.3
5	600 + 1200	100 + 100	7.7	58	41	363	10.8	9.0
	Signif. Level (%):		94	99	99	41	8	19
	BLSD (.05) :			16.	14.			
	CV (%) :		22.	22.	30.	12.	16.	79.

1/ Treatments applied each Fall.
2/ Samples were taken in October before 1988 treatments were applied.

CONCLUSIONS

Long-term (12-yr) P additions to these two soils created a wide range in soil test P levels. Soybean yields were optimized over the no P treatments at soil test P levels of 40 lb/A at Waseca. Yields were not affected by K at Waseca or by P at Morris, primarily because of the very dry conditions. Soil test P levels at both locations were similar to 1987; however, soil test K was 10 to 20% higher at Waseca in 1988. Additional years will be needed to more accurately determine the decline rates.

WATER QUALITY RESEARCH WITH NITROGEN AT THE HERMAN ROSHOLT WATER QUALITY RESEARCH FARM, WESTPORT, MN 1988 [1]
Small plot phase.

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

Abstract: The objective of the small plot water quality reseach phase is to evaluate and quantitate the impact of a variety of agricultrual practices on crop nitrogen utilization efficiency and the potential impact on water quality. Currently agricultrual practices such as crop rotation, tillage, and fertilizer N management including, rates, sources, time of application, methods of application and use of nitrification inhibitors are being evaluated. Due to the hot, dry summer, relativily few differences in crop production were noted due to management practices. Corn grain yields aveaged 5 bu/a higher when the preceding crop was soybeans rather than corn. Corn grain yields utilizing a traditional chisel-plow tillage systems was 7-11 bu/a higher than ridge-till systems. Early N applications in 1988 were superior to split or late N applications. Nitrogen rates in excess of 120 kg/ha resulted in excess nitrate - N present in the soil profile at the end of the growing season. This excess nitrate has a high potential of being moved down toward the groundwater before the next growing season.

In 1987 three phases of nitrogen (N) research were started at the Herman Rosholt Water Quality Research Farm at Westport, MN. The three phases of research included a lysimeter phase, a large plot groundwater phase and a small plot N management/crop production phase. Each phase will be reported separately.

The soil at the Rosholt farm is an Estherville sandy loam with 38-76 cm of sandy loam soil overlying glacial outwash composed mainly of coarse sand and gravel. Because of the coarse nature of these soils and the low water holding capacity, they are frequently irrigated to attain high yields. The higher yield potential along with higher fertilizer inputs, low water holding capacity, and shallow underlying aquifer create conditions which could result in groundwater contamination with nitrate N. Improper fertilizer N management can result in reduced yields, reduced fertilizer use efficiency, decreased profits, and increased groundwater contamination. The purpose of this phase of research was to determine the impacts of different N and crop management practices on crop yield, N utilization and their resulting impacts on groundwater quality.

Experimental Procedures

Two separate N experiments were established at the Rosholt farm in 1988.

Experiment 1 consisted of 25 N treatments randomized within a split-split plot design with three replications. The main plot consisted of two cropping sequences (continuous corn and corn following soybeans) with the sub-plots being tillage (ridge till and chisel plow). Ridges were constructed the previous growing season in 1987. In 1988 the entire experiment was planted to corn. The 25 N treatments within each sub-plot consisted of a control (zero N) plus four N rates (60, 120 180, and 240 kg/ha), two nitrification inhibitors (none and N-Serve) and three times/methods of application (all N early-4 leaf growth stage, all N late-8 leaf growth stage, and split with 2/3 N early and 1/3 late). All fertilizer N treatments were applied as anhydrous ammonia. The nitrification inhibitor N-Serve was applied with an in-line injection pump which inserted the chemical in front of a bidirectional flow integrator and the manifold. N-Serve was applied at a rate of 0.56 kg/ha active ingredient.

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1. Funding provided by the University of Minnesota Agricutrual Experiment Station and the Center for the Impacts of Agicultral Practices on Water Quality.
Appreciation is also expressed to Pioneer Hybrid International for suppyling seed corn.
2. Associate Professor and Asst. Scientist, respectively, Dept. of Soil Science. University of Minnesota.

Soil samples were taken from 0-30 and 30-60 cm depth from 13 of the 25 treatments on April 12th before planting and on October 3rd after harvest. The soil samples were analyzed for ammonium and nitrate concentration and the data is reported in tables 4 and 5. Only fall samples were taken if soybeans were the previous crop.

Experiment 2 consisted of 16 N treatments randomized within a split plot design with three replications. The main plots variable was tillage (ridge till and chisel plow). The 16 N treatments within each sub-plot consisted of two N rates (120 and 180 kg/ha), two N sources (anhydrous ammonia and urea) and two nitrification inhibitor treatments (with and without) at two times of application (early-4 leaf and late-8 leaf). Nitrification inhibitor treatments consisted of 0.56 kg/ha a.i. of N-Serve applied with anhydrous ammonia or 10% DCD-N with urea. The DCD urea was supplied by Tennessee Valley Authority-National Fertilizer Development Center. Urea treatments were injected at a depth of 15 cm and positioned approximately 15 cm away from the row similar to the anhydrous ammonia treatments.

Experiments 1, and 2: Corn (Pioneer 3902 - 90 day R.M.) was planted on April 28 in 0.76 m rows at a population of 78,600 seeds/ha using a four-row Buffalo planter. Starter fertilizer was applied at the rate of 93.5 l/ha of 7-22-5 as a band below the seed. A tank mix of Dual (1.96 kg/ha), Bladex (1.96 kg/ha) and Roundup (2.24 kg/ha) was applied on May 6th for weed control. Because of poor weed control the area was resprayed with a tank mix of Bladex 90 DF(2.0 kg/ha), and Prowl (1.1 kg/ha) on May 23rd. For additional weed control the experiments were cultivated twice. The first cultivation was on June 4th, and second on June 18th, ridges were also built on June 18th. Nitrogen treatments were applied on June 2nd (early-4 leaf) and on June 16th (late-8 leaf). The irrigation program (traveling boom) was started on May 18th and continued through July 29th with 31.8 cm of water being applied through irrigation. An additional 17.9 cm of water was obtained during the growing season as rainfall.

Grain yields were obtained on September 26th by hand harvesting 9.3 m^2 of plot area. All grain yields were adjusted to 15.5% moisture.

General Results

Experiment 1 Because of the hot temperatures experienced in 1988 along with bird damage, few treatments averaged over 130 bu/a. When no fertilizer N was applied corn yields ranged from 70-110 bu/a depending on previous crop and tillage system. When no fertilizer N was applied corn yields were 16 bu/a higher with the chisel tillage system and 42 bu/a higher on the ridge-till system when the previous crop was soybeans rather that corn. This large advantage to the corn following soybean rotation was reduced when fertilizer N was applied. Across all treatment comparisons, however, corn yields were 5 bu/a higher following soybeans than following corn. Tillage system also influenced final grain yield. Although the ridge-till treatments provided better yields than the chisel tillage system when no fertilizer N was applied following soybeans this did not continue with all comparisons. Across the entire experiment corn grain yields were 7 and 11 bu/a higher utilizing a chisel system of tillage in 1988 rather than ridge tillage for corn following corn and corn following beans respectively.

Yield increases were obtained with fertilizer N up to rates of 120 kg/ha (108 lbs/a). The hot dry summer created conditions for some very interesting responses to fertilizer management. Fertilizer use efficiency would normally increase by delaying the time of fertilizer N application thereby minimizing N loss. In 1988 highest yields were obtained when the fertilizer was applied early (4-leaf) rather than in split or 8-leaf applications. This did, however, appear to be more pronounced with corn-corn rather than soybeans-corn. The lack of a yield response when the timing of fertilizer N was changed would indicate that N losses were not large during the 1988 growing season. A significant yield increase (4-5 bu/a) was obtained with the use of N-Serve. Since N-Serve is a chemical additive used with fertilizer to minimize N loss from soil, and the amount of N loss was low in 1988, the reason for a respose is not well understood at this time.

The concentration of nitrate-N in the surface 0.6 m of soil in the spring of 1988 was high if the fertilizer N treatment in 1987 was above 120 kg/ha (108 lbs/a). This would support the fact that winter recharge of the aquifer and leaching of nitrate-N through the soil during the late fall, winter, and early spring were minimal in 1987-1988. The soil nitrate-N concentration following harvest were generally lower than that found before planting. This reduced concentraion of nitrate-N may be due to either efficient utilization of the N by the plant or movement of the N below the 0-0.6 m sampling region. Since yields were not high it would seem feasible that at least a portion of the nitrate moved deeper into the soil profile during the growing season. The highest rate of fertilizer N tended to have higher concentrations of nitrate-N in the soil profile when it followed soybeans with chisel plow tillage.

Experiment 2 The fertilizer N rates of 120 and 180 kg/ha were at or above the necessary rate to obtain optimum yields. Differences between various fertilizer N management options were therefore minimal. There was no treatment effect due to tillage, N source, N rate, or time of application.

Table 1. Influence of N-rates, nitrification inhibitors, method of application and tillage on continuous corn grain yields, Westport,MN 1988.

Total N-Rate kg/ha	Early N	Inh.	Late N	Tillage	Grain Bu/A	Grain % N	Grain mt/ha	N-Removal kg/ha
Control	-----	---	-----	C	78.4	1.33	4.93	55.76
60	60	---	-----	C	102.5	1.63	6.45	88.87
60	-----	---	60	C	122.0	1.62	7.67	104.57
60	40	---	20	C	113.5	1.70	7.14	102.38
60	60	NS	-----	C	108.4	1.66	6.82	95.45
60	-----	NS	60	C	117.3	1.62	7.38	100.98
60	40	NS	20	C	120.6	1.74	7.59	111.21
120	120	---	-----	C	117.9	1.65	7.42	103.40
120	-----	---	120	C	102.4	1.77	6.45	95.93
120	80	---	40	C	121.9	1.74	7.67	112.71
120	120	NS	-----	C	105.9	1.75	6.67	98.23
120	-----	NS	120	C	120.4	1.72	7.57	110.08
120	80	NS	40	C	109.4	1.73	6.88	100.29
180	180	---	-----	C	106.8	1.83	6.72	103.69
180	-----	---	180	C	117.2	1.72	7.37	106.64
180	120	---	60	C	106.2	1.79	6.68	100.48
180	180	NS	-----	C	116.2	1.67	7.31	102.56
180	-----	NS	180	C	113.3	1.72	7.13	103.54
180	120	NS	60	C	105.4	1.74	6.63	97.33
240	240	---	-----	C	127.7	1.70	8.04	115.35
240	-----	---	240	C	108.4	1.71	6.82	98.00
240	160	---	80	C	108.7	1.73	6.84	99.53
240	240	NS	-----	C	109.4	1.78	6.88	103.34
240	-----	NS	240	C	117.3	1.55	7.38	96.26
240	160	NS	80	C	126.0	1.66	7.93	110.86
Control	-----	---	-----	R	69.8	1.38	4.39	50.99
60	60	---	-----	R	99.5	1.70	6.26	89.64
60	-----	---	60	R	92.9	1.80	5.85	88.73
60	40	---	20	R	98.8	1.62	6.22	84.70
60	60	NS	-----	R	110.2	1.67	6.94	96.82
60	-----	NS	60	R	107.7	1.82	6.77	103.78
60	40	NS	20	R	100.3	1.71	6.31	90.50
120	120	---	-----	R	109.3	1.72	6.88	99.45
120	-----	---	120	R	105.2	1.73	6.62	96.41
120	80	---	40	R	110.2	1.71	6.93	99.70
120	120	NS	-----	R	122.4	1.74	7.70	112.50
120	-----	NS	120	R	122.5	1.75	7.71	113.20
120	80	NS	40	R	116.6	1.76	7.33	108.45
180	180	---	-----	R	121.8	1.77	7.66	113.82
180	-----	---	180	R	80.0	1.66	5.03	70.60
180	120	---	60	R	99.1	1.82	6.24	95.43
180	180	NS	-----	R	104.4	1.86	6.57	102.51
180	-----	NS	180	R	104.0	1.73	6.55	95.58
180	120	NS	60	R	102.7	1.80	6.46	97.98
240	240	---	-----	R	113.4	1.74	7.13	104.45
240	-----	---	240	R	98.0	1.77	6.16	91.99
240	160	---	80	R	103.7	1.78	6.53	97.55
240	240	NS	-----	R	119.1	1.78	7.49	112.15
240	-----	NS	240	R	94.5	1.82	5.94	91.34
240	160	NS	80	R	107.2	1.70	6.75	96.82

Table 1. continued: Continuous Corn Split Plot Statistical Analysis

	Grain		Grain	N-Removal
Tillage	Bu/A	% N	mt/ha	kg/ha
Chisel	113.5	1.70	7.14	102.56
Ridge Till	106.0	1.74	6.66	98.08
P-Value	99	95	99	99
N-Rate X Method X Inhibitor				
N-Rate kg/ha				
60	107.8	1.69	6.78	96.46
120	113.7	1.73	7.15	104.19
180	106.4	1.75	6.69	99.18
240	111.1	1.72	6.99	101.46
P-Value	99	99	99	99
BLSD (.05)	3.4	0.02	0.21	2.75
Method				
1. 4 leaf	112.2	1.72	7.05	102.63
2. 8 leaf	107.7	1.72	6.77	97.975
3. Split 2/3 1/3	109.4	1.73	6.88	100.37
P-Value	99	38	99	99
BLSD (.05)	3.1		0.19	2.47
Inhibitor				
None	107.8	1.72	6.78	98.50
N-Serve	111.7	1.72	7.02	102.15
P-Value	99	30	99	99
N-Rate X Method	99	99	99	99
N-Rate X Inhibitor	35	68	35	90
Method X Inhibitor	99	45	99	98
N-Rate X Method X Inhibitor	99	94	99	99
N-Rate X Method X Inhibitor X Tillage				
N-Rate X Tillage	99	73	99	97
Method X Tillage	99	93	99	99
Inhibitor X Tillage	96	92	96	99
N-Rate X Method X Tillage	86	99	86	99
N-Rate X Inhibitor X Tillage	79	55	79	60
Method X Inhibitor X Tillage	53	45	53	74
N-Rate X Method X Inhibitor X Tillage	99	79	99	99

Table 2. Influence of N-rates, nitrification inhibitors, method of application and tillage on corn grain yields, corn following soybeans. Westport,MN 1988.

Total N-Rate kg/ha	Early N	Inh.	Late N	Tillage	Grain Bu/A	% N	Grain mt/ha	N-Removal kg/ha
Control	-----	---	-----	C	94.7	1.52	5.96	76.53
60	60	---	-----	C	122.4	1.80	7.70	116.97
60	-----	---	60	C	113.4	1.78	7.13	106.82
60	40	---	20	C	111.8	1.75	7.03	103.43
60	60	NS	-----	C	127.6	1.73	8.03	116.60
60	-----	NS	60	C	118.1	1.73	7.43	107.93
60	40	NS	20	C	109.4	1.71	6.89	99.20
120	120	---	-----	C	118.2	1.76	7.43	110.15
120	-----	---	120	C	102.6	1.66	6.46	90.02
120	80	---	40	C	132.4	1.60	8.33	112.42
120	120	NS	-----	C	127.9	1.64	8.04	111.04
120	-----	NS	120	C	129.7	1.63	8.16	111.52
120	80	NS	40	C	128.0	1.73	8.05	117.47
180	180	---	-----	C	99.6	1.72	6.27	90.79
180	-----	---	180	C	130.8	1.62	8.23	112.62
180	120	---	60	C	130.8	1.57	8.19	108.56
180	180	NS	-----	C	120.4	1.68	7.58	106.99
180	-----	NS	180	C	124.3	1.69	7.82	111.12
180	120	NS	60	C	122.3	1.61	7.69	104.40
240	240	---	-----	C	119.6	1.78	7.53	112.94
240	-----	---	240	C	114.7	1.68	7.21	102.08
240	160	---	80	C	130.3	1.66	8.20	114.27
240	240	NS	-----	C	134.5	1.61	8.46	114.67
240	-----	NS	240	C	97.9	1.69	6.16	87.61
240	160	NS	80	C	116.9	1.60	7.36	99.10
Control	-----	---	-----	R	112.5	1.47	7.08	87.52
60	60	---	-----	R	112.8	1.63	7.10	97.16
60	-----	---	60	R	106.0	1.62	6.67	91.01
60	40	---	20	R	117.3	1.69	7.38	104.99
60	60	NS	-----	R	103.8	1.78	6.53	97.66
60	-----	NS	60	R	108.3	1.69	6.81	97.17
60	40	NS	20	R	115.1	1.74	7.24	105.60
120	120	---	-----	R	122.6	1.63	7.71	105.37
120	-----	---	120	R	85.4	1.71	5.37	77.30
120	80	---	40	R	106.2	1.69	6.68	95.33
120	120	NS	-----	R	104.2	1.73	6.56	95.20
120	-----	NS	120	R	123.3	1.54	7.76	99.92
120	80	NS	40	R	125.8	1.58	7.92	105.42
180	180	---	-----	R	113.4	1.67	7.13	100.33
180	-----	---	180	R	102.1	1.82	6.42	98.44
180	120	---	60	R	92.7	1.65	5.83	81.43
180	180	NS	-----	R	108.9	1.80	6.85	104.05
180	-----	NS	180	R	101.4	1.73	6.38	93.36
180	120	NS	60	R	108.0	1.81	6.79	103.75
240	240	---	-----	R	100.1	1.73	6.30	91.69
240	-----	---	240	R	101.3	1.68	6.37	90.05
240	160	---	80	R	105.2	1.70	6.62	94.65
240	240	NS	-----	R	122.1	1.71	7.68	110.59
240	-----	NS	240	R	106.3	1.83	6.69	103.17
240	160	NS	80	R	122.1	1.65	7.69	106.54

Table 2. continued: Corn Following Soybeans Split Plot Statistical Analysis

	Grain		Grain	N-Removal
Tillage	Bu/A	% N	mt/ha	kg/ha
Chisel	120.1	1.68	7.55	107.02
Ridge Till	108.9	1.70	6.85	97.92
P-Value	97	82	97	98
N-Rate X Method X Inhibitor				
N-Rate kg/ha				
60	113.8	1.72	7.16	103.71
120	117.2	1.65	7.37	102.59
180	112.8	1.69	7.09	101.31
240	114.2	1.69	7.18	102.27
P-Value	71	96	71	38
BLSD (.05)		0.04		
Method				
1. 4 leaf	116.1	1.71	7.30	105.13
2. 8 leaf	110.3	1.69	6.94	98.75
3. Split 2/3 1/3	117.1	1.67	7.36	103.53
P-Value	99	91	99	99
BLSD (.05)	3.9		0.25	2.97
Inhibitor				
None	112.1	1.69	7.05	100.36
N-Serve	116.9	1.69	7.35	104.58
P-Value	99	3	99	99
N-Rate X Method	97	48	97	99
N-Rate X Inhibitor	93	76	93	82
Method X Inhibitor	38	20	38	22
N-Rate X Method X Inhibitor	99	90	99	99
N-Rate X Method X Inhibitor X Tillage				
N-Rate X Tillage	82	99	82	59
Method X Tillage	11	70	11	25
Inhibitor X Tillage	82	99	82	99
N-Rate X Method X Tillage	99	46	99	99
N-Rate X Inhibitor X Tillage	94	99	94	99
Method X Inhibitor X Tillage	99	99	99	95
N-Rate X Method X Inhibitor X Tillage	35	99	35	45

Table. 1 and 2 continued: Split plot statistical analysis for corn-corn and corn following soybeans, Westport MN 1988

	Grain Bu/A	Grain % N	Grain mt/ha	N-Removal kg/ha
Crop				
Corn-Corn	109.7	1.72	6.90	100.32
Corn-Soybeans	114.5	1.69	7.20	102.47
P-Value	99	82	99	95
Tillage				
Chisel	116.8	1.69	7.35	104.79
Ridge Till	107.4	1.72	6.76	98.00
P-Value	99	99	99	99
Crop X Tillage	65	73	65	86
N-Rate X Method X Inhibitor				
N-Rate				
60	110.8	1.70	6.97	100.08
120	115.4	1.69	7.26	103.39
180	109.6	1.72	7.08	101.87
240	112.7	1.70	7.08	101.87
P-Value	99	97	99	97
Inhibitor				
None	110.0	1.70	6.91	99.43
N-Serve	114.3	1.71	7.19	103.37
P-Value	99	25	99	99
Method				
1. 4 leaf	114.2	1.72	7.18	103.88
2. 8 leaf	109.0	1.70	6.85	98.36
3. Split 2/3 1/3	113.2	1.70	7.12	101.95
P-Value	99	86	99	99
N-Rate X Inhibitor	74	83	74	86
N-Rate X Method	96	70	96	95
Method X Inhibitor	86	22	86	91
N-Rate X Method X Inhibitor	99	85	99	91
N-Rate X Method X Inhibitor X Crop				
N-Rate X Crop	44	99	44	99
Inhibitor X Crop	34	18	34	28
Method X Crop	87	92	87	53
N-Rate X Inhibitor X Crop	81	84	81	83
N-Rate X Method X Crop	93	96	93	99
Method X Inhibitor X Crop	72	50	72	63
N-Rate X Method X Inhibitor X Crop	99	98	99	99
N-Rate X Method X Inhibitor X Tillage				
N-Rate X Tillage	82	96	82	67
Inhibitor X Tillage	95	98	95	99
Method X Tillage	97	70	97	96
N-Rate X Inhibitor X Tillage	60	70	60	77
N-Rate X Method X Tillage	94	55	94	99
Method X Inhibitor X Tillage	96	80	96	84
N-Rate X Method X Inhibitor X Tillage	95	76	95	95
N-Rate X Method X Inhibitor X Tillage X Crop				
N-Rate x Tillage X Crop	96	99	96	86
Inhibitor X Tillage X Crop	17	36	17	5
Method X Tillage X Crop	91	94	91	95
N-Rate X Inhibitor X Tillage X Crop	92	94	92	96
N-Rate X Method X Tillage X Crop	95	98	95	97
Method X Inhibitor X Tillage X Crop	99	99	99	90
N-Rate X Method X Inh. X Till X Crop	83	94	83	77

Table 3. Influence of N-rates, N-forms, nitrification inhibitors, time of application and two tillage systems on grain yields at Westport, MN. 1988

N-Rate Kg/ha	N-Form	Inh.	Time	Tillage	Grain Bu/A	Grain % N	Grain mt/ha	N-Removal kg/ha
120	AA	---	1	C	115.3	1.69	7.25	102.92
120	AA	NS	1	C	118.5	1.66	7.45	104.01
120	UREA	---	1	C	119.1	1.75	7.49	110.51
120	UREA	DCD	1	C	112.6	1.66	7.08	98.88
120	AA	---	2	C	122.6	1.64	7.71	105.81
120	AA	NS	2	C	113.7	1.73	7.15	104.02
120	UREA	---	2	C	113.3	1.67	7.13	100.01
120	UREA	DCD	2	C	112.0	1.69	7.05	100.31
180	AA	---	1	C	138.7	1.67	8.72	122.96
180	AA	NS	1	C	114.1	1.75	7.18	105.50
180	UREA	---	1	C	101.0	1.75	6.35	93.03
180	UERA	DCD	1	C	113.8	1.64	7.16	99.02
180	AA	---	2	C	122.7	1.75	7.72	113.94
180	AA	NS	2	C	96.4	1.73	6.06	88.31
180	UREA	---	2	C	112.0	1.72	7.04	101.75
180	UREA	DCD	2	C	113.5	1.67	7.14	100.27
120	AA	---	1	R	93.3	1.72	5.87	84.87
120	AA	NS	1	R	116.1	1.66	7.30	102.19
120	UREA	---	1	R	110.4	1.66	6.94	97.39
120	UREA	DCD	1	R	115.3	1.75	7.25	106.98
120	AA	---	2	R	123.6	1.71	7.78	112.01
120	AA	NS	2	R	121.4	1.70	7.63	108.92
120	UREA	---	2	R	117.3	1.72	7.38	106.41
120	UREA	DCD	2	R	113.2	1.69	7.12	101.33
180	AA	---	1	R	124.7	1.77	7.84	117.14
180	AA	NS	1	R	103.7	1.78	6.52	97.54
180	UREA	---	1	R	122.9	1.62	7.73	105.61
180	UREA	DCD	1	R	125.4	1.72	7.88	114.08
180	AA	---	2	R	108.2	1.74	6.81	99.74
180	AA	NS	2	R	96.1	1.73	6.05	88.02
180	UREA	---	2	R	128.1	1.64	8.05	111.16
180	UERA	DCD	2	R	110.4	1.77	6.94	103.28

Table 3. continued: Split Plot Statistical Analysis

	Grain Bu/A	Grain % N	Grain mt/ha	N-Removal kg/ha
Tillage				
Chisel	114.9	1.69	7.23	103.20
Ridge Till	114.3	1.71	7.19	103.54
P-Value	35	46	35	17
N-Form X Inh. X Time X N-Rate				
N-Form				
Anhydrous Ammonia	118.7	1.71	7.46	107.42
Anhydrous Ammonia + N-Serve	110.0	1.71	6.91	99.81
Urea	115.5	1.69	7.26	103.23
Urea + DCD	114.5	1.69	7.20	103.02
P-Value				
Inhibitor				
Without	117.0	1.70	7.36	105.32
With	112.2	1.70	7.06	101.41
P-Value	99	27	99	99
Time				
1. 4 leaf 6/2/88	115.2	1.70	7.25	103.91
2. 8 leaf 6/16/88	114.0	1.70	7.17	102.83
P-Value	53	10	53	52
N-Rate kg/ha				
120	114.8	1.69	7.22	102.90
180	114.4	1.71	7.20	103.83
P-Value	17	76	17	45
N-Form X Inh.	97	10	97	98
N-Form X Time	50	5	50	47
N-Form X N-Rate	76	89	76	7
Inh. X Time	98	36	98	95
Inh. X N-Rate	99	31	99	99
Time X Rate	99	22	99	99
N-Form X Inh X Time	15	23	15	10
N-Form X Inh X Time X N-Rate	99	30	99	1
N-Form X Inh. X Time X N-Rate X Tillage				
N-Form X Tillage	99	49	99	99
Inh. X Tillage	72	80	72	96
Time X Tillage	89	6	89	86
N-Rate X Tillage	74	8	74	67
N-Form X Inh. X Tillage	99	99	99	57
N-Form X Time X Tillage	99	69	99	92
N-Form X N-Rate X Tillage	99	37	99	99
Inh. X Time X Tillage	77	70	77	95
Inh. X N-Rate X Tillage	97	81	97	78
Time X N-Rate X Tillage	99	40	99	99
N-Form X Inh. X Time X Tillage	68	67	68	93
N-Form X Inh. X Time X N-Rate X Tillage	68	47	68	93

Table 4. Influence of N-rates, nitrification inhibitors, method of application and tillage in continous corn on soil ammonium and soil nitrate from spring and fall soil samples depth 1 (0-30 cm) and depth 2 (30-60cm) Westport MN.

Total N-Rate	Early N	Inh.	Late N	Tillage	Depth	Ammonium Spring	Ammonium Fall	Nitrate Spring	Nitrate Fall
kg/ha						------PPM------		-----PPM-----	
Control	-----	---	-----	C	1	---	2.7	---	4.8
					2	---	2.0	---	3.1
60	60	---	-----	C	1	2.0	3.3	10.7	5.6
					2	2.1	2.4	7.7	6.0
60	-----	---	60	C	1	2.3	2.8	11.0	5.1
					2	2.3	2.4	5.5	4.7
120	120	---	-----	C	1	2.3	3.1	11.3	7.3
					2	1.6	2.5	12.3	6.5
120	-----	---	120	C	1	2.4	3.4	9.3	6.6
					2	1.8	2.5	9.0	8.2
180	180	---	-----	C	1	2.4	2.9	13.7	7.9
					2	1.8	3.4	20.0	8.5
180	-----	---	180	C	1	2.1	3.4	10.1	6.9
					2	1.8	3.0	12.5	10.6
180	120	---	60	C	1	2.0	3.1	11.6	7.0
					2	1.6	2.6	13.9	10.0
180	180	NS	-----	C	1	3.4	5.0	14.6	10.1
					2	7.0	3.5	19.2	11.2
180	-----	NS	180	C	1	1.7	3.2	10.7	6.2
					2	2.0	2.5	11.7	8.6
180	120	NS	60	C	1	1.9	5.7	11.9	11.4
					2	1.6	3.1	9.4	13.7
240	240	---	-----	C	1	5.1	4.0	20.0	13.7
					2	2.4	3.0	37.6	12.9
240	-----	---	240	C	1	2.1	2.9	14.8	7.0
					2	1.8	2.3	20.3	7.3
Control	-----	---	-----	R	1	---	2.8	----	3.7
					2	---	2.0	----	3.4
60	60	---	-----	R	1	1.8	3.2	11.6	6.1
					2	1.9	2.2	9.5	4.0
60	-----	---	60	R	1	1.9	3.6	11.9	6.5
					2	2.6	2.8	6.7	5.2
120	120	---	-----	R	1	2.1	4.9	17.2	10.5
					2	2.0	2.7	12.4	7.3
120	-----	---	120	R	1	2.3	3.4	12.7	5.7
					2	1.6	2.4	9.7	7.7
180	180	---	-----	R	1	2.0	3.0	11.9	11.3
					2	2.1	2.1	24.7	8.3
180	-----	---	180	R	1	2.0	5.5	18.9	5.6
					2	2.2	2.8	26.8	5.7
180	120	---	60	R	1	2.0	3.5	17.7	6.2
					2	2.3	2.3	24.5	5.1
180	180	NS	-----	R	1	1.9	4.6	15.8	20.9
					2	1.6	5.6	16.5	28.6
180	-----	NS	180	R	1	1.8	3.2	12.3	11.0
					2	1.7	2.4	8.5	6.9
180	120	NS	60	R	1	1.8	4.4	11.9	9.9
					2	2.0	2.8	9.2	6.7
240	240	---	-----	R	1	3.2	2.9	15.1	8.3
					2	2.2	2.7	33.2	7.3
240	-----	---	240	R	1	2.1	3.1	24.3	6.9
					2	2.2	2.6	20.5	19.1

Table 5. Influence of N-Rates, nitrification inhibitors, methods of application and tillage in corn following soybeans on soil ammonium and soil nitrate form fall soil samples depth 1 (0-30 cm) and depth 2 (30-60 cm) Westport, MN 1988.

Total N-Rate	Early N	Inh.	Late N	Tillage	Depth	Ammonium	Nitrate
kg/ha						------PPM--------	
Control	-----	---	-----	C	1	3.0	5.8
					2	2.3	3.9
60	60	---	-----	C	1	2.8	5.9
					2	2.2	5.3
60	-----	---	60	C	1	2.7	4.8
					2	2.3	3.7
120	120	---	-----	C	1	4.3	17.3
					2	2.1	13.2
120	-----	---	120	C	1	3.1	4.9
					2	2.2	4.2
180	180	---	-----	C	1	3.8	6.9
					2	3.6	13.0
180	-----	---	180	C	1	4.1	8.8
					2	2.8	7.8
180	120	---	60	C	1	3.1	6.5
					2	2.4	5.8
180	180	NS	-----	C	1	3.0	5.4
					2	2.9	6.5
180	-----	NS	180	C	1	2.7	5.4
					2	2.8	4.4
180	120	NS	60	C	1	3.8	12.9
					2	4.0	13.3
240	240	---	-----	C	1	4.6	16.1
					2	2.3	13.5
240	-----	---	240	C	1	5.6	21.6
					2	4.2	32.7
Control	-----	---	-----	R	1	3.2	4.2
					2	2.9	4.5
60	60	---	-----	R	1	2.8	5.6
					2	2.5	4.4
60	-----	---	60	R	1	3.5	7.3
					2	2.4	5.2
120	120	---	-----	R	1	3.2	6.9
					2	2.7	6.3
120	-----	---	120	R	1	2.8	6.6
					2	2.4	8.2
180	180	---	-----	R	1	3.1	6.0
					2	2.4	8.4
180	-----	---	180	R	1	3.0	6.8
					2	2.2	7.7
180	120	---	60	R	1	3.1	6.8
					2	2.2	10.7
180	180	NS	-----	R	1	3.4	7.1
					2	2.4	7.1
180	-----	NS	180	R	1	3.8	7.6
					2	2.5	7.4
180	120	NS	60	R	1	4.2	6.0
					2	2.6	4.8

INFLUNCE OF NITROGEN RATE AND CROP ROTATION ON GRAIN YIELD AND NITRATE-NITROGEN MOVEMENT THROUGH SOIL [1]

Large plot research phase Westport, MN. 1988

J. Neiber, D. Steele, G.L. Malzer, D. Clay and T.J. Graff [2]

Abstract: Several sampling devices, including suction lysmeters, glass blocks, sheet metal containers, and wick samplers, were installed in 1987 and 1988. Corn grain yield increases to N fertilization over 160 lbs/a were minimal in both 1987 and 1988. Increasing the rate of N fertilization on continous corn from 160 to 214 lbs N/a/yr resulted in increased concentrations of NO_3-N in soil water at the 4 ft depth toward the end of 1988. Other sampling devices were installed too late in 1988 to obtain useable results.

In 1987 three phases of nitrogen (N) research were started at the Herman Rosholt Water Quality Farm at Westport, MN. The three phases of research included a lysimeter phase, a large plot groundwater phase and a small plot nitrogen management/crop production phase. This report is a summary of the results obtained from the large plot groundwater phase.

The purpose of this phase of research was to determine the impacts of N rate and crop management practices on both the crop yield, N utilization and movement of nitrate-N through the soil profile to the groundwater.

Experimental Procedures

In 1987 six large plots (approximately one acre were established at the Rosholt farm. The experiment area consisted of three treatments with two replications. Two treatments are continuous corn with N rates of 160 and 214 lbs N/a. The third treatment is in a corn following soybeans rotation with 160 lbs N/a applied during the corn year. In 1987 all treatments were planted to corn. In 1988 soybeans were planted into the corn-soybean rotation treatment. Nitrogen was applied as anhydrous ammonia in split application of two-thirds of the N rate which was applied with a nitrification inhibitor (N-Serve) at an early growth stage 4-leaf (June 2), and one-third at the 8-leaf growth stage (June 16). N-Serve was applied only at the 4-leaf stage utilizing an in-line injection pump which inserted the chemical in front of a bidirectional flow integrator and the manifold. N-Serve was applied at a rate of 0.5 lbs. a.i./a.

Corn (Pioneer 3902 - 90 day R.M.) was planted on April 28 in 30 inch rows at a population of 29,900 seeds/A using a four-row Buffalo planter. Starter fertilizer was applied at the rate of 10 gal/A of 7-22-5 as a band below the seed. A tank mix of Atrazine (1.0 #/A), Lasso (3.0 #/A) and Dicamba (.25 #/A) was used on May 6th for weed control on corn treatments.

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Soybeans (Pioneer 9061) were planted on May 24th in 30 inch rows with the same buffalo planter at a seeding rate of 192,000 seeds/a (60 lbs/a). A tank mix of Lasso (2.0 lbs/a) plus Amiben (2.5 lbs/a) was applied May 26 for weed control on the soybean treatments.
The irrigation program (traveling boom) was started on May 18th and continued through July 29th with 12.55 inches of water being applied through irrigation and an additional 7.06 inches of water coming through rainfall during the growing season.

Grain yields were obtained on September 26th by hand harvesting 800 ft^2 of plot area. Corn grain yields were adjusted to 15.5% moisture. Soybean yields were obtained on September 27th by hand harvesting 400 ft^2 of plot area and were adjusted to 13% moisture. Grain yields results are in table 1.

Chemical movement through soils to groundwater

To follow the movement of nitrate-N through soils to the groundwater several types of soil water sampling devices have been installed. These include suction lysimeters, glass blocks, sheet metal, wick samplers, and wells. The wells were installed by the United States Geological Survey, and data from the wells will not be presented at this time.

Glass block samplers are made from glass building blocks,(12" X 12"X 4" - L X W X D). Holes were drilled into the blocks to allow water to enter and permit access for removing the water collected. Three glass blocks were installed in plots at a soil depth of 18-24 inches (depth where soil becomes very coarse). Three blocks were installed side by side, one directly under a crop row and one on either side.

Suction lysimeters were installed at depths of 4 and 7 feet during 1987. The ceramic cup of the suction sampler was cast into a silica slurry which hardens in the soil to insure continuous contact between the soil and the ceramic cup. Outflow tubes were run to the surface for sampling. This type of sampler allows for the collection of soil water samples at the aforementioned depths. Concentrations of nitrate-N in soil water samples utilizing this technique are presented in table 2.

Sheet metal samplers consist of 18-guage sheet metal, cut, bent, and spot welded into a trough-like collection box. The samplers are 30" long 12" wide and 3" deep and made watertight by soldering along seams. Holes were drilled into the top of the sampler to allow entry of water. Access tubes were installed to the soil surface to facilate extraction of the water collected.

Wick samplers a one-half inch glass plate, 12 inches X 30 inches. A hole was drilled in the center of the glass plate and a 2 inch lenght of PVC pipe was attached to it. A braided glass rope was inserted through the PVC pipe and onto the glass plate. The strands of glass rope were unraveled over the surface of the glass plate and epoxied to the edges of the plate, forming a spider web-like pattern. The glass rope thus acted as a wicking device to draw water from the surface of the plate into a one gallon collection jar. These also have outflow tubes going to the surface. The sheetmetal and wick samplers were installed at approximately the same depth as the glass blocks.

General Results: Preliminary results would suggest that there was no yield advantage to the application of fertilizer N over 160 lbs/a in 1987 and only a modest increase in 1988. The concentration of nitrate-N in soil solutions at the four and seven ft. depth should be viewed cautiously since 1987 and 1988 were the years of installation. Increased concentrations of nitrate-N were detected at the 4 ft. depth approximately two months after N application. Concentations of nitrate appeared to increase gradually with time. Higher rates of fertilizer N resulted in higher concentrations of NO_3-N toward the end of 1988.

Table 1. Corn grain and soybean yields from the large plot area Westport MN. 1988.

Corn Yields

Total N-Rate	Early N	Late N	Crop Rotation	Bu/A 15.5%		Grain % N		N-Removal Grain #/a	
lbs/a				1987	1988	1987	1988	1987	1988
160	105	55	Corn-Corn	120.5	109.0	1.69	1.71	96.3	88.2
214	140	74	Corn-Corn	123.4	118.4	1.69	1.74	98.3	97.5
160	105	55	Corn-Soybean	124.5	-----	1.55	----	91.3	----

Soybean Yields 1988

Bu/A at 13 % miosture 51.6

Table 2. Nitrate-N concentration of soil solution from 4 and 7 foot suction lysimeters 1988.

Treatments	Corn-Corn 160 lbs/a		Corn-Corn 214 lbs/a		Corn-Soybean 160 lbs/a	
Depth ft	4	7	4	7	4	7
Date(M/D/Y)	ppm NO_3-N					
7/2/87	5.5	11.5	7.7	9.7	7.6	13.8
7/6/87	6.7	9.8	8.9	9.3	7.6	11.8
7/10/87	7.1	10.5	7.2	9.9	9.4	11.8
7/24/87	14.6	13.1	13.5	11.7	19.0	11.8
8/7/87	14.1	13.8	20.1	12.5	22.2	13.0
8/25/87	13.2	15.0	21.8	14.4	22.0	14.7
9/16/87	----	----	22.2	14.9	24.1	16.2
4/4/88	----	----	----	----	19.1	----
4/7&8/88	----	----	----	----	39.3	----
4/27/88	----	----	----	----	21.8	22.7
8/12/88	23.2	38.0	15.3	22.6	18.7	----
10/3/88	25.3	21.4	45.9	24,4	21.7	18.1
10/25/88	31.3	26.7	53.4	45.3	43.4	26.1

---- = no sample

1/ Fertilizer N applied only in 1987

TILLAGE, N RATE AND NITRIFICATION INHIBITOR INFLUENCE ON CORN PRODUCTION AND NO_3 LEACHING[1]

D.E. Clay, G.L. Malzer, and J.L. Anderson[2]

ABSTRACT. Course textured soils in central Minnesota are frequently irrigated and fertilized with N to obtain maximum corn (Zea mays L.) yields. If excessive N fertilizer or over irrigation occurs then NO_3 leaching may be a potential health problem. The objective of this research was to determine the impact of different tillage systems, N rates, and nitrification inhibitor (DCD) on corn yield, N utilization and efficiency. Over the 2 years of the study corn yield and NO_3 concentration in the percolated water increased with N rate. Tillage treatment did not influence corn yield or NO_3 leaching. Nitrification inhibitor reduced NO_3 leaching into the ground water and did not have a impact on corn yields.

In central Minnesota course textured soils are frequently irrigated and fertilized with N to obtain maximum corn (Zea mays L.) yields. When excessive amounts of water or N fertilizer are applied to cropland NO_3-N leaching may pose a potential health problem. Nitrate leaching may be reduced by: (i) improved N and water management and/or (ii) improved N fertilizer recommendations. The objective of this research was to determine the impact of different tillage systems, N rates, and a nitrification inhibitor on corn yield, N utilization and efficiency, and NO_3-N leaching under a irrigated system in central Minnesota.

EXPERIMENTAL PROCEDURES

In 1975, 30 non-weighing lysimeters were installed on the Rosholt farm at Westport Minnesota. Each lysimeter was 5.75 ft in diameter and 4 ft 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. Soil at the experimental site was a Estherville sandy loam (Typic Hapludolls) and was used to fill the lysimeters by depth.

Prior to the initiation of this experiment the experimental site had been under 2 years of dryland no-tillage soybean (Glycine max) production. Selected chemical and physical characteristics are shown in Table 1. 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 (Zea mays L.). Water was pumped through the irrigation system at 13.8 kPa pressure. Emission rate for each dripper was 0.35 gal/h. Each lysimeter contained 4 drippers. Irrigation water (1 inch) was applied when less than 2 inches of water were available in the soil profile. Irrigation water was metered through 3 main irrigation lines.

Corn (Pioneer 3790) was planted in the spring of 1987 and 1988 at a density of 27,000 seeds/A. Starter fertilizer (0-26-26) was banded below the seed at the rate of 35 lb/A. The crop rotation was corn-corn-soybeans. Soil temperature, wind speed, rainfall, and air temperatures were measured at regular intervals each day over the 2 growing seasons. This is the second year of the three year study.

A factorial arrangement of treatments were 2 tillage treatments (roto-tillage and no-tillage), 3 rates of urea (0, 70, and 140 lb urea-N/A) and 3 blocks. Dicyandiamide (DCD), a nitrification inhibitor, was applied at rates of 0 or 10% of the applied N to the 140 lb N/A treatments.

[1]Funding provided by the Center for the Impact of Agricultural Practices on Water Quality.
[2]Research Associate, Associate Professor, and Associate Professor, respectively, all Department of Soil Science, University of Minnesota, St. Paul, MN 55108.

Corn was harvested from a 30 ft row at the silking stage and 60 ft row following black layer in both 1987 and 1988. Subsamples from the stover, cob and grain components were analyzed for total Kjeldahl N. Corn yields (grain) are reported at 15.5% moisture.

Following rainfall events water that had collected on the bottom of the lysimeters was removed, amount determined, and analyzed for NO_3-N.

RESULTS

Corn grain yields increased with N fertilizer in both 1987 and 1988 (Table 2). However, the application of 140 lbs. N/A when compared to the 70 lb N/A did not result in a significant increase in corn grain yield. Corn yields in either 1987 or 1988 were not observed to be influenced by tillage treatment or nitrification inhibitor.

Nitrogen uptake increased with N fertilizer in both 1987 and 1988. Maximum N uptake in the roto-tillage treatment was observed at the 140 lb N/A treatment in both 1987 and 1988. In the no-tillage treatment in 1987 increasing the N fertilizer rate beyond 70 lb N/A was not detected to increase N uptake. However, in 1988 for the no-tillage treatment increasing the N rate up to 140 lb N/A increased N uptake.

Inorganic N in the spring of 1987 ranged from 40 to 70 lb N/A in the surface 12 inches of soil (Table 3). These relatively high levels of inorganic N may have resulted from 2 previous years of soybeans. Inorganic N in the surface 12 inches of soil in the spring and fall of 1988 increased with N rate (Table 3). Highest inorganic N levels were observed in soil fertilized with urea treated with DCD while the lowest levels were observed in the unfertilized soil.

Water percolation through the profile did not occur in 1987 and most of 1988 growing seasons. However, in August through October in 1988 7.7 inches of rain fell resulting in 0- to 5-inches of water percolating through the lysimeters (Table 4). Total amount of NO_3 leached or water percolation through the profile was not influenced by fertilizer or tillage treatment. However, NO_3-N concentration in the percolating water was increased with N rate. Treatment of urea with a nitrification inhibitor reduced NO_3-N concentrations in the percolating water.

Nitrate movement through the soil profile was correlated to the amount of percolated water. As the amount of percolated water increased the NO_3-N concentration decreased (Fig. 1), and total amount of NO_3-N increased (Fig. 2).

DISCUSSION

The lack of corn grain yield response from treatment of urea with DCD must be considered as a product of climatic conditions. Over the two years of the study rainfall was much lower than normal resulting in little NO_3 leaching. If NO_3 does not leach then yield increases would not be expected. Dicyandiamide (DCD) was effective at reducing nitrification in that inorganic N levels in the surface soil was increased in the fall of 1988, and NO_3-N concentration of percolating water was reduced.

Nitrate concentration of the percolating water can be reduced by increasing the amount of water percolating through the profile. As the amount of water percolation increases N loss also increases. Corn yields often times are correlated to N fertilizer rate. However, maximum corn yields may be obtained at relatively low N fertilizer rates as observed in this study.. This can occur if residual N does not leach, and/or N mineralization from the organic matter was greater than expected. Applying higher than required N fertilizer levels to insure optimum yields may increase the potential for NO_3-N leaching. Under the climatic conditions observed in this experiment a substantial amount of inorganic N was contained in the soil at planting which did not leach. In order to reduce the potential for NO_3 leaching and minimize fertilizer cost the N management system should be adaptive to take advantage of these conditions.

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

Soil depth	Gravel	Sand	Silt	Clay	Organic matter	pH
in	----------	----------	%	----------	----------	
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

Table 2. Corn grain yield and N uptake during 1987 and 1988.

		grain yield		N uptake	
Tillage	N rate	1987	1988	1987	1988
	lb N/A	---- bu/A ----		---- lb/A ----	
Roto-till	0	130	47	98	42
	70	161	101	154	87
	140	174	127	184	141
	140DCD	169	127	183	148
No-till	0	125	53	91	41
	70	158	101	150	89
	140	163	119	168	122
	140DCD	150	111	150	108
LSD (0.05)		25	19	27	19
Tillage					
Roto-till		159	155	101	105
No-till		149	140	96	90
LSD (0.05)		NS	NS	NS	NS
N rate					
	0	127	95	50	42
	70	160	152	101	88
	140	170	176	123	132
	140DCD	160	167	119	128
LSD (0.05)		17	18	13	19

Table 3. Inorganic N from the surface 12 inches at 2 date during the 1988 growing season.

Tillage	N rate	Sampling dates 4/16/87	4/12/88	9/18/88
	lb N/A	-------- lb N/A 12" --------		
Roto-till	0	47	29	24
	70	45	37	28
	140	46	50	48
	140DCD	49	74	89
No-till	0	48	33	25
	70	64	27	34
	140	47	58	56
	140DCD	46	60	60
LSD (0.05)		NS	20	18
Tillage				
Roto-till		46	48	47
No-till		51	45	44
LSD (0.05)		NS	NS	NS
N rate				
	0	48	31	25
	70	55	32	31
	140	47	54	52
	140DCD	48	67	75
LSD (0.05)		NS	15	16

Table 4. The influence of tillage, N rate, and nitrification inhibitor on water percolation and NO_3-N concentration in the soil solution between August and October in 1988.

Tillage	N rate	NO_3-N leached	water leached	NO_3-N concentration
		lb N/A	in	ppm NO_3
Roto-till	0	4.6	3.0	7.5
	70	7.9	3.1	12.1
	140	4.4	1.3	25.5
	140DCD	3.7	1.4	12.3
No-till	0	5.0	3.3	6.4
	70	8.9	3.3	14.2
	140	8.2	1.6	25.9
	140DCD	5.0	1.7	16.0
LSD(0.05)		NS	NS	11.1
Tillage				
Roto-till		5.2	2.2	14.4
No-till		6.8	2.5	15.6
LSD(0.05)		NS	NS	NS
N rate				
	0	4.8	3.2	7.0
	70	8.4	3.2	13.2
	140	6.3	1.4	25.7
	140DCD	4.4	1.6	14.2
LSD(0.05)		NS	NS	8.9

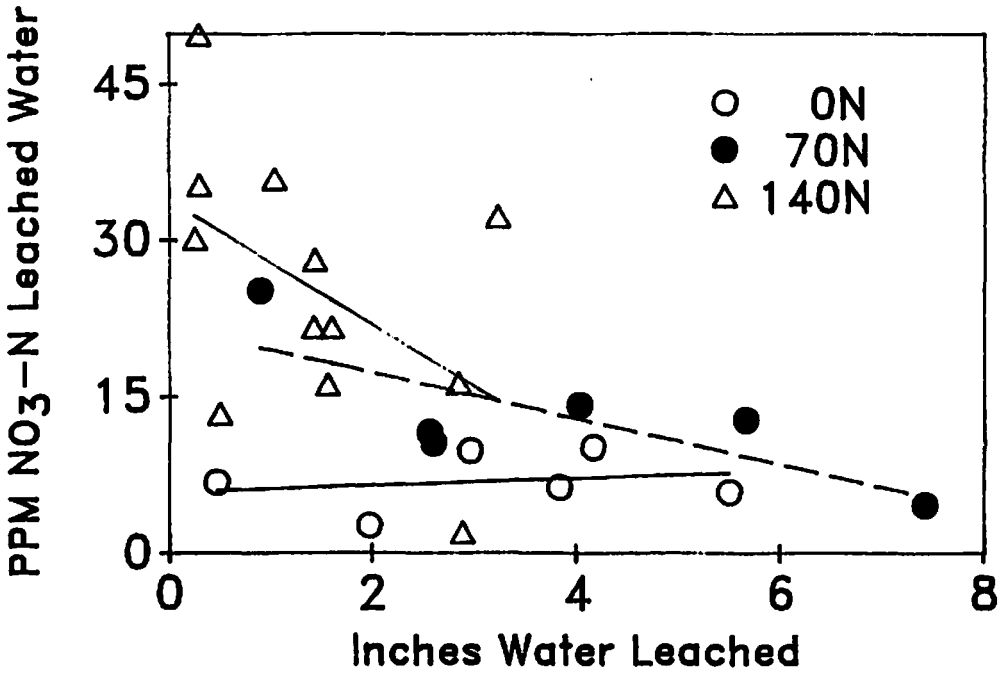

Fig. 1 The relationship between percolated water and NO_3-N concentration for 3 N rates.

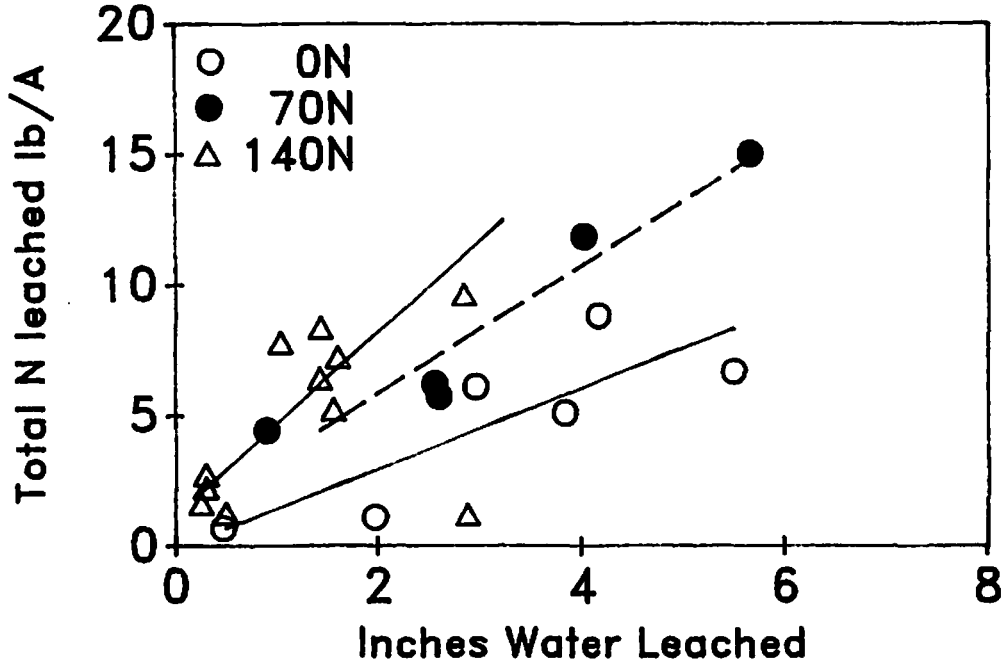

Fig. 2 The relationship between percolated water and total NO_3-N leached for 3 N rates.

PRELIMINARY STUDY ON THE IMPACT OF NBPT ON CORN PRODUCTION[1]

D.E. Clay and G.L. Malzer[2]

ABSTRACT. Ammonia volatilization from surface applied urea reduces N fertilizer efficiency, and thus, may reduce crop yields. The objective was to determine if N-(n-butyl)thiophosphoric triamide (NBPT) has the potential in Minnesota to reduce N loss and increase corn yields. N-(n-butyl)thiophosphoric triamide reduced the rate of urea hydrolysis which in turn reduced NH_3-N volatilization loss. However, results of this one year field study indicated that urea treatment with NBPT did not influence corn grain yield or N uptake. The lack of a yield increase was attributed to the lack of N fertilizer response and low corn grain yields.

Volatilization losses of NH_3 from surface applied urea may reduce N fertilizer efficiency. Reduced fertilizer efficiency may reduce crop yields or increase fertilizer requirements. N-(n-butyl)thiophosphoric triamide (NBPT) may reduce the rate of urea hydrolysis, which in turn may reduce the amount of NH_3 volatilized. The objectives of this study were to determine if NBPT has the potential in Minnesota to reduce N loss and increase corn grain yields.

EXPERIMENTAL PROCEDURES

Field and laboratory studies were conducted on Estherville sandy loam (coarse loamy over sandy, mixed mesic, Typic Hapludolls). The field experiments were conducted at Westport Minnesota. Seven treatments with three replications were arranged in a randomized block design. The treatments consisted of factorial combinations of 2 N rates (67 and 135 lb N/A) and 3 NBPT rates (0, 0.0025, and 0.005 lb NBPT/lb fertilizer) plus a 0 N control. Fertilizer treatments were surface banded on 2 June when corn was at the 4 leaf growth stage. Fertilizer band was placed approximately 3 inches away from the corn plant. Corn grain was hand harvested from 100 ft^2 area on 15 September. Grain yields were adjusted to 15.5% moisture. Subsamples of corn grain were dried, ground, and analyzed for Kjeldahl N.

The previous crop was Soybeans. A traveling boom was used to apply 12.6 inches of water between June and August while 7.1 inches of water fell as rainfall in August and September. The experimental area was chisel plowed on 20 April and planted with corn (Pioneer 3902) on 28 April in 30 inch rows at a density of 29,900 seeds/A. Liquid starter (7-22-5) fertilizer was banded below the seed at the rate of 6, 9 and 4 lb of N, P, and K, respectively.

To determine the influence of NBPT on urea hydrolysis a incubation experiment was conducted using soil samples collected from the 0- to 6-inch soil depth on 2 June from the field experimental plots. Soil was incubated at field moisture capacity and 77°F with urea (1000 ug N/g of soil) and with (10 ug NBPT/g of soil) or without NBPT. The soil was analyzed for urea at 1, 2, 3, 7 and 10 day.

To determine if the potential exist for NH_3-N volatilization in the field a experiment was conducted next to the field experiment. The field site was prepared for the experiment by thoroughly wetting the soil profile with a sprinkler and allowing the profile to drain for 24 hours. Following excess water drainage a plastic cylinder 15 cm high with a diameter of 24 cm was pushed 14 cm into the wet soil. Fertilizer treatments were urea or urea plus NBPT. Fertilizer treatments were dissolved in 100 mL of water. Urea was sprinkled over the bare soil surface within the cylinder at the rate of 1800 lb N/A to simulate the fertilizer concentration in a surface band having a application rate of 180 lb N/A. The inhibitor (NBPT) was applied at the rate of 0.9 lb/A.

[1]Funding provided by EniChem Americas Inc., and the Center for the Impacts of Agricultural Practices on Water Quality.

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Caps, fitted to the cylinders, were placed over the cylinders for a period of 20 minutes every 3 hours over a 4 day period. Air was drawn through the cylinders, at this time, and passed through boric acid to collect volatilized NH_3-N. The boric acid solutions were titrated with 0.01 M H_2SO_4 to determine volatilized NH_3-N.

RESULTS AND DISCUSSION

Neither N rate or NBPT treatment influenced corn yields, N uptake, moisture percentage of the grain at harvest (Table 1). The lack of differences was attributed to abnormally high temperatures reducing corn grain yields.

The incubation study indicated that treatment of urea with NBPT reduced the rate of urea hydrolysis (Fig. 1). The reduced rate of urea hydrolysis reduces both NH_4-N and NH_3-N in the soil solution. Reduction in the NH_4-N and NH_3-N concentration in the soil solution should reduce the potential for NH_3-N to be volatilized. Treatment of urea with NBPT reduced ammonia volatilization in the field over the 4 days of the study (Fig. 2). Treatment of the urea with NBPT reduced the amount of volatilized NH_3 from 10 to 20% to less than 1% of the applied fertilizer. Maximum NH_3 volatilization in untreated urea occurred 2 days following application. Volatilization from NBPT treated urea was increasing as the experiment proceeded.

Although treatment of urea with NBPT did not increase corn yield, field and laboratory experiments indicates that NBPT does have the potential to reduce NH_3-N volatilization from urea.

Table 1. Corn grain yields, N uptake, and percentage moisture of the grain as influenced by N rate and NBPT hydrolysis inhibitors.

N Rate	NBPT	Grain Yield at 15.5% moisture	Grain N	Grain N Uptake	Grain moisture
lb/A	%	bu/A	%	lb/A	%
0	0.0	102	1.68	81	16
67	0.0	109	1.62	81	17
135	0.0	100	1.69	79	17
67	0.25	100	1.60	74	16
135	0.25	117	1.54	85	15
67	0.50	111	1.54	81	15
135	0.50	115	1.56	84	16
LSD (0.05)		NS	NS	NS	NS
P-value		30	38	24	70
N Rate					
67		106	1.59	79	16
135		111	1.59	83	16
LSD (0.05)		NS	NS	NS	NS
P-value		26	9	38	0
Inhibitor Rate					
0		105	1.65	80	17
0.25		108	1.57	80	15
0.50		113	1.55	83	15
LSD (0.05)		NS	NS	NS	NS
P-value		16	64	6	9

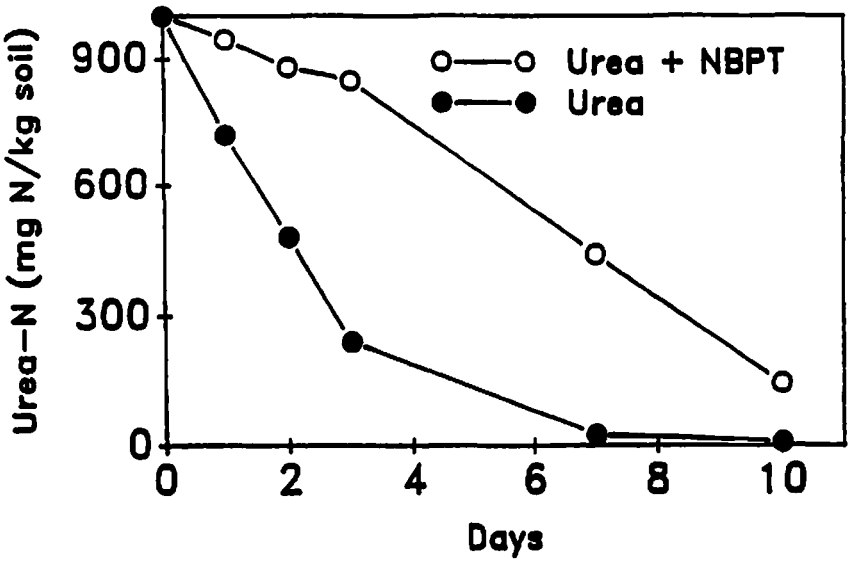


Fig. 1. The influence of NBPT on urea hydrolysis.

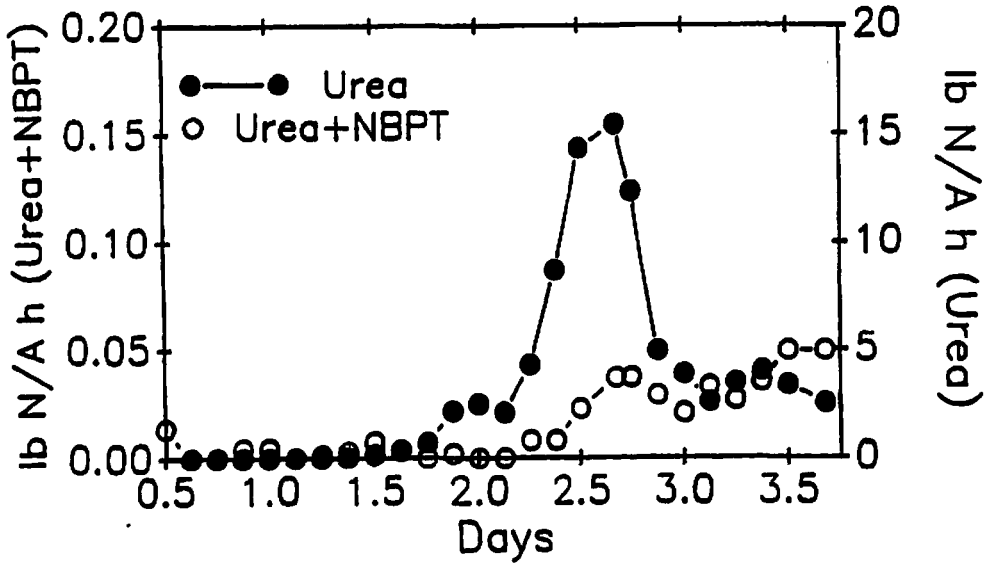


Fig. 2. Ammonia volatilization from urea and urea treated with NBPT applied to bare soil over 4 days.

LAND TREATMENT OF SEWAGE SLUDGE INCINERATOR ASH[1]

C. Rosen, and R. Polta[2]

ABSTRACT: This experiment was conducted at the Rosholt Research farm in Westport, MN to evaluate the use of sewage sludge incinerator ash as a phosphorus source for corn production. Three rates of phosphate fertilizer (70, 140, and 280 lb P_2O_5/A) were compared with equivalent rates of P supplied by ash based on the citrate soluble P test. Early plant (8-12 leaf) dry weight significantly increased with both ash and fertilizer compared to the control. At equivalent P rates, response was greater with the fertilizer compared to the ash. Final grain yield was not affected by either amendment. Tissue analysis revealed that both P sources increased P levels in the plant; however, at equivalent P rates, response was greater with the fertilizer source compared to the ash source. Although ash was a good source of Zn, movement of this element was apparent through the soil profile. Other heavy metals such as Cd, Pb, Ni, and Cr did not move out of the top 6" nor did they accumulate in the corn grain, stover, or cob.

Incineration of sewage sludge is a common means of reducing the volume of municipal waste material. As landfill usage is being reduced, disposal of the resulting ash is becoming more of a problem. Finding an environmentally acceptable disposal method for incinerator ash is important as increasing quantities of sewage sludge wastes are burned. Sewage sludge incinerator ash contains many elements that are essential for plant growth. In particular, high concentrations of phosphorus, calcium and magnesium have been reported in previous studies. However, this ash also contains heavy metals such as cadmium, lead, zinc, copper, and others which can pose problems to plants and animals in high concentrations. When properly managed, recycling incinerator ash nutrients by land spreading may provide a disposal method that is beneficial to both incinerator operators and crop producers. The purpose of this study was to determine whether sewage sludge ash can be used as a soil amendment/fertilizer without lowering crop quality or polluting the environment. Results reported here are from the second year of a three year study.

Materials and Methods. A field experiment was initiated in May 1987 at the Rosholt Research Farm in Westport, MN. This site was selected because irrigation was available and soil test P was at a level where a response to applied phosphorus might be expected. The soil is characterized as a Estherville sandy loam with an initial pH of 5.7 and Bray P1 of 35 lb/A.

Ash was collected from the Metropolitan Waste Water Treatment Plant in St. Paul in April 1987 and stored in 5 gallon covered plastic containers. A complete elemental analysis of the material was presented in detail last year (see 1988 Bluebook). Briefly, the ash is 8.8% P_2O_5 based on the citrate acid soluble P test and has a calcium carbonate equivalent of 13.7%. Particle size analysis revealed that 99% passed through a 60 mesh screen and 88% passed through a 100 mesh screen.

Treatments consisted of a control, three rates of phosphate fertilizer (0-46-0: 70, 140 and 280 lb P_2O_5/A) and three equivalent rates of sewage sludge incinerator ash based on available phosphate. Treatments were applied to the same plots at the same rates as in 1987. Loading rates of Cd, Ni, Cr, and Pb based on the digest analysis and application rates were less than the annual maximum application rates set by the Minnesota Pollution Control Agency. A Gandy fertilizer spreader was used to broadcast applications of 0-0-60 (200 lbs/A) and 45-0-0 (195 lbs/A). Sludge ash and phosphate fertilizer were applied by hand. The entire plot area was disked to a depth of 4-6". A randomized complete block design with four replications was used. Field corn (Funks G-4100 hybrid) was planted on April 28, 1988 at a population of 32,000 in 30" rows along with a furrow application of Counter insecticide. Each plot consisted of four 30' rows. Irrigation supplemented rainfall to provide approximately 1" of water per week. Suction cup lysimeters

[1] Funding for this project was provided by the Metropolitan Waste Control Commission.

[2] Extension Soil Scientist, Soil Science Department, University of Minnesota, and Director of Research and Development, Metropolitan Waste Control Commission, respectively.

were installed in all treatments in reps 1 and 3 on May 20 at a depth of 18". Water samples were collected on June 9, August 25, and September 15 approximately 3 or 4 days after at least 1" of rainfall or irrigation was supplied. On June 15, 8 whole plants were sampled from each plot at the ends of the two middle rows. At this sampling, plant development corresponded to the 8-10 leaf stage. The entire plot was sidedressed with 34-0-0 (295 lbs/A) with a Gandy on June 15. Ear leaf samples were collected from each plot at the mid-silking stage (July 20). Plots (20' from the middle two rows) were harvested for grain plus cob and stover yields on September 9. Subsamples of stover and grain plus cob were collected for moisture determinations, shelling percentage, and elemental analyses. All plant samples were ground in a Wiley mill to pass through a 30 mesh screen. Multiple element analysis using ICP procedures were performed on ashed samples dissolved in 2 N HCl. Following Kjeldahl digestion, total nitrogen in plant tissues was determined using conductimetric procedures.

Soil samples were collected on September 15 at 3 depths: 0-6", 6-12", and 12-24". Samples were air dried, ground using a rolling pin and extracted with 1 N nitric acid. Multiple elements were determined using ICP procedures. Available nutrients were determined using the following extractants: Bray P1 extractant, Olsen P, ammonium acetate, and DTPA. Soil pH was determined on a 1:1 soil - water extract.

Results

Soil and Water Samples. Elemental analyses of the water collected in the suction cup lysimeters are presented in Table 1. Because of the dry year, some lysimeters were often dry. Therefore, data presented are sometimes based on only one sample. For phosphorus and all heavy metals, except nickel, concentrations were generally below detection limits of the ICP spectrophotometer. Nickel levels tended to increase at the second and third sampling date, but these increases did not appear to be related to treatment. Other elements such as Cu, Zn and B were at background levels. One exception was zinc at the last sampling date and at the highest ash rate was nearly 5 times higher than the other treatments. However, even at this higher Zn concentration, it was still 30 times lower than the allowable limit for Zn in safe drinking water (< 5 ppm). None of the other elements determined exhibited trends with increasing ash or fertilizer treatments.

As expected, extractable P increased with increasing ash and fertilizer rate in the 0-6" depth (Tables 2a and 2b). Nitric acid extracted more P from the soil amended with ash than with fertilizer, while there was no difference between the two amendments when the Bray P extractant was used. In contrast, Olsen P extractant extracted more P from soil amended with fertilizer than with ash. Soil pH was not significantly affected by ash or fertilizer treatments. Ammonium acetate and nitric acid extractable Na increased slightly with increasing ash rates. Nitric acid extractable Mg, Ca, Al, Fe, Zn, Cu, Ni, Cr, and Cd increased with ash applications. Of particular interest is the DTPA or 'plant available' metals. Ash amendments significantly increased DTPA extractable Zn, Cu, and Cd in the top 6".

In the 6 - 12" depth, Bray and Olsen extractable P increased with both amendments (Table 3a). In contrast, there was no difference in nitric acid extractable P (Table 3b). DTPA extractable Zn and Cu and nitric acid extractable Cu tended to increase with increasing ash applications.

In the 12 -24" depth, Bray and Olsen extractable P increased with both amendments (Table 4a) with no differences in nitric acid extractable P (Table 4b). DTPA and nitric acid extractable Zn increased with increasing ash rates. These results indicate that zinc is moving to some extent through the soil profile.

Yield Data. Both triple superphosphate fertilizer and ash significantly increased early plant dry weight compared to plants growing in the check plot (Table 5). This early plant response to P fertilizer is common in corn grown in cool soils. At the final harvest, however, none of the treatments significantly increased grain or stover yield over the check plot. The reason for lack of yield response to applied phosphorus is that soil P in the plow layer was at a higher level than the initial soil tests indicated. The check plots were actually in a range where response to applied P is not likely. Another factor that might be involved is that corn yields were low considering that irrigation was used. Consequently, the

demand for P would not be as great had yields been higher. The cause for low yields was undoubtedly due to the hot and dry period when plants were silking. In either case, the results do indicate that application of ash does not detrimentally affect yield.

Tissue Analyses. Fertilizer and ash treatments increased tissue P concentrations in corn sampled at the 8 - 10 leaf stage (Table 6). Even though rates of ash were adjusted to equivalent rates of available P in fertilizer using the citrate acid test, corn grown in plots supplied with fertilizer source was superior to the ash source in supplying P. Both Cu and Zn concentrations tended to increase with ash applications; however, both of these nutrients are essential for plant growth and levels reported are well below those considered toxic to plants or animals. The other heavy metals, Pb, Ni, Cr, and Cd were generally at background levels. Concentrations of Pb in whole plant samples from some of the lower ash treatments were higher than those in the control or P fertilizer treatments. This trend did not continue in tissue sampled later in the season.

Ear leaves sampled at silking increased in P with fertilizer and ash applications (Table 7). As in whole plant samples, the increase was greater in the 0-46-0 plots than with the ash plots. Phosphate fertilizer increased Mn, but decreased Fe, Cu, and Zn concentrations compared to the ash treatments. Other heavy metals were not consistently affected by fertilizer or ash treatments.

Concentrations of P increased in stover to a greater extent in plants supplied with 0-46-0 than in plants supplied with ash (Table 8). Stover K tended to increase in ash plots but not P fertilizer plots. Levels of Zn and Cu in stover were highest in the control plots although ash treatments tended to increase stover Zn and Cu compared to fertilizer treatments. The only elements significantly affected in cob tissue were Zn and Cu where fertilizer decreased and ash increased levels of these elements (Table 9). Levels of N, P, K, Mg, and Mn in grain increased with fertilizer and ash treatments compared to those in the control plots (Table 10). Levels of these elements tended to be greater with the fertilizer than with the ash treatments. Grain Cu decreased with increasing P fertilizer rate. Concentrations of Pb, Ni, Cr, and Cd in stover, cob, and grain tissue were either at background levels or below detection limits of the ICP.

General Discussion. Even though no differences in corn yields due to treatments were detected, the results do show that ash treatments are not detrimental to yield or quality in the short term. The positive response to P from fertilizer and ash at the early plant stage is encouraging. From tissue analysis results, phosphate availability at equivalent rates does not appear to be as good from the ash source as from fertilizer source. This may be due to lower P solubility in the ash compared to the fertilizer which may not be readily detected by the available (citrate soluble) P test. The Olsen P soil test seemed to predict response to the ash amended soils better than the Bray P1 or Nitric acid extractants. Ash appears to be a good source of Zn, a nutrient which can be limiting when high rates of P fertilizer are used. Further experiments on this same site are required to evaluate longer term effects of incinerator ash on element movement in the soil profile as well as effects on element uptake and yield response by the crop.

Table 1. Elemental composition of lysimeter water as affected by fertilizer or ash treatments at three sampling dates.

Treatment lb P_2O_5/A	P Source	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
June 9		ppm														
Control	--	<0.57	5.9	165.7	42.5	0.42	<0.01	13.5	0.09	<0.01	0.01	0.04	<0.13	<0.05	0.02	<0.01
70	Fert.	<0.57	13.3	238.2	64.0	0.61	<0.01	18.4	0.20	0.02	0.01	0.04	<0.13	<0.05	<0.01	<0.01
140	Fert.	0.74	1.3	139.8	15.8	0.87	0.12	5.3	0.18	0.09	0.02	0.03	<0.13	0.10	<0.01	<0.01
280	Fert.	0.62	3.6	139.4	34.2	0.32	<0.01	11.5	0.11	<0.01	0.02	0.04	<0.13	<0.05	<0.01	<0.01
70	Ash	<0.57	13.8	244.2	62.5	0.52	<0.01	18.1	0.16	<0.01	0.01	0.04	<0.13	<0.05	0.02	<0.01
140	Ash	<0.57	9.8	204.0	56.9	0.47	<0.01	14.1	0.16	<0.01	0.01	0.04	<0.13	<0.05	0.02	<0.01
280	Ash	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
August 25																
Control	--	<0.57	4.6	595.0	156.4	0.68	<0.01	9.9	0.01	0.05	0.04	0.05	<0.13	0.24	<0.01	<0.01
70	Fert.	<0.57	7.4	775.8	200.6	0.77	<0.01	13.8	0.02	<0.01	0.02	0.04	<0.13	0.44	0.02	<0.01
140	Fert.	<0.57	8.2	706.6	184.6	0.80	<0.01	14.1	0.01	0.04	0.04	0.04	<0.13	0.20	<0.01	<0.01
280	Fert.	<0.57	5.7	500.4	127.1	0.64	<0.01	14.1	0.02	0.04	0.02	0.04	<0.13	0.28	<0.01	<0.01
70	Ash	<0.57	10.2	1107.4	290.1	0.64	<0.01	18.3	0.07	0.09	0.04	0.04	<0.13	0.80	<0.01	<0.01
140	Ash	<0.57	4.3	445.6	116.6	0.66	<0.01	9.2	0.01	<0.01	0.02	0.04	<0.13	0.12	<0.01	<0.01
280	Ash	<0.57	6.5	858.7	220.6	0.78	<0.01	17.1	0.04	0.04	0.04	0.04	<0.13	0.13	<0.01	<0.01
September 15																
Control	--	<0.57	3.0	674.2	182.0	0.72	<0.01	9.3	0.01	0.04	0.02	0.02	<0.13	0.14	<0.01	<0.01
70	Fert.	<0.57	4.6	530.2	140.3	0.70	<0.01	12.3	0.01	0.03	0.01	0.03	<0.13	0.53	<0.01	<0.01
140	Fert.	<0.57	8.9	1064.2	264.2	0.68	<0.01	11.6	0.01	0.03	0.01	0.03	<0.13	0.20	<0.01	<0.01
280	Fert.	<0.57	4.6	441.7	118.7	0.64	<0.01	11.0	0.01	0.06	<0.01	0.03	<0.13	0.18	<0.01	<0.01
70	Ash	<0.57	6.9	942.6	259.2	0.71	<0.01	12.9	0.02	0.04	0.02	0.02	<0.13	0.34	0.02	<0.01
140	Ash	<0.57	4.6	564.4	152.1	0.74	<0.01	8.8	0.01	0.02	0.01	0.02	<0.13	0.16	0.02	<0.01
280	Ash	<0.57	3.8	716.7	193.7	0.80	<0.01	13.4	0.02	0.15	0.03	0.03	<0.13	0.20	<0.01	<0.01

Table 2a. Effect of sludge ash and phosphate fertilizer on soil pH Bray P1, Olsen P, Ammonium Acetate (NH_4OAc) extractable cations, and DTPA extractable micro elements (0-6" depth).

Treatment	P Source	pH	Bray P1	Olsen P	NH_4OAc Extractable				DTPA Extractable							
					K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Ni	Cr	Cd
lb P_2O_5/A			ppm													
Control	-	5.5	18.3	6.3	124	1889	265	7.0	75.3	48.0	1.4	0.78	1.01	1.89	0.04	0.12
70	Fert.	5.3	33.8	12.2	131	1896	262	8.5	76.4	60.9	1.2	0.71	1.01	2.07	0.05	0.12
140	Fert.	5.3	61.0	26.6	129	1850	256	8.8	77.4	73.3	1.2	0.68	1.02	2.04	0.07	0.12
280	Fert.	5.4	96.3	39.3	151	1829	250	8.5	75.1	50.2	1.2	0.73	0.86	1.91	0.05	0.12
70	Ash	5.4	43.0	15.1	164	1832	254	7.9	77.4	64.6	1.6	1.19	1.01	2.09	0.06	0.16
140	Ash	5.5	98.8	20.8	130	1893	268	9.7	77.5	53.6	2.1	2.00	1.01	2.03	0.04	0.19
280	Ash	5.6	130.8	22.0	135	1949	292	10.4	71.1	49.9	3.1	3.05	1.18	2.15	0.06	0.24
Significance		NS	*	**	NS	NS	NS	**	NS	*	**	**	NS	NS	NS	**
BLSD (0.05)			72.7	6.3	-	-	-	1.6	-	18.4	0.4	0.31	-	-	-	0.02
Contrasts																
Ctrl vs Rest		NS	*	**	NS	NS	NS	**	NS	NS	*	**	NS	NS	NS	**
Fert vs Ash		*	NS	**	NS	NS	NS	NS	NS	NS	**	**	NS	NS	NS	**
Linear Fert.		NS	*	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	*	NS
Linear Ash		NS	**	**	NS	NS	NS	**	NS	NS	**	**	NS	*	NS	**
Quad Ash		NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 2b. Effect of sludge ash and phosphate fertilizer on 1N nitric acid extractable elements. (0-6" depth)

Treatment	Source	1 N Nitric Acid Extractable														
		P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb P_2O_5/A		ppm														
Control	-	57	169	2604	442	1630	385	7	149	5.5	3.3	0.9	<1.66	3.86	0.86	0.23
70	Fert	67	184	2610	440	1623	382	8	165	5.6	3.4	1.2	<1.83	4.13	1.01	0.17
140	Fert	108	176	2576	434	1682	423	10	183	5.5	3.3	0.9	<1.96	3.89	1.02	0.19
280	Fert	143	199	2514	405	1657	408	8	159	6.1	3.1	1.0	1.93	3.48	0.91	0.18
70	Ash	99	222	2594	418	1662	372	8	174	6.2	4.7	0.9	<1.61	3.79	0.99	0.30
140	Ash	161	157	2722	460	1760	430	11	164	7.9	7.1	0.9	3.40	4.03	1.43	0.50
280	Ash	267	309	2967	513	1893	485	14	180	11.0	11.6	1.0	3.34	4.51	2.06	0.56
Significance		**	NS	*	*	**	**	**	NS	**	**	NS	-	*	**	**
BLSD (0.05)		47	-	281	71	117	47	2	-	1.6	1.4	-	-	0.6	0.2	0.14
Contrasts																
Ctrl. vs Rest		**	NS	NS	NS	NS	NS	**	*	*	**	NS	-	NS	**	NS
Fert. vs Ash		**	NS	*	*	**	NS	**	NS	**	**	NS	-	NS	**	**
Linear Fert.		**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	*	NS	NS
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS
Linear Ash		**	NS	**	**	**	**	**	NS	**	**	NS	-	**	**	**
Quad Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 3a. Effect of sludge ash and phosphate fertilizer on soil pH, Bray P1, Olsen P, Ammonium Acetate (NH_4OAc) extractable cations, and DTPA extractable micro elements (6-12" depth).

Treatment	P Source	pH	Bray P1	Olsen P	NH_4OAc Extractable				DTPA Extractable							
					K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Ni	Cr	Cd
lb P/A			ppm													
Control	-	5.9	5.8	2.5	46	1634	265	5.8	24.4	11.0	0.2	0.53	<0.42	0.99	<0.02	0.03
70	Fert.	5.7	8.5	2.8	58	1740	282	6.9	38.0	25.3	0.5	0.62	0.47	1.46	<0.03	0.06
140	Fert.	5.7	12.3	5.0	48	1645	271	6.7	25.3	13.3	0.3	0.56	0.43	1.23	<0.02	0.04
280	Fert.	5.8	13.3	4.8	50	1671	270	6.7	24.7	10.6	0.2	0.56	0.39	1.00	<0.03	0.03
70	Ash	5.8	9.5	2.8	54	1745	274	6.5	28.4	15.5	0.3	0.58	<0.47	1.26	<0.03	0.04
140	Ash	5.9	10.3	3.5	47	1628	259	6.3	24.1	10.7	0.3	0.60	<0.37	1.04	<0.02	0.04
280	Ash	5.9	19.5	4.8	52	1722	280	6.7	26.7	13.6	0.5	0.81	0.40	1.27	<0.02	0.05
Significance		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	NS
BLSD (0.05)		-	7.3	-	-	-	-	-	-	-	-	-	-	-	-	NS
Contrasts																
Ctrl vs Rest		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	NS
Fert vs Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	NS
Linear Fert.		NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	NS
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	*	-	NS
Linear Fert.		NS	**	*	NS	NS	NS	NS	NS	NS	*	**	-	NS	-	NS
Quad Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	NS

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 3b. Effect of sludge ash and phosphate fertilizer on 1 N nitric acid extractable elements (6-12" depth).

Treatment	P Source	1 N Nitric Acid Extractable														
		P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb. P_2O_5/A		ppm														
Control	-	46	59	1946	518	1489	558	11	65	5.0	2.6	0.6	3.05	2.81	1.32	0.41
70	Fert.	29	62	2039	553	1523	539	12	60	6.3	3.0	0.6	4.27	2.73	1.27	0.30
140	Fert.	43	63	2133	558	1609	606	12	74	5.9	3.4	0.6	2.99	3.09	1.36	0.26
280	Fert.	39	59	1921	529	1497	573	11	60	4.3	2.9	0.6	2.72	2.74	1.28	0.34
70	Ash	45	74	2174	557	1654	598	11	73	6.7	3.3	0.7	2.87	3.00	1.39	0.30
140	Ash	59	69	1957	515	1541	570	13	67	4.5	3.4	0.6	3.24	2.74	1.35	0.31
280	Ash	59	66	2099	594	1624	679	13	72	5.8	4.1	0.7	4.78	3.16	1.60	0.38
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
BLSD (0.05)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Contrasts																
Ctrl vs Rest		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	*
Fert. vs Ash		**	**	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Linear Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS
Linear Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Quad Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 4a. Effect of sludge ash and phosphate fertilizer on soil pH, Bray P1, Olsen P, Ammonium Acetate (NH_4OAC) extractable cations, and DTPA extractable micro elements (12-24" depth).

Treatment	P Source	pH	Bray P1	Olsen P	NH_4OAc Extractable				DTPA Extractable							
					K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Ni	Cr	Cd
lb. P_2O_5/A			ppm													
Control	-	6.9	5.0	2.3	39	1132	168	4.0	15.3	13.6	0.11	0.54	<0.25	0.58	<0.03	<0.03
70	Fert.	6.6	6.3	2.8	41	1163	175	4.0	17.3	16.2	0.10	0.56	<0.26	0.67	<0.03	<0.03
140	Fert.	6.8	8.3	3.8	47	1160	183	5.0	15.2	13.6	0.10	0.45	<0.25	0.55	<0.02	<0.03
280	Fert	6.7	13.5	5.3	43	1074	160	3.7	17.6	15.5	0.12	0.55	<0.24	0.63	<0.03	<0.03
70	Ash	6.9	6.8	2.3	42	1447	166	4.3	15.8	15.5	0.10	0.56	<0.24	0.63	<0.03	<0.03
140	Ash	7.3	7.3	2.8	35	1971	169	3.6	13.4	11.9	0.13	0.54	<0.22	0.48	<0.02	<0.03
280	Ash	6.7	16.8	4.5	45	1131	188	5.0	18.5	16.8	0.27	0.76	<0.25	0.95	<0.04	<0.03
Significance		NS	**	**	NS	*	NS	NS	NS	NS	**	NS	-	NS	-	-
BLSD (0.05)		-	5.0	1.3	-	618	-	-	-	-	-	-	-	-	-	-
Contrasts																
Ctrl vs Rest		NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	-
Fert. vs Ash		NS	NS	NS	NS	*	NS	NS	NS	NS	*	NS	-	NS	-	-
Linear Fert.		NS	**	**	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	-
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	-
Linear Ash		NS	**	**	NS	NS	NS	NS	NS	NS	**	*	-	NS	-	-
Quad Ash		NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	-	NS	-	-

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 4b. Effect of sludge ash and phosphate fertilizer on 1 nitric acid extractable elements (12-24" depth).

Treatment	P Source	1 N Nitric Acid Extractable														
		P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb. P_2O_5/A		ppm														
Control	-	101	49	5045	1679	685	491	11	64	2.8	2.4	0.5	<2.24	2.16	0.74	0.20
70	Fert.	90	49	3050	1184	653	479	9	53	2.6	2.1	0.5	2.08	2.56	0.79	0.17
140	Fert.	92	52	6094	2911	638	476	11	65	2.6	1.7	0.5	2.34	2.34	0.82	0.28
280	Fert.	88	53	5684	2313	672	510	10	58	2.4	1.7	0.5	2.25	2.44	0.78	0.24
70	Ash	113	50	4644	1839	660	535	10	60	2.7	2.1	0.5	<2.61	2.07	0.73	0.25
140	Ash	108	48	17795	5372	623	596	15	89	2.6	2.0	1.0	2.57	2.99	0.89	0.17
280	Ash	125	60	2737	867	914	735	12	74	4.0	3.1	0.6	<1.76	3.13	1.06	0.21
Significance		NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	-	NS	NS	NS
BLSD (0.05)		-	-	-	-	-	-	-	-	1.1	-	-	-	-	-	-
Contrasts																
Crtl vs Rest		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS
Fert. vs Ash		*	NS	NS	NS	NS	NS	*	NS	NS	*	NS	-	NS	NS	NS
Linear Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS
Linear Ash		NS	*	NS	NS	**	NS	NS	NS	**	*	NS	-	NS	NS	NS
Quad Ash		NS	NS	**	*	NS	NS	*	NS	NS	NS	*	-	NS	NS	NS

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 5. Effect of sludge ash and phosphate fertilizer on whole plant dry weight at the 8-12 leaf stage, grain yield (dry weight basis), stover yield (dry weight basis).

Treatment	P Source	Early plant yield 8-12 leaf	Grain Yield	Stover Yield
lb P_2O_5/A		g dw	bu/A	T/A
Control	-	26.1	130.1	2.38
70	Fert.	37.3	127.8	2.70
140	Fert.	45.4	129.8	2.95
280	Fert.	53.4	125.7	2.82
70	Ash	33.2	130.9	2.86
140	Ash	35.3	130.8	2.66
280	Ash	46.2	128.9	2.65
Significance		*	NS	NS
BLSD (0.05)		16.8	--	--
Contrasts				
Ctrl. vs Rest		**	NS	NS
Fert. vs Ash		NS	NS	NS
Linear Fert.		**	NS	NS
Quad. Fert.		NS	NS	NS
Linear Ash		**	NS	NS
Quad. Ash		NS	NS	NS

NS = Non significant, * = Significant at 5%, ** = Significant at 1%

Table 6. Effect of sludge ash and phosphate fertilizer on the elemental composition of whole plants sampled at the 8-12 leaf stage.

Treatment	P Source	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb P_2O_5/A		%					ppm										
Control	-	3.77	0.28	3.70	0.57	0.40	117	150	12	196	60	8.3	9.5	1.15	0.64	0.75	0.32
70	Fert.	3.95	0.34	3.64	0.55	0.41	100	145	10	199	58	8.3	9.9	1.08	0.62	0.74	0.32
140	Fert.	3.83	0.33	3.66	0.54	0.38	94	143	10	197	53	7.6	10.0	2.04	0.86	1.01	0.33
280	Fert.	3.64	0.34	3.70	0.55	0.39	97	139	11	200	48	6.8	10.1	1.08	0.73	0.85	0.46
70	Ash	3.76	0.30	3.77	0.53	0.40	97	132	13	183	60	8.3	9.3	3.11	0.75	0.68	0.37
140	Ash	3.73	0.29	3.80	0.55	0.40	112	146	11	183	64	8.6	9.1	2.22	0.78	0.77	0.41
280	Ash	3.53	0.32	3.57	0.56	0.41	121	157	10	184	60	8.8	10.2	1.51	0.83	0.90	0.46
Significance		NS	**	NS	NS	NS	NS	NS	NS	NS	*	*	NS	**	NS	NS	NS
BLSD (0.05)		-	0.04	-	-	-	-	-	-	-	12	1.6	-	1.17	-	-	-
Contrasts																	
Ctrl. vs Rest		NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fert. vs Ash		NS	**	NS	NS	NS	NS	NS	NS	NS	**	*	NS	**	NS	NS	NS
Linear Fert.		NS	**	NS	NS	NS	NS	NS	NS	NS	*	*	NS	NS	NS	NS	NS
Quad. Fert.		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Linear Ash		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad. Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS

NS = Non significant, * = Significant at 5%, ** = Significant at 1%

Table 7. Effect of sludge ash and phosphate fertilizer on elemental composition of the ear leaf sampled during initial silking.

Treatment	P Source	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb P_2O_5/A		----------%----------					----------ppm----------										
Control	-	2.66	0.23	1.82	0.83	0.43	28	530	59	232	49	5.3	9.0	1.76	0.64	0.41	0.29
70	Fert.	2.70	0.25	1.85	0.85	0.38	24	481	52	248	39	4.4	10.1	1.09	0.53	0.47	0.13
140	Fert.	2.66	0.28	2.05	0.88	0.40	29	482	60	301	37	3.9	10.1	1.21	0.71	0.54	0.10
280	Fert.	2.68	0.34	1.92	0.85	0.38	31	451	56	286	29	3.1	8.9	1.40	0.81	0.46	0.16
70	Ash	2.70	0.25	2.01	0.79	0.37	29	509	56	255	48	5.0	10.1	1.56	0.74	0.49	0.15
140	Ash	2.74	0.25	1.91	0.80	0.40	26	507	62	220	49	6.3	9.2	2.06	0.95	0.54	0.23
280	Ash	2.68	0.26	1.92	0.86	0.43	32	534	61	216	51	5.9	9.5	1.45	0.56	0.41	0.15
Significance		NS	**	NS	NS	NS	NS	NS	NS	NS	**	**	NS	NS	NS	NS	NS
BLSD (0.05)		-	0.02	-	-	-	-	-	-	-	8	1.1	-	-	-	-	-
Contrasts																	
Ctrl. vs Rest		NS	**	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
Fert. vs Ash		NS	**	NS	NS	NS	NS	*	*	*	**	**	NS	NS	NS	NS	NS
Linear Fert.		NS	**	NS	NS	NS	*	*	NS	NS	**	**	NS	NS	NS	NS	NS
Quad. Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
Linear Ash		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad. Ash		NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS

NS = Non significant * = Significant at 5% ** = Significant at 1%

Table 8. Effect of sludge ash and phosphate fertilizer on elemental composition of stover at harvest.

Treatment	P Source	N	K	Ca	Mg	P	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb. P_2O_5/A		--------- % ---------				---------- ppm ----------											
Control	-	0.61	1.77	0.52	0.36	526	71	211	44	175	28	4.1	7.3	<1.1	<0.5	0.61	<0.1
70	Fert.	0.91	1.87	0.59	0.32	650	74	222	45	194	22	3.2	7.5	<1.1	<0.6	0.70	<0.1
140	Fert.	1.02	1.89	0.65	0.29	987	87	243	49	208	16	2.7	8.2	<1.1	<0.5	0.60	<0.1
280	Fert.	0.96	1.96	0.59	0.28	1405	91	222	42	166	12	1.1	7.5	<1.1	<0.5	0.60	<0.1
70	Ash	0.89	1.95	0.54	0.32	633	76	214	44	186	25	4.0	7.1	<1.1	<0.5	0.60	<0.1
140	Ash	0.79	1.72	0.47	0.29	544	79	192	40	145	25	3.5	7.2	<1.1	<0.5	0.56	<0.1
280	Ash	0.90	2.34	0.57	0.33	718	85	222	48	167	26	3.9	7.6	<1.1	<0.5	0.56	<0.1
Significance		NS	**	NS	NS	**	NS	NS	NS	NS	**	**	NS	-	-	NS	-
BLSD (0.05)		-	0.26	-	-	229	-	-	-	-	8	0.9	-	-	-	-	-
Contrasts																	
Ctrl vs Rest		**	NS	NS	*	**	NS	NS	NS	NS	*	*	NS	-	-	NS	-
Fert vs Ash		NS	NS	*	NS	**	NS	NS	NS	NS	**	**	NS	-	-	NS	-
Linear Fert.		NS	NS	NS	*	**	NS	NS	NS	NS	**	**	NS	-	-	NS	-
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-	NS	-
Linear Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-	NS	-
Quad Ash		NS	*	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	-	-	NS	-

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 9. Effect of sludge ash and phosphate fertilizer on the elemental composition of cob at harvest.

Treatment	P Source	N	K	P	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb. P_2O_5/A		— % —		ppm													
Control	--	0.51	0.47	409	204	841	5.8	18	2.9	23	72	4.7	3.7	<1.3	1.44	1.21	<0.09
70	Fert.	0.53	0.43	438	229	909	6.0	17	3.0	27	61	3.5	3.7	<1.4	1.10	1.16	<0.08
140	Fert.	0.56	0.45	455	236	806	6.1	18	3.8	28	48	3.0	3.7	<1.8	1.40	1.22	<0.09
280	Fert.	0.62	0.44	555	215	699	7.7	19	4.8	28	34	2.5	3.5	<1.7	1.05	1.03	<0.09
70	Ash	0.53	0.44	425	203	850	5.7	17	2.9	26	64	4.3	3.5	<1.9	1.33	1.21	<0.10
140	Ash	0.54	0.47	384	189	717	7.6	19	3.2	25	60	4.8	3.8	<2.2	1.35	1.28	<0.10
280	Ash	0.56	0.46	505	209	601	5.5	17	2.9	25	58	4.0	3.5	<1.5	1.26	1.13	<0.10
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	**	**	NS	-	NS	NS	-
BLSD (0.05)		-	-	-	-	-	-	-	-	-			-	-	-	-	-
Contrasts																	
Ctrl vs Rest		NS	NS	NS	NS	NS	NS	NS	NS	*	**	**	NS	-	NS	NS	-
Fert. vs Ash		NS	NS	NS	*	NS	NS	NS	*	NS	*	**	NS	-	NS	NS	-
Linear Fert.		*	NS	NS	NS	NS	NS	NS	**	*	**	**	NS	-	NS	NS	-
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	-
Linear Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	-
Quad Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	-

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 10. Effect of sludge ash and phosphate fertilizer on the elemental composition of grain at harvest.

Treatment	Source	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb. P_2O_5/A		— % —			ppm												
Control	-	1.47	0.26	0.33	40	1308	1.4	22	4.1	9.6	27	1.5	2.6	<1.7	<0.5	<0.2	<0.1
70	Fert.	1.68	0.30	0.34	39	1445	1.2	23	4.2	10.9	26	1.0	2.4	<1.5	<0.5	<0.2	<0.1
140	Fert.	1.71	0.35	0.38	41	1596	1.2	25	4.7	11.6	26	0.7	2.5	<1.2	<0.6	<0.2	<0.2
280	Fert.	1.68	0.38	0.40	42	1694	1.5	26	4.3	13.7	24	0.5	2.2	<1.6	<0.5	<0.3	>0.1
70	Ash	1.64	0.28	0.34	37	1330	1.2	22	3.1	10.3	26	1.0	2.4	<1.2	<0.5	<0.2	<0.1
140	Ash	1.58	0.29	0.35	41	1379	1.6	25	4.2	10.8	27	1.3	2.6	<1.7	<0.5	<0.2	<0.1
280	Ash	1.62	0.30	0.35	41	1411	1.7	23	6.1	10.5	26	1.2	2.5	<2.6	<0.5	<0.3	<0.1
Significance		**	**	**	NS	**	NS	NS	NS	**	NS	**	NS	-	-	-	-
BLSD (0.05)		0.10	0.04	0.03	-	212	-	-	-	2.1	-	0.4	-	-	-	-	-
Contrasts																	
Ctrl vs Rest		**	**	*	NS	*	NS	NS	NS	*	NS	**	NS	-	-	-	-
Fert. vs Ash		*	**	**	NS	**	NS	NS	NS	**	NS	**	NS	-	-	-	-
Linear Fert.		NS	**	**	NS	**	NS	*	NS	**	NS	**	*	-	-	-	-
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	-	-	-	-
LInear Ash		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-	-	-
Quad Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-	-	-

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

NITROGEN RATES FOR CORN PRODUCTION IN SOUTHEAST MINNESOTA

Tim Wagar, Greg Cremers, Andy Scobbie, and George Rehm[1/]

ABSTRACT: This study was conducted to measure the effect of legumes in rotation and history of manure use on the response of corn in southeastern Minnesota to N fertilization. Seven rates of fertilizer N (0, 40, 80, 120, 160, 200, 240 lb./acre) supplied as urea were applied to corn following varied histories of legumes in rotation and manure use. Treatments were repeated on the same plots at each site. The drought caused a substantial reduction in yield in 1988. Therefore, only limited information can be obtained from yields measured in 1988.

Stimulated by concerns for a quality environment, there has been a renewed interest in refining fertilizer nitrogen recommendations for corn production in southeast Minnesota. Special emphasis has been placed on giving proper credit for the amount of N supplied by manure as well as the N provided by the legume crops used in the rotation. Therefore, this study was conducted to document the effect of manure use and legume crops in rotation on the response of corn to use of fertilizer nitrogen.

EXPERIMENTAL PROCEDURE:

This study was initiated at 3 sites in Winona County in 1986. Differences in cropping history and manure use were used as criteria for site selection. Two of these original three sites were continued with treatments repeated in both 1987 and 1988. Three additional sites were added in 1987. Again, differences in manure use and cropping history were used as criteria for site selection. Treatments were repeated in 1988.

At each site, each year, urea (46-0-0) was applied to supply 0, 40, 80, 120, 160, 200, and 240 lb. N/acre. The urea was incorporated soon after application to prevent N loss. Treatments were arranged in a randomized complete block design with 4 replications.

Corn production practices acceptable for profitable yields were used at each location. Grain yields were harvested each fall and corrected to 15.5% moisture.

RESULTS AND DISCUSSION:

The grain yields measured at each site are summarized in the tables that follow. Grain yields at a site which had not been manured and had been in continuous corn for 9 years prior to 1986 were increased by the use of fertilizer N each year (Table 1).

Table 1. The effect of rate of fertilizer N on corn yield at a site where no legumes were used and no manure had been applied.

N Applied	Year 1986	1987	1988
lb./acre	- - - - - - - - - -	bu./acre	- - - - - - - -
0	107.4	84.8	29.1
40	124.4	140.8	30.7
80	138.2	149.3	48.6
120	139.3	161.0	75.2
160	139.1	159.5	82.2
200	147.5	162.4	85.4
240	143.9	171.1	72.9

[1/] Area Crops and Soils Agent, Assistant Scientist, Junior Scientist and Extension Specialist, respectively.

Each year, the most profitable yield was produced by the application of 120 lb. N/acre. This was true, even though the 1988 yields were reduced by the drought. The nitrogen fertilizer die not reduce corn yields in dry weather. In 1988, yields were more than doubled by the use of fertilizer N.

The second site chosen for this study in Winona County in 1986 had been planted to alfalfa and manure was applied to the alfalfa crop. The alfalfa was chiseled in the fall of 1985 and corn was planted in 1986. Yields from this site are summarized in Table 2.

Table 2. The effect of rate of fertilizer N on corn yield at a site where alfalfa was used in rotation and manure was applied to the alfalfa.

N Applied	Year 1986	1987	1988
lb./acre	- - - - - - - -	bu./acre	- - - - - - - - -
0	214.6	197.5	100.3
40	223.2	197.4	123.4
80	209.3	196.1	124.2
120	210.5	198.7	133.9
160	207.3	195.5	128.4
200	211.6	191.2	122.1
240	213.7	196.6	127.1

At this site, there was no response to the N fertilizer applied in 1986 and 1987 even though yields were exceptionally good. There was apparently ample N for corn growth supplied from the combination of the previous alfalfa crop, the manure used and the soil organic matter.

There was a response to applied N in 1988. A rate of 120 lb. N per acre produced the most profitable yield. The use of this rate of N produced a 34 bu./acre increase in production. Even though the 1988 yield was reduced by drought, it was still profitable to use fertilizer N in 1988.

Grain yields from the sites established in 1987 and continued in 1988 are summarized in Table 3. In Houston County, the experimental site was in alfalfa in 1986 and no manure was applied. For the site in Olmsted County, manure had been applied to the alfalfa in 1986 prior to planting corn in 1987. In Rice County, the previous crop was alfalfa, but no manure had been applied.

Table 3. Effect of a previous crop of alfalfa and manure use on the response of corn to the application of fertilizer N.

	Site and Year					
N	Houston Co.		Olmsted Co.		Rice Co.	
Rate	1987	1988	1987	1988	1987	1988
lb./acre	- - - - - - - - -	- - - - - - - - -	bu./acre	- - - - - - - - -	- - - - - - - - -	- - - - - - - - -
0	195.0	97.9	175.3	82.1	185.6	92.2
40	193.7	95.8	181.9	86.5	189.6	104.4
80	200.8	100.6	178.6	85.0	182.0	106.6
120	195.1	103.8	168.7	89.5	189.5	107.4
160	204.9	104.4	173.6	77.6	176.1	92.1
200	194.8	100.9	174.5	82.4	187.4	106.9
240	197.2	104.0	172.3	92.3	191.1	112.8

Grain yields were very good in 1987 at all sites; but there was no response to fertilizer N. Apparently, the N supplied by the previous alfalfa crop and the mineralization of soil organic matter was adequate for corn production in 1987.

Drought severely reduced the grain yields measured in 1988. The dry weather also caused a large amount of variability in the data and there was no significant response to the fertilizer N applied in 1988. Results may have been different if moisture had not limited yield.

The data collected from this study clearly show that the alfalfa in rotation as well as the animal manure applied can have a substantial effect on the response of corn to fertilizer N in southeast Minnesota. The challenge is to predict the amount of N that will be supplied by these two sources. This challenge will have to be met with future research.

EFFECT OF SOIL MINERAL N AND TIME OF SAMPLING FOR PREDICTING NITROGEN NEEDS OF CORN[1]

P. L. Kelly, G. L. Malzer and G. W. Randall[2]

ABSTRACT: A reliable nitrogen test for corn has yet to be developed in the high rainfall area of SE Minnesota. This study addresses an early season soil and plant nitrate test as a means of obtaining sidedress nitrogen fertilizer recommendations for corn. Results of this one year study indicate that although soil and plant sampling were successful in predicting grain yield, date of sampling and nitrogen source does influence the "critical" values of soil and plant nitrate concentrations.

A need exists for a diagnostic technique to determine the nitrogen (N) needs of corn in southeast Minnesota. This karst area of Minnesota is characterized by abundant rainfall which may leach N fertilizers to groundwater. Traditional fall and spring soil sampling for nitrates (NO_3^--N) are unreliable because of the risk of N loss between soil sampling and the time of greatest N uptake by corn.

There has been some success with young corn stalk NO_3^--N analysis as an indicator of the N status of the plant. Delayed sampling for N (6-1f stage) has the advantage of being close to the time of greatest N uptake by the corn plant and still allows for sidedress applications of N if needed.

If substantial amounts of N are present as soil NH_4^+-N (i.e. fertilizers, organic matter mineralization, legume fixation, manure, etc.) soil and plant tissue analysis for NO_3^--N may underestimate available N by not addressing soil NH_4^+-N.

The objectives of this study were to:

1) Relate soil NO_3^--N to stalk NO_3^--N concentrations.
2) Determine the effect of sampling time on stalk NO_3^--N.
3) Examine NH_4^+-N nutrition effects on stalk NO_3^--N.
4) Correlate stalk and soil NO_3^--N with grain yield.

EXPERIMENTAL PROCEDURES:

This one year study was conducted in 1988 on a Port Byron silt loam on the Lawler Farm in Olmsted County. Two years of unfertilized corn preceded the experiment on this very high phosphorus and high potassium testing site.

A randomized complete block design was used with four replications. The treatments consisted of two N sources: (1) a nitrate source, calcium nitrate: $Ca(NO_3)_2$ and (2) an ammonium source, urea with 10% Dicyandiamide (DCD10). Each N source was applied at five rates: 0, 40, 80, 120 and 160 lb N per acre (A). The N fertilizer was broadcast by hand to the fall chiseled soil and immediately incorporated with disking on April 25. Pioneer 3737 was planted on May 4th at 30,200 plants per acre in 30" rows with a JD Max-Emerge planter without starter fertilizer and with Counter insecticide. On May 16, 50% of the seedlings had emerged. Populations were recorded on June 20. Plant samples were taken 22 (V5) and 31 (V7) days

1. Funding provided by the Center for the Impacts of Agricultural Practices on Water Quality and the Agricultural Experiment Station.
2. Graduate Assistant, Assoc. Professor, and Professor, respectively, Dept. of Soil Science, Univ. of Minnesota.

after emergence (DAE) with the previous day being warm and sunny. No measurable precipitation occurred between 13 and 34 DAE. These plant samples consisted of the basal two inches of stalk tissue removed from 8-10 plants from a predetermined area of each plot. Soil samples were taken in one foot increments to a depth of three feet at the same time and same designated place as the stalk sampling. The stalk and soil samples were then analyzed for soluble NO_3^--N. Grain and fodder were harvested at physiological maturity on September 20 from 20 feet of row. Grain yields were adjusted to 15.5% moisture. Soil sampling throughout the growing season showed most NO_3^--N accumulation in the top two feet due to below normal precipitation.

RESULTS AND DISCUSSION:

Stalk NO_3^--N concentrations were significantly greater when the N source was calcium nitrate for 22 and 31 DAE (Table 1). Soil NO_3^--N in the top three feet was also significantly greater with calcium nitrate. The amount of total N in the plant tissue was not significantly different at 22 DAE which indicates that the plants were able to obtain the N required for growth regardless of the form of N present. At 31 DAE, plant uptake of N was significantly less for the urea (DCD10) N source. Extended leaf heights of the plants taken at 31 DAE was not influenced by N source but dry weights and N concentrations were higher for calcium nitrate. Stalk NO_3^--N concentrations increased at the later date of sampling while soil NO_3^--N concentrations decreased. Soil NO_3^--N concentration did not decrease as rapidly over the ten day period with urea (DCD) as with $Ca(NO_3)_2$. Both stalk and soil NO_3^--N were responsive to the amount of N applied. As N rate increased both stalk and soil NO_3^--N increased. N uptake (g/plant) by the small plants increased with increasing N rate also.

Plant population was lower than expected due to surface crusting as a result of 1.55" of rainfall occurring shortly after planting (Table 2). Plant population was not affected by source nor rate of N. Total silage yields were greater for the calcium nitrate treatments. Grain yields for the two N sources were not significantly different at the .10 level but there was a trend toward greater yields for N applied in the nitrate form.

Fodder, silage and grain yields increased with increasing N rates. The highest yields were obtained at the 160 lb N per acre rate but due to the high CV these yields weren't significantly (95% level) higher than with the 80 lb N rate.

CORRELATION OF GRAIN YIELD WITH STALK NITRATE AND SOIL NITRATE

The Cate and Nelson Graphical Method is a simple procedure to partition yield values which are either responsive or non responsive to either soil or stalk NO_3^--N. The idea is to draw parallel lines to the x and y axes forming four quadrants within the scatter plot. The number of points in the lower left (responsive) and upper right (non responsive) quadrants are maximized. The point where these two lines cross indicates a "critical value" of soil or stalk NO_3^--N for a given grain yield.

In Figures 1-4, grain yield was plotted against soil and stalk NO_3^--N concentrations sampled 22 and 31 DAE. The four scatter plots have two graphical procedures associated with each. One graphical analysis was drawn with the calcium nitrate data (darkened circles) while a second was drawn with the urea (DCD10) data (triangles). The checks (empty circles) were included in both N sources. In all four figures or scatter plots the line parallel to the x axis was shared by both N sources. This line intersected the y axis at a grain yield of 123 bushels per acre.

In all four figures the urea (DCD10) N source had critical levels of stalk and soil NO_3^--N less than the calcium nitrate N source. The critical values of soil NO_3^--N sampled at 22 and 31 DAE was 38 and 6 lb N per acre less for the urea (DCD10) N source respectively. Stalk NO_3^--N concentrations for 22 and 31 DAE was .90 and .70 g NO_3^--N/kg DM greater for the calcium nitrate N source than the urea (DCD10) N source respectively. The differences between N sources tended to decrease with time of sampling.

CONCLUSIONS

The relationship between soil and stalk NO_3^--N concentrations appears to be very good. These "N tests" are responsive to the amount of spring applied broadcast N fertilizer present in the NO_3^--N form. Fertilizer applied in an ammonium form with a nitrification inhibitor may not entirely nitrify to nitrate at the time of sampling. By analyzing only the NO_3^--N fraction the contributions of other available N sources are not included. The rate of nitrification is heavily influenced by the weather and soil moisture conditions prior to sampling. Therefore, the probability exists of yearly weather induced fluctuations in these NO_3^--N critical values.

Table 1. The effect of N source and N rate on early stalk and soil nitrate analysis.

N Treatments		Stalk Nitrate		Soil Nitrate		Total N Uptake	
Source	Rate	22 DAE	31 DAE	22 DAE	31 DAE	22 DAE	31 DAE
	-lb/A-	---g/kg DM[1]---		----lbs/A----		---g/plant---	
---	0	.42	.75	50	35	.05	.20
$Ca(NO_3)_2$	40	3.23	3.49	96	92	.12	.48
"	80	5.20	5.84	173	132	.16	.55
"	120	5.84	6.01	202	112	.13	.54
"	160	6.20	7.57	275	182	.15	.58
Urea (DCD10)	40	1.70	2.14	65	56	.10	.31
"	80	2.53	3.11	74	61	.12	.42
"	120	3.90	4.25	100	96	.13	.44
"	160	4.30	5.21	115	92	.17	.58
Signif. Level (%):		99	99	99	99	99	99
BLSD (.05):		.97	1.07	110	72	.03	.17
CV (%):		20	19	56	48	18	25
INDIVIDUAL FACTORS							
Nitrogen Sources							
$Ca(NO_3)_2$		5.12	5.73	187	129	.14	.54
Urea (DCD)		3.11	3.68	88	76	.13	.44
Signif. Level (%):		99	99	99	99	82	97
Nitrogen Rate (lb/A)							
40		2.47	2.82	80	74	.11	.40
80		3.87	4.47	123	96	.14	.48
120		4.87	5.13	151	104	.13	.49
160		5.26	6.39	195	137	.16	.58
Signif. Level (%):		99	99	96	91	99	95
BLSD (.05):		.71	.77	87		.02	.14
INTERACTION		----------significance level----------					
Nitrogen Source x Rate		51	65	57	58	90	40

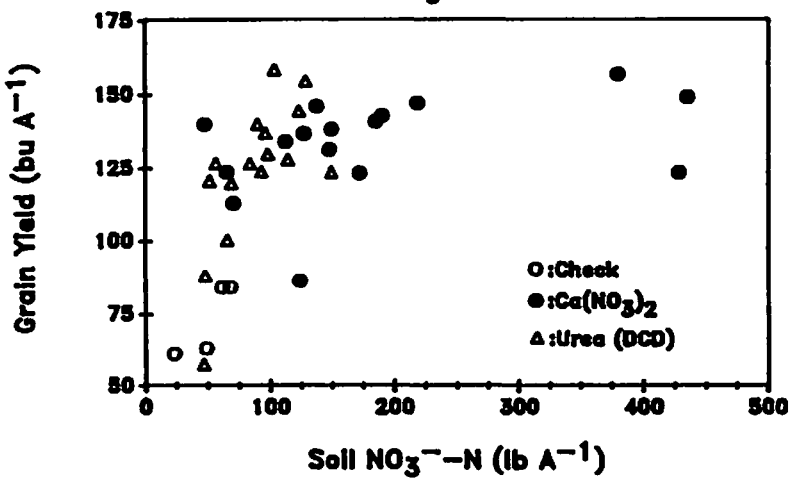
1. DM: dry matter.

Table 2. The effect of N source and N rate on population and yield.

N Treatments		Population	Yield		
Source	Rate	(thousands)	Fodder	Silage	Grain
	-lb/A-	-plants/A-	---tons DM/A--		-bu/A-
---	0	24.4	1.69	3.76	72.9
$Ca(NO_3)_2$	40	24.6	2.13	5.31	114.7
"	80	24.8	2.30	6.10	136.7
"	120	23.9	2.37	6.06	135.5
"	160	26.5	2.61	6.67	145.7
Urea (DCD10)	40	25.7	2.11	4.98	103.4
"	80	25.9	2.20	5.42	116.7
"	120	24.8	2.37	6.09	135.2
"	160	25.4	2.33	6.16	137.9
Signif. Level (%):		70	99	99	99
BLSD (.05):			.29	.73	23.1
CV (%):		5.8	9.0	9.4	13
INDIVIDUAL FACTORS					
Nitrogen Sources					
$Ca(NO_3)_2$		24.9	2.35	6.03	133.2
Urea (DCD10)		25.4	2.25	5.66	123.3
Signif. Level (%):		63	81	93	89
Nitrogen Rate					
40		25.2	2.12	5.15	109.1
80		25.4	2.25	5.77	126.8
120		24.4	2.37	6.08	135.4
160		25.9	2.48	6.42	141.8
Signif. Level (%):		75	98	99	99
BLSD (.05):		--	.23	.56	18
INTERACTION		----------significance level (%)----------			
Nitrogen Source x Rate		57	46	39	29

22 Days After Emergence

Figure 1



31 Days After Emergence

Figure 2

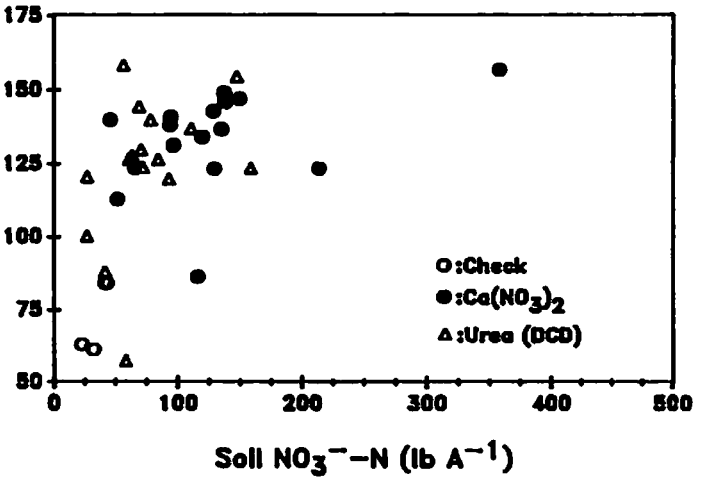


Figure 3

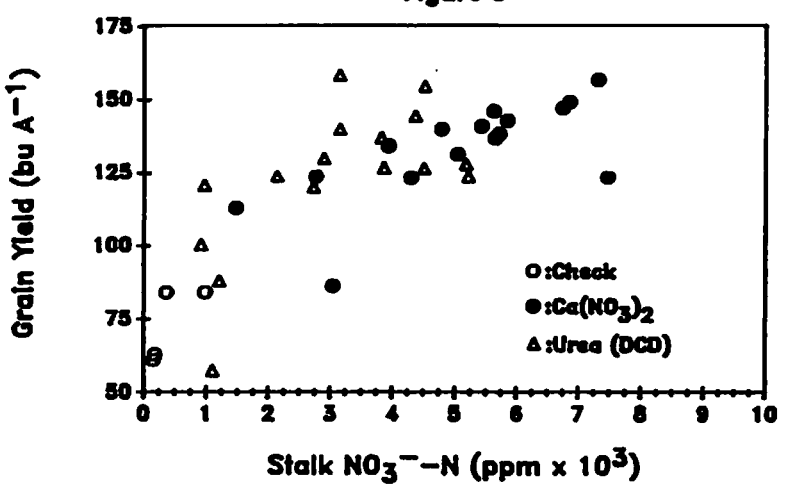
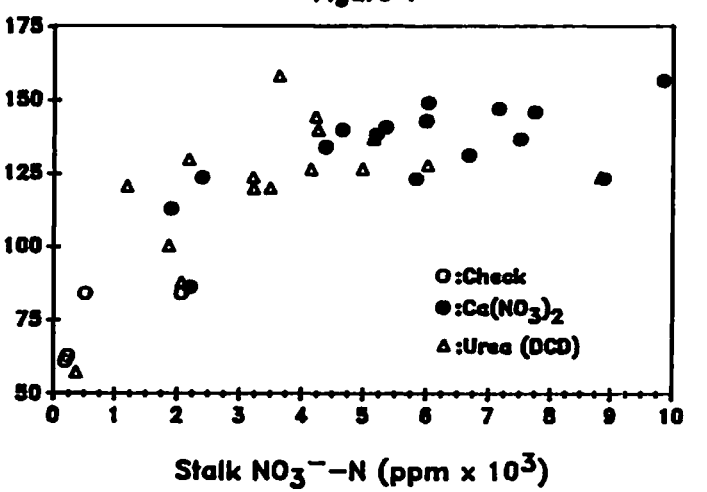


Figure 4



INFLUENCE OF NITROGEN AND POTASSIUM FERTILIZATION ON THE YIELD AND NUTRIENT ACCUMULATION OF FOUR DIFFERENT CORN HYBRIDS--1988 [1]

G.L. Malzer, G.W. Randall and T.J. Graff [2]

ABSTRACT: How different corn hybrids utilize fertilizer and soil nutrients may impact the best fertilizer management that a producer should utilize. Previous research results would suggest that hybrids do vary in the total quantity and time period of nutrient absorption. The objective of this experiment are to evaluate the N accumulation patterens of different corn hybrids and to determine the impact of N rate, K rate, and nitrification inhibitors on yield and N utilization. Results from both Becker and Waseca support the yields and N utilization differences between hybrids. Numerous interactions of hybrid with N and K and nitrification inhibitors treatments would suggest that management treatmements can impact the utilization efficiency of a given corn hybrid.

Two experimental locations were selected in 1986 and two experiments established at each location. The two locations were: 1. The Sand Plains Research farm, Becker, MN (irrigated) and 2. Southern Experiment Station, Waseca, MN (dryland). In 1986 a corn and soybean experiment was started at each location to provide for a future corn-soybean sequence. In 1987 nitrogen (N) and potassium (K) treatments were established at each location.

The objectives of these experiments were to: 1. Determine the nutrient accumulation patterns of different corn hybrids grown in a high yield enviroment, and 2. Evaluate the impact of N, and K, and the the use of nitrification inhibitors on the yields and nutrient utilization of different corn hybrids in a corn-soybean sequence.

Experimental Procedures

Becker: A total of 56 treatments with four replications were established on the corn experimental site. A split plot design was utilized with K as the main plot. N and hybrid treatments were randomized within the main plots. A modified factorial arrangement consisting of four corn hybrids (Pioneer 3732, Pioneer 3737, A632 x LH39, and DeKalb 484), three N rates (80, 160, and 240 lbs/A), two nitrification inhibitor treatments (w/wo N-Serve 0.5 lbs/A a.i.), and three K fertilizer rates (0, 100, and 200 lbs K/A) were utilized. To reduce the size of the experiment not all combinations of K were utilized with the 160 lbs/A N treatment.

Potassium treatments were broadcast before planting and incorporated by plowing. The four corn hybrids were planted on April 28th, at a population of 30,700 seeds/A in 30 inch rows. Starter fertilizer was applied as a side banded application of 160 lbs/A of 10-10-10. Weed control was accomplished by using Dual 8E (2.0 lbs/A a.i.) on April 29th and two cultivations one on May 23 and the other on June 3rd. Nitrogen treatments were applied as anhydrous ammonia on June 1st (4-5 leaf growth stage). The nitrification inhibitors were injected into the anhydrous ammonia flow stream and forced to passed through a bidirectional flow integrator prior to the manifold.

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

Plant and soil samples were taken four times during the growing season. Plant samples were taken on June 22, July 11th, August 4th, and September 13. These dates corresponded to the 12-leaf, silking, predent, and physiological maturity, growth stages, respectively. Total plant material was removed from 20 ft^2 of plot area for each of the first three harvests and 100 ft^2 was sampled for the final sampling. For the first two harvests total dry matter production was determined and subsamples collected for N concentration and determination of total N uptake. Plant samples obtained during the third and fourth harvest were separated into grain and stover samples. Separate determinations were made for dry matter production and N concentrations. Grain yields were adjusted to 15.5% moisture. Soil samples were collected from all N combinations at the high K rate for two hybrids (Pioneer 3732 and A632 x LH39). Six to eight cores were taken from a depth of 0-1 ft through the anhydrous ammonia injection zone. All soil samples were analyzed for nitrate and ammonium N.

The irrigation program began on June 6th and continued through August 19th with a total of 16.9 inches being applied through an overhead solid set irrigation system. An additional 9.0 inches of water was obtained during the growing season as rainfall.

Waseca: The corn experiment at Waseca was similar to that established at Becker except only 40 treatments were evaluated. The experimental design was a split plot with four replications. Treatments included a factorial combination of four hybrids (Pioneer 3732, Pioneer 3475, LH74 X LH51, AND A632 X LH38), with two N rates (80 AND 160 lbs N/A), two K rates (0 and 100 lbs K/A), and two nitrification inhibitor treatments (w/wo N-Serve 0.5 lbs/A). Two controls both with no fertilizer N but w/wo K and one without was also included in the experiment.

Potassium treatments were applied in the fall of 1987. The four corn hybrids were planted on April 3rd at a population of 32,000 seeds/A in 30 inch rows. Weed control was accomplished with a tank mix of Lasso (3.5 lbs/A a.i.) and Bladex (3 lbs/A a.i.) on May 5th. Nitrogen treatments were applied as anhydrous ammonia on June 7th using procedures similar to that used at Becker.

Plant and soil samples were taken four times (June 24th, July 18th, August 10th, and September 12th), during the growing season. (This coincides with the comparable growth stages at the Becker location.) The same plant sampling procedures were used at Waseca as was described for Becker. Soil samples were collected from the zero K rate (all N combinations) for two of the hybrids (Pioneer 3732 and A632 x LH38) at each plant sampling.

General Results

The results from the Becker location are presented in tables 1-10, and a summary of the results from Waseca are presented in tables 11-23. The discussion presented here will not attempt to interpret all of the results. Major emphasis will be placed on the interpretations of the final yield and N utilization by the crop. A more thorough evaluation of the remaining data will be conducted at a later time.

Becker: Grain yields at this location were lower than average due to the high temperatures that were experienced during the 1988 growing season. Even though this location is irrigated water stress conditions were incountered due to the prolonged dry, hot season. Yields obtained from the four hybrids selected were significantly different. In 1987, P-3732 was one of the lowest yielding hybrids, while in 1988 it was one of the highest. P-3732 and DeKalb 484 were the highest yielding, P-3737 was intermediate and A632 x LH39 was the lowest yielding of the four hybrids tested. A significant yield increase was obtained when the fertilizer N rate was increased from 80 to 240 lbs/a. The magnitude of the yield increase was relatively modest averaging only 8 bu/a. There were, however, many significant N management hybrid interactions when the final yield was determined. A significant hybrid x N rate interaction in 1988 would suggest that P-3732 was more responsive to higher rates of fertilizer N than were the other hybrids examined. The hybrids also responded differently to the addition of K fertilizer. In general P-3732 and P-3737 were not influenced greatly with K addition, while the yields of A632 x LH39 and DeKalb 484 decreased with K fertilization. The use of a nitrification inhibitor tended to reduce yields if no