Fall 1987 Surface Soil Samples: The surface soil sample test results are given in Table 4. There was a tremendous difference in the values by rep. In most cases the soil test values for P, K, and Zn increased with increasing manure rate. All manure treatments except LB1 appear to have adequate P for many more years. The K levels of all manure treatments are adequate, but LB1 and LB2 will need additional K in one or two years. The Zn levels of all SB treatments are adequate, but the lower two LB rates are borderline in their Zn levels.

Fall 1987 Deep Soil Samples: The results of the nitrate nitrogen analyses are given in Table 5. There was a tremendous difference between reps. The FE treatment has the highest levels in the upper 4 feet, reflecting annual applications. For all manure treatments the levels below the normal rooting depth of corn are generally far above those of the fertilized treatment. In most cases the nitrate-nitrogen levels increase with increasing manure rate. The SB1 and LB1 treatments have levels comparable to those of FE. The ammonium-nitrogen analyses (Table 6) are low compared to the nitrate-nitrogen levels. Even though the rep, treatment, and depth effects are significant, the range is below 4 ppm. The nitrate-nitrogen contents of the 0 to 4-foot and 4- to 18-foot zones are given in Table 7. The SB2, SB3, and LB3 treatments have much more total nitrate-nitrogen than the FE treatment. In all treatments there is a considerable amount of nitrogen below the 4-foot depth and much of this would be unavailable for corn growth.

Summary: The effect of 7 applications of two types of cattle manure from 1972-1978 remains. The lower rates of both manures were adequate for yields during the application years and for a number of years afterward. These lower rates also resulted in nitrogen levels in the subsoil comparable to those resulting from normal fertilizer practices. Using higher manure rates did not result in higher yields during the application years, but yields in 1987 of the highest solid beef manure indicated a measurable response to the residual fertility as compared to the normal fertilizer treatment. However, nitrate-nitrogen movement below the root zone of corn is much higher with the higher rates of manure.

Table 3. Summary of plant measurements - 1987.

			Grain		Silage		
Treatment	Early plant height	Early plant(10) dry wt.	Moisture at harvest	Yield at 15.5% moisture	Dry matter at harvest	Silage yield (D.M.)	Ear wt. as a % of silage
	inches	-grams-	-%-	bu/acre	-%-	lb/acre	-%-
CK	22.8	30.1	23.7	97.2	43.0	10556	52.6
FE	27.4	53.0	21.8	155.5	41.9	17217	55.6
SB1	28.6	60.1	22.8	144.1	41.0	15436	54.5
SB2	30.0	72.4	20.7	155.6	44.3	15461	56.3
SB3	34.5	96.5	21.3	171.6	40.2	17605	55.7
LB1	23.6	36.2	22.5	118.2	42.9	11192	54.8
LB2	23.9	50.8	23.0	148.4	42.2	15772	57.2
LB3	27.4	53.3	21.8	141.3	43.3	16260	53.9
Signif. level(%)	>99	>99	95	98	81	>99	31
BLSD (.05)	5.9	12.5	2.1	40.0	4	3194	NS
CV (%)	11.6	19.4	35.4	14.7	4.1	12.0	5.5

Table 4. Effect of two types of cattle manure and commercial fertilizer on P, K, and Zn values of a Tara soil (0-8") - Fall 1987.

Treatment	Elements			
	Bray P	Olson P	Exch. K	Zn
	- - - - lbs/acre - - - - -			ppm
CK	13	8	236	0.5
FE	31	17	265	2.5
SB1	104	67	514	1.7
SB2	212	249	1037	3.6
SB3	294	224	1323	5.0
LB1	20	16	259	0.7
LB2	57	40	288	0.9
LB3	118	82	371	1.5
Signif. level(%)	>99	>99	>99	>99
BLSD (.05)	81	110	116	0.8
CV (%)	46	71	14	23

Table 5. Effect of two types of cattle manure and commercial fertilizer on the nitrate-nitrogen levels of a Tara soil - Fall 1987.

DEPTH INCREMENT	Treatment								
	CK	FE	SB1	SB2	SB3	LB1	LB2	LB3	Mean
- ft -	- - - - - - - - - - ppm NO_3-N - - - - - - - - - - - - - -								
0-1	4	31	9	11	16	5	21	16	11
1-2	1	29	3	25	19	1	37	25	22
2-3	1	21	17	33	78	6	20	21	33
3-4	1	13	17	76	75	10	24	26	37
4-6	5	9	17	73	64	11	20	37	30
6-8	8	9	18	39	61	12	21	38	22
8-10	9	7	12	25	37	9	15	25	13
10-12	5	6	8	9	19	6	4	10	6
12-14	3	6	6	5	13	4	1	7	5
14-16	2	4	4	3	10	5	1	6	5
16-18	1	4	10	2	6	5	1	7	6
Mean	4	13	7	34	35	5	15	22	

Signif. levels (%):

Replication	- >99	
Treatment	- >99	BLSD (.05)-10
Depth	- >99	BLSd (.05)-8
Trt x Depth	- >99	

Table 6. Effect of two types of cattle manure and commercial fertilizer on the ammonium-nitrogen levels of a Tara Soil - Fall 1987.

DEPTH INCREMENT	Treatment								
	CK	FE	SB1	SB2	SB3	LB1	LB2	LB3	MEAN
- ft -	ppm NH_4-N								
0-1	4	5	3	2	4	4	4	6	4
1-2	3	2	2	2	2	3	3	3	2
2-3	2	2	2	2	3	3	2	2	2
3-4	2	2	2	2	2	2	4	3	3
4-6	2	3	2	2	2	3	3	2	3
6-8	2	3	3	3	3	4	3	3	3
8-10	2	3	3	3	3	4	3	3	3
10-12	3	3	3	3	4	3	3	3	3
12-14	3	4	3	3	3	3	3	3	3
14-16	3	3	3	3	4	3	3	3	3
16-18	3	3	2	3	4	3	4	3	3
Mean	3	3	3	3	3	3	3	3	

Signif. levels (%):

Replication	-	>99	
Treatment	-	97	(BLSD(.05)-0.6
Depth	-	>99	(BLSD(.05)-0.4
Trt x Depth	-	87	

Table 7. Calculated nitrate-nitrogen contents of various profile increments of a Tara Soil-Fall 1987.

DEPTH INCREMENT	Treatment							
	CK	FE	SB1	SB2	SB3	LB1	LB2	LB3
- ft -	NO_3-N, lbs/acre							
0-6	48	412	252	872	1008	132	488	500
6-18	276	448	588	1228	1424	372	424	892
Total	324	860	840	2100	2432	504	912	1392

RESIDUAL EFFECT OF HEAVY APPLICATIONS OF ANIMAL MANURES ON CORN GROWTH AND YIELD AND ON SOIL PROPERTIES MORRIS, MN 1987

S. D. Evans, P. R. Goodrich, G. L. Malzer and R. C. Munter

OBJECTIVES: This study which was initiated in 1970 was continued to measure the residual effect of 1970 and 1971 applications of two types of manure on corn yields and soil nitrogen levels. The total manure applications were as follows: Solid Beef Manure - 200 tons/acre (wet weight), Liquid Beef Manure - 136,000 gallons/acre, Liquid Hog manure - 136,000 gallons/acre. The fertilized plots receive the same amount of fertilizer annually.

MATERIALS AND METHODS: The plots were sampled in the fall of 1986 after corn harvest to a depth of 4 feet. Two cores were taken in each plot, separated into 1-foot increments and mixed. The samples were dried at 100°F. The samples were then tested for total inorganic nitrogen, nitrate nitrogen, and ammonium nitrogen. In the fall of 1986 the plots were moldboard plowed. In the spring of 1987 the area was field cultivated twice on April 22 and then planted to Pioneer 3790 @ 26,000 seeds/acre on April 23. Thimet was applied @ 10 lbs/acre (1.5 lbs/acre a.i.) in the row to the entire area at planting. The fertilized plots had received a broadcast application of 120 + 50 + 50 ($N + P_2O_5 + K_2O$) lbs/acre on October 29, 1986. Lasso @ 3 lbs/acre (a.i.) + Bladex @ 2.2 lbs/acre (a.i.) were broadcast on April 28. On June 9 plant heights were recorded and 10 plants were harvested for dry weight determination. Leaf samples were collected at mid-silk and analyzed for a number of elements. Silage yields were calculated from two 10-foot rows hand harvested on August 25. Two rows 110 feet long were harvested with a plot combine on September 23. Harvest weights were recorded with a weigh cell on the combine and a grain sample was saved for moisture determination in the lab. After grain harvest 0 to 8-inch soil samples were collected from all plots for P, K, and Zn determination. Deep soil samples were then taken for nitrogen analysis. The cores were separated into 1-foot increments to the 4-foot depth and then into 2-foot increments to the 18-foot depth. An attempt was made to get two complete cores/plot but rocks and other problems prevented this on some plots. This was only a problem below the 12-foot depth. The two cores were mixed, subsampled, and dried at 100°F.

RESULTS AND DISCUSSION:

Fall 1986 Soil Samples: The results of the nitrate- and ammonium-nitrogen analyses are given in Table 1. There were no significant differences between the manure treatments and the fertilized or check treatments. The nitrate-nitrogen levels increased with depth while the ammonium-nitrogen levels decreased with depth.

Leaf Tissue Analysis: The nutrient concentration in the ear leaves at silking in 1987 is given in Table 2. There were significant treatment effects on all elements except Fe, Cu, and B. The N, P, Ca, Mg, Zn, and Mn levels of leaves from the manure treatments were below those of the fertilized treatment. The levels of N, P, and Zn were below those considered sufficient for adequate nutrition.

Plant and Yield Measurements: The early plant height, early dry weight, silage yields, and grain yields are given in Table 3. The early height of all the manure treatments was not different from the fertilized check. Early plant dry weight of the liquid hog manure treatment was significantly different from the other two manure treatments and from the fertilized check. The manure treatments were lower yielding than the fertilized check, but the only significant difference was between the fertilized check and liquid hog manure. The manure treatments were not significantly different from one another. Silage yields showed about the same pattern as grain yields with liquid hog manure significantly lower in yield than the beef manure and fertilized treatments.

Fall 1987 Surface Soil Samples: The surface soil sample test results are given in Table 4. There was a tremendous difference in the values by rep. However, all manure treatments have numerically higher Bray P, Olsen P, and exchangeable K levels than the fertilized treatment, but in some cases the differences are

P, Olsen P, and exchangeable K levels than the fertilized treatment, but in some cases the differences are not significant. The zinc levels of the manure treatments are numerically lower than the fertilized check, but still in the sufficient range.

Fall 1987 Deep Soil Samples: The results of the nitrate nitrogen analyses are given in Table 5. As in the fall of 1986, the only significant effect was depth. Levels increase down to the 6-8 foot zone and then decrease thru the rest of the profile measured. There seems to be some movement of nitrate-nitrogen to the bottom of the profile. The ammonium-nitrogen analyses are given in Table 6. There is a significant treatment x depth interaction. However, the values are quite low and the maximum range in a given treatment is only 5 ppm. The calculated nitrate-nitrogen contents (lbs/acre) in Table 7 show the fertilized treatment has the most nitrogen in the root zone. Below the root zone of corn the levels in manure treatments exceed the fertilized treatment from 47% more with liquid hog manure to 110% more with solid beef manure. Most of this nitrogen below the 6-foot level is below most corn roots and will eventually move down to groundwater in years of high rainfall. The only possible way to recover this deep nitrate-nitrogen would be with a deep rooted crop such as alfalfa.

Summary: The effect of the 1970-71 manure application on yield has decreased to the extent that the manure treatments are not significantly different from the fertilized treatment or from the check treatment. There are still significant effects on soil P and K levels and on ear leaf levels of many nutrients. Nitrate-nitrogen levels are fairly high in the subsoil and considerably more nitrogen is below the root zone of corn where it is not available to the crop and is in a position for deeper movement to the groundwater.

Table 1. Nitrate and ammonium nitrogen values in a 4-foot profile of a Tara Soil 16 years (Fall 1986) after application of high rates of manure.

	Treatment						Treatment					
DEPTH INCREMENT	CHECK	FERTILIZED	SOLID BEEF MANURE	LIQUID BEEF MANURE	LIQUID HOG MANURE	MEAN	CHECK	FERTILIZED	SOLID BEEF MANURE	LIQUID BEEF MANURE	LIQUID HOG MANURE	MEAN
	ppm, NO_3-N						ppm, NH_4-N					
0-1	4	4	5	4	5	4	16	16	11	11	12	13
1-2	3	5	5	3	4	4	4	3	2	3	3	3
2-3	4	9	5	3	6	5	3	3	3	3	3	3
3-4	5	16	6	9	11	9	3	2	2	3	2	3
Mean	4	9	5	5	6		6	6	4	5	5	

Signif. level (%):

Replication	- 53		Replication	- 23	
Treatment	- 77		Treatment	- 64	
Depth	- >99	BLSD (.05)-3	Depth	- >99	BLSD(.05) - 1
Trt x Depth	- 82		Trt x Depth	- 49	

Table 2. Summary of analysis of corn leaves at silking - 1987.

Treatment	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	- - - - - - - - - - % - - - - - - - - - -					- - - - - - - - - - ppm - - - - - - - - - -				
Check	1.88	0.15	1.51	0.52	0.42	99.6	15.2	7.3	63.5	5.0
Fertilized	2.79	0.25	2.02	0.57	0.37	109.6	38.9	6.7	76.8	5.4
Solid Beef Manure	1.85	0.19	2.27	0.45	0.22	98.8	16.7	6.5	54.2	5.5
Liquid Beef Manure	1.81	0.20	2.35	0.47	0.22	98.2	17.8	6.1	51.2	5.5
Liquid Hog Manure	1.79	0.20	2.12	0.52	0.28	89.8	18.1	6.6	51.5	5.6
Signif. level (%)	>99	>99	>99	>99	>99	83	>99	32	>99	57
BLSD (.05)	0.51	0.03	0.22	0.05	0.06	NS	3.8	NS	12.1	NS
CV (%)	13.1	7.3	5.9	4.9	10.4	8.4	10.1	15.1	10.7	6.8

Table 3. Summary of plant measurements - 1987.

Treatment	Early plant height	Early plant(10) dry weight	Grain: Moisture at harvest	Grain: Yield at 15.5% moisture	Silage: Dry matter at harvest	Silage: Silage yield (D.M.)	Silage: Ear wt. as a % of silage
	inches	- grams -	- - % - -	- bu/acre -	- % -	- lb/acre	- % -
Check	20.2	23.7	23.1	82.1	41.6	9388	53.5
Fertilized	29.2	60.5	19.7	146.8	47.6	16845	51.7
Solid Beef Manure	30.2	57.9	21.5	122.1	42.7	15674	54.2
Liquid Beef Manure	29.5	57.2	21.5	125.2	43.9	14158	55.0
Liquid Hog Manure	27.1	47.6	22.1	113.4	44.4	10465	53.1
Signif. level (%)	>99	>99	96	>99	41	>99	57
BLSD (.05)	2.7	9.3	2.1	25.5	NS	3141	NS
CV (%)	5.6	10.5	4.9	11.4	10.3	12.6	3.8

Table 4. Soil Test values in the 0 to 8-inch zone for P, K, and Zn in a Tara Soil after 17 years (Fall 1987) after application of high rates of manure

Treatment	Elements: Bray P	Olsen P	Exch. K	Zn
	- - - - - - - lbs/acre - - -			ppm
Check	7	6	209	0.4
Fertilized	46	28	253	4.0
Solid Beef Manure	130	85	654	1.7
Liquid Beef Manure	201	159	504	2.0
Liquid Hog Manure	91	63	312	2.2
Signif. level (%)	95	>99	>99	>99
BLSD (.05)	136	81	137	0.7
CV (%)	70	61	20	20

Table 5. Nitrate-nitrogen values in an 18-foot profile of a Tara Soil 17 years (Fall 1987) after application of high rates of manure.

Depth Increment	Check	Fertilized	Solid Beef Manure	Liquid Beef Manure	Liquid Hog Manure	Mean
	Treatment					
- ft -	ppm NO_3-N					
0-1	4	8	5	5	5	5
1-2	4	17	1	1	1	5
2-3	6	13	1	4	7	6
3-4	4	12	4	10	9	8
4-6	6	17	9	18	8	11
6-8	8	12	18	27	30	19
8-10	6	10	20	22	10	13
10-12	3	7	17	17	8	10
12-14	3	5	11	11	9	8
14-16	4	4	9	8	7	6
16-18	2	3	8	10	5	6
Mean	4	10	9	12	9	

Signif. level (%):

Replication	- 13	
Treatment	- 67	
Depth	- >99	BLSD (.05) - 6
Trt x Depth	- 81	

Table 6. Ammonium-nitrogen values in an 18-foot profile of a Tara Soil 17 years (Fall 1987) after application of high rates of manure.

Depth Increment	Check	Fertilized	Solid Beef Manure	Liquid Beef Manure	Liquid Hog Manure	Mean
	Treatment					
- ft -	ppm, NH_4-N					
0-1	6	8	4	6	6	6
1-2	4	6	3	4	3	4
2-3	4	4	3	5	3	4
3-4	3	3	3	3	3	3
4-6	4	3	3	3	5	4
6-8	5	3	6	4	3	4
8-10	4	3	5	5	3	4
10-12	7	4	5	4	4	4
12-14	6	4	3	4	4	4
14-16	6	4	4	3	4	4
16-18	4	4	7	4	4	5
Mean	5	4	4	4	4	

Signif. level (%):

Replication	- 95	
Treatment	- 21	
Depth	- >99	BLSD (.05)-1
Trt x Depth	- >99	

Table 7. Calculated nitrate-nitrogen contents of various profile increments of a Tara Soil in the fall of 1987.

Depth Increment	Treatments				
	Check	Fertilized	Solid Beef Manure	Liquid Beef Manure	Liquid Hog Manure
- ft -	NO_3-N, lbs/acre				
0-6	96	268	80	152	120
6-18	232	396	700	832	584
Total	328	664	780	984	704

MANAGEMENT OF BORON FOR CORN PRODUCTION ON IRRIGATED SANDY SOILS IN MINNESOTA

George Rehm, Greg Cremers, Andy Scobbie

Background Justification:

Past research studies with boron in Minnesota have not yielded consistent results. Early studies with alfalfa-grass mixtures in northeastern Minnesota showed that addition of B to a fertilizer program increased yields. In another study in north-central Minnesota, however, broadcast applications of boron increased corn yield but had little effect on the yield of alfalfa. Trials at the Sand Plains Irrigated Field showed that B did not increase yield of corn grown on an irrigated sandy soil. So, there was a need to examine again the effect of boron applied to corn grown on an irrigated sandy soil.

Boron, like nitrogen and sulfur, is considered to be mobile in sandy soils. The earlier research cited above showed that there was substantial downward movement of applied boron through the soil profile. In Minnesota, however, no research efforts have been directed to the development of management systems that will minimize the loss of applied boron due to leaching.

In past research, the applied boron was broadcast and incorporated before planting. It is possible that some of the boron applied in this way was lost because of leaching and this might help to explain some of the erratic responses noted to date. This study was designed to evaluate the effect of rate and frequency of applied boron on the production of corn grown on an irrigated sandy soil.

Experimental Procedures:

This study was initiated in 1985 and continued during the 1986 and 1987 growing seasons. This report summarizes the research conducted in 1987.

In 1985 and 1986, there was no grain yield response to applied boron at the Irrigation Research Center at Staples. The soil at the sites used had a medium level of organic matter and mineralization during the growing season was thought to have produced adequate amounts of boron for corn growth. A research area with a very low organic matter level was selected in 1987. Appropriate soil properties are summarized in Table 1.

Treatments used in 1987 are listed in Table 2. Except for the one situation where 1 lb. boron per acre was applied preemergence as part of a split application, all boron was applied at either the 4-leaf or the presilk stage of growth. Pioneer 3953 corn was planted on May 4 at a population of approximately 27,000 plants per acre.

The preemergence application of boron was made on May 5. The 4-leaf application was made on June 18 and the presilk application on July 20. The boron was supplied as Solubor dissolved in water. Application rate was adjusted to supply the amount of boron desired.

Prior to planting, 30 lb. N and 80 lb. K_2O were broadcast and incorporated. The starter fertilizer supplied 10 lb. N, 20 lb. P_2O_5, 30 lb. K_2O and 10 lb. S per acre. The additional N (140 lb. N/acre as 82-0-0) was applied as a sidedress treatment. Eradicane at a rate of 3 quarts/acre was used for weed control. Ear leaf samples were collected at silking and yields were measured in mid-October.

Results and Discussion:

The data collected from the 1987 growing season are summarized in Table 2. In 1987, neither the rate nor method of application of boron had a significant effect on corn yield. The yields were lower than those

reported in past years and would be considered to be low for irrigated corn in the region. These low yields, however, were expected because a site with a very low organic matter content (1.0%) was selected. With this low organic matter content, available water holding capacity was probably reduced. Irrigation water was applied according to the needs of the remainder of the field which had a higher water holding capacity. Therefore, the corn in the research area was under moisture stress early in the growing season and this probably limited yield.

The method of boron application (split vs. single) had no effect on the boron content of the ear leaf tissue (Table 2). The boron content of the ear leaf tissue did, however, increase with the rate of boron applied. This increase was linear and would be expected. Although the added boron was absorbed by the corn, it had no impact on yield.

The data collected indicate that adequate boron was supplied by the soil with an organic matter content of 1.0% The irrigation water was analyzed and the boron concentration was .01 ppm. Very small amounts of boron would be supplied with the irrigation water again indicating that this soil was supplying boron in amounts adequate for a corn yield of about 100 bu. per acre.

Table 1. Relevant soil properties for the experimental site selected in 1987.

pH	6.5
P (Bray & Kurtz #1), lb./acre	112
K (1N $NH_4C_2H_3O_2$), lb./acre	77
SO_4-S, ppm	4
Organic Matter, %	1.0
*B (0-6 in.), ppm	.2
B (6-12 in.), ppm	.1
B (12-18 in.), ppm	.2

* Hot Water Soluble Boron

Table 2. Effect of rate and method of boron application on corn yield and concentration of boron in ear leaf tissue.

Treatment	Yield	Boron Concentration
	bu./acre	ppm
Control	108.0	4.3
1 lb. boron/acre @ 4-leaf	110.6	6.4
2 lb. boron/acre @ 4-leaf	101.0	8.9
.5 lb. boron/acre @ 4-leaf + .5 lb. boron/acre @ presilk	107.0	9.0
1 lb. boron/acre @ 4-leaf + 1 lb. boron/acre @ presilk	113.6	7.9
2 lb. boron/acre preemerge + 1 lb. boron/acre @ 4-leaf + 1 lb. boron/acre @ presilk	108.1	12.1

CORN - SOYBEAN ROTATION

H. Meredith, Mel Weins, Greg Cremers and Andy Scobbie

The irrigated corn-soybean rotation experiment initiated in 1981 at the Staples Station to evaluate potential corn yields of continuous corn vs corn and soybean yields in rotation continues.

This study applies best management practices available to commercial farmers. The growing season in 1987 was perhaps one of the warmest and hence one of the most ideal corn-soybean years on record.

Special recognition for the assistance and interest by Dr. George Rehm, Greg Cremers and Andy Scobbie.

Table 1. Corn Yield, @ 15.5% Moisture, bu/A, Staples 1987

No	Treatment	1981	1982	1983	1984	1985	1986	1987
1	Corn-Corn 1/	151	168	135	130	125	149	170
2	Corn-Corn 2/	151	166	150	128	124	180	181
3	SB_1-SB_2-Corn						142	
4	Corn-SB-Corn			148		123		155
5	SB-Corn-SB		170		140		144	
6	SB_1-SB_2-Corn							173

1/ Pioneer 3902, 90-day R. M. on all treatments except No. 2
2/ Pioneer 3790, 95-day R. M.

Table 2. Soybean Yields, Variety Ozzie, bu/A., Staples 1987

No	1981	1982	1983	1984	1985 1/	1986	1987
3	39	47	47	38	36		54
4						49	
5							52
6						53	
7							53

1/ All soybeans yields averaged through 1985

Table 3. Supportive Information Pertaining to Corn Yields, Staples 1987

No	Treatment	Harvest Population (x 1000)	Kernel Moisture (%H_2O)	Grain Yield T/A DM	Silage Yield T/A DM	Stover Yield T/A DM	Grain/ Stover Ratio
1	Corn-Corn	40.2	22.3	4.02	8.08	4.06	.50
2	Corn-Corn	39.3	25.1	4.28	7.64	3.36	.56
4	Corn-SB-Corn	40.9	20.3	3.67	7.81	4.14	.47
6	SB_1-SB_2-Corn	43.0	21.7	4.10	8.10	4.00	.51

Table 4. Nutrient Removal in Corn Grain, Staples 1987

	N	S	P_2O_5	K_2O	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------Lbs/A----------										
1	114.9	8.1	44.8	31.7	.26	9.2	.19	.04	.20	.008	.021
2	123.3	8.5	51.1	32.5	.26	9.7	.19	.04	.20	.007	.021
4	112.2	7.7	44.4	29.8	.25	9.3	.20	.04	.20	.007	.015
6	118.5	8.4	51.3	33.4	.26	10.0	.21	.04	.20	.005	.083

Table 5. Nutrient Removal in Corn Silage (Grain + Stover), Staples 1987

Treatment No	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------Lbs/A----------										
1	196	18	64	275	46	26	4.7	.57	.43	.04	.10
2	187	17	66	297	47	25	4.4	.57	.40	.04	.09
4	185	16	57	288	50	27	4.0	.55	.52	.04	.08
6	200	18	70	283	51	30	4.3	.58	.46	.03	.08

Table 6. Whole Corn Plant Nutrient Concentration at Silage Harvest, Staples 1987

Treatment No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------%----------							---------ppm--------			
1	1.2	.11	.17	1.4	.29	.16	.03	36	27	2.6	6.2
2	1.2	.11	.19	1.6	.31	.16	.03	37	27	2.4	5.8
4	1.2	.10	.16	1.5	.32	.18	.02	35	34	2.4	5.4
6	1.2	.11	.19	1.4	.32	.18	.03	36	29	1.0	5.0

Table 7. Corn Leaf Tissue Analysis at Silking, Staples 1987

Treatment No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------%----------							------ppm------			
1	2.8	.21	.25	2.6	.47	.19	.05	58	29	4.8	6.0
2	2.8	.21	.26	2.4	.42	.17	.05	56	32	4.8	5.6
4	2.7	.22	.24	2.4	.54	.23	.05	63	35	4.8	5.6
6	2.7	.23	.25	2.5	.60	.24	.06	69	30	4.2	5.8

Table 8. Chemical Analysis of Corn Grain, Staples 1987

Treatment No.	N	S	P	K	Mg	Fe	Mn	Zn	Cu	B	Ca
	----------%----------					----------ppm----------					
1	1.4	.10	.24	.33	.12	23	4.6	25	1.0	2.6	33
2	1.4	.10	.26	.32	.11	23	5.0	23	0.8	1.4	31
4	1.5	.10	.26	.34	.13	27	5.2	27	1.0	2.0	34
6	1.4	.10	.27	.34	.12	25	5.0	24	0.6	2.2	32

Table 9. Sequence of events and practices employed during the growing season, Staples 1987

Practice	Corn	Soybean
DISK	4/22	4/22
Planting	4/23	5/23
Cultivation	6/8	-
Herbicide	2 1/2# Dual, 2/3# Lorox	Amiben 2#/A, 5/26
Insecticides	Lorsban 2#/A 4/23	
Emergence	5/6	5/29
Tasseling	7/9	7/30
Silking Complete	7/23	-
Mature	9/1	9/1
Forage Hanes	9/8	9/8
Grain Hanes	10/2	10/2
Irrigation	12.4 in.	12.4 in.
Rainfall, 4/27-9/15	12.6 in.	12.6 in.
Crop Water Use 4/27-9/15	18.0	18.0
Fertilization	200-100-400 (NPK) 10# Zn, 100# S, 1# B	None

Table 10. Soybean Whole Plant Analysis, Staples 1987

Treatment No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------%----------							-------ppm-----			
3	2.8	.20	.34	2.4	.81	.39	.02	53	27	3.2	27
5	2.7	.19	.33	2.5	.99	.39	.03	69	29	3.8	36
7	2.7	.19	.32	2.5	.94	.42	.02	57	35	3.8	34

Table 11. Soybean Whole Plant Uptake, Staples 1987

Treatment No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------Lbs/A----------										
3	159	11	19	134	45	22	1.4	.30	.15	.02	.14
5	164	11	20	151	60	24	2.0	.42	.18	.02	.22
7	150	10	18	139	52	23	1.3	.31	.20	.02	.18

Table 12. Concentration of Nutrients in Soybean Grain, Staples 1987

Treatment No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------%----------							-------ppm-------			
3	6.0	.35	.68	2.1	.14	.26	.01	30	56	5.8	32
5	6.1	.38	.70	2.1	.14	.26	.01	31	57	7.5	34
7	6.0	.37	.69	2.1	.15	.26	.01	30	64	6.8	30

Table 13. Soybean Grain Nutrient Uptake, Staples 1987

Treatment No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------Lbs/A----------										
3	169	9.8	19.2	58.5	4.0	7.2	.30	.08	.16	.02	.09
5	166	10.5	19.0	57.3	3.9	7.1	.29	.08	.16	.02	.09
7	167	10.2	19.0	58.4	4.1	7.2	.28	.08	.18	.02	.08

Table 14. Soybean Trifoliate Leaf Analysis (early pod set), Staples 1987

Treatment No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------%----------							--------ppm------			
3	6.0	.34	.62	2.7	.83	.45	.013	86	62	5.2	48
5	6.0	.33	.62	2.6	.83	.44	.012	88	62	6.5	49
7	5.8	.33	.62	2.6	.84	.44	.012	86	75	7.0	43

TRITICALE - RYE STUDIES

H. Meredith, Mel Weins, Greg Cremers and Andy Scobbie

Triticale is a cross between wheat and rye. The Latin names of wheat and rye - Triticum aestivum and Secale cereale - are bunched to form triticale. A natural occuring triticale was identified as early as 1875. A successful cross between wheat and rye was made in 1890.

Triticale in essence is an "artificial" genus combining the desirable characteristics of wheat and rye into one new species. Triticales are not hybrids. When a cross between wheat and rye is made, the progeny or F_1 plant is sterile because of the difference in the chromosome number of wheat and rye. Wheat has 42 chromosomes and rye has 14 chromosomes. The trick is to treat the developing embryo with colchicine. All of the chromosomes are doubled and the resulting F_1 triticale plant is fertile and has 56 chromosomes. Triticales are largely self fertilized and usually breed true from one generation to the next.

Winter hardiness continues to plague newer triticale varieties and accounts for the low yields of triticale compared to rye at Staples in 1987.

Both the triticale and rye plots looked excellent through the mild winter of 1986-87. However, a severe cold spell hit on March 9. The four days preceding this date recorded temperature highs of 50, 55, 65 and on March 9 the temperature hit 71° F. The night of the high of 71° F reached a low of 7° F. The low temperature for the next four nights was 8, 9, 15 and 15. The soil temperature at both the 4 and 8-inch depths was 36° on March 9.

Clearly the plant was off and running before being jolted back into winter. The rye plants handled the abrupt change in temperature but the triticale was visually hurt. It appeared all or most of the above ground portion of the crop of the triticale was dead while the rye did not appear to be damaged.

The objective of this study is to evaluate new varieties which combine the potential for high yield coupled with the requisite winter hardiness.

Table 1. Yield of Rye and Triticale Staples 1987

No.	Variety	Crop	Bu/A	Test Wt Lbs/bu
1	Ia 2-19-4	Triticale	41.5	49.5
2	Ind 2-2-4	"	56.6	49.0
3	Mitzie	Rye	79.5	55.2
4	Ind 6-6-2	Triticale	41.6	45.2
5	Mitzie	Rye	70.3	55.2
6	Rymin	Rye	77.5	55.6

Table 2. Nutrient Content of Rye and Triticale Seed, Staples 1987

Variety	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------%----------						--------ppm--------				
Ia 2-19-4	2.8	.17	.48	.63	.06	.18	40	53	58	1.4	1.2
Ind 2-2-4	2.4	.16	.45	.57	.07	.18	42	54	55	1.7	1.3
Mitzie	2.0	.14	.40	.58	.05	.15	51	40	39	2.3	1.4
Ind 6-6-2	2.5	.17	.51	.67	.07	.18	41	60	57	1.9	1.2
Mitzie	2.0	.14	.41	.58	.05	.15	52	34	40	2.3	1.4
Rymin	1.9	.14	.40	.58	.05	.15	51	36	37	2.2	1.2

Table 3. Nutrient Uptake in Grain of Triticale and Rye, Staples 1987

Variety	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------lbs/A----------										
Ia 2-19-4	55	3.5	10	13	1.2	3.7	.08	1.2	.12	.003	.002
Ind 2-2-4	64	4.4	12	16	2.0	4.8	.11	1.4	.15	.005	.003
Mitzie	76	5.6	16	22	2.0	5.9	.20	1.5	.15	.009	.005
Ind 6-6-2	51	3.4	10	14	1.3	3.6	.08	1.2	.11	.004	.002
Mitzie	67	4.8	14	20	1.7	5.2	.18	1.2	.14	.008	.005
Rymin	71	5.3	15	22	1.8	5.5	.19	1.3	.14	.008	.005

Table 4. Nutrient Composition of Straw of Triticale and Rye, Staples 1987

Variety	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------%----------						----------ppm----------				
Ia 2-19-4	.42	.05	.06	1.3	.28	.07	.02	.34	.14	1.0	2.4
Ind 2-2-4	.56	.06	.11	1.5	.41	.10	.01	.50	.16	1.3	5.0
Mitzie	.41	.06	.09	1.2	.30	.07	.02	.42	.10	1.0	2.2
Ind 6-6-2	.43	.06	.08	1.4	.36	.08	.03	.50	.13	1.2	4.0
Mitzie	.46	.06	.12	1.3	.31	.08	.02	.33	.10	1.0	2.3
Rymin	.48	.05	.11	1.4	.30	.08	.02	.38	.10	1.1	2.3

WATER QUALITY STUDIES

H. Meredith and Mel Weins

Water quality continues to be a high interest item at this location particularly due to the presence of a shallow aquifer. Legumes, commercial nitrogen fertilizer, livestock manure and mineralization of soil organic matter are the four dominant sources of nitrogen which have the potential to affect the nitrogen level of aquifers.

Table 1. Nutrients in Irrigation Water at the Staples Station, 1987

Location	NO_3-N	P	K	Ca	Mg	Na	Zn	Cu	B	Mn
	ppm									
Well B (M)	6.0	T	1.9	9	22	1.7	T	T	.01	T
Well B (M/R)	6.2	T	3.2	10	22	1.8	T	T	.02	T
Well B (ST)	5.3	T	2.5	17	1	.7	.12	T	T	.15
Well C (M)	3.5	T	2.6	30	22	1.7	.02	.01	.01	.06
Well D (ST)	4.0	T	1.6	38	26	2.4	T	T	.01	.10
SE RT (ST)	0.8	T	1.2	17	17	1.4	T	T	T	.05
SW Pit (Rain)	T	T	2.0	22	13	1.7	T	T	T	.03

Table 2. Nutrients in Irrigation Water Expressed in Pounds per Acre based on 13 inches of Irrigation Water delivered in 1987, Staples

Location	Pounds Per Acre - 13 inches Water	
	NO_3-N	$CaCO_3$ Equivalent
Well B (M)	17.6	390
Well B (M/R)	18.3	260
Well B (ST)	15.6	455
Well C (M)	10.3	572
Well D (ST)	11.8	520
SE Rt (St)	2.3	273
SW Pit (Rain)	T	260

Summary: With high usage of supplemental water less than 20 pounds of nitrogen would be supplied to a high N use crop such as corn. This value is only slightly higher than the amount of nitrogen supplied by rainfall.

The deposition of $CaCO_3$ equivalent in irrigation water over an extended duration has increased soil pH on the station from 5.8 to 7.5 or higher.

LUPIN BEAN STUDY

H.L. Meredith, Melvin Weins, Greg Cremers and Andy Scobbie

The sweet white lupin (Lupinus albus) studies initiated at the Staples Station in 1984 were continued. Previous yield data indicated no response to applied fertilizer. In 1987 two sites were planted to lupins for the fertility evaluation. One site is continuous lupins since 1984 while the second site is planted to an area following a non-lupin crop. The yield data appear in Table 1.

Table 1. Summary of yields of Lupins 1984 to date, Staples Station, Staples, MN. Yields are based on 13.5 percent moisture and 60 pound bushel weight.

Treatment	Yield bu/A					
	1984	1985	1986		1987	
	Exp #1	Exp #1	Exp #1	Exp #2	Exp #1	Exp #2
1. No Fertilizer	39.1	71.4	40.6	32.0	57.2	61.8
2. S 100#/A	43.2	71.2	44.0	31.7	54.3	62.8
3. S + 300# K_2O	40.5	63.8	40.6	43.3	49.9	61.9
4. S + K + 60# P_2O_5	39.4	68.8	39.2	40.2	56.6	61.8
5. S + K + P + 10# Zn	39.4	64.1	41.8	37.4	47.2	56.3
6. S + K + P + Zn + 2# B	41.5	64.9	33.8	32.8	54.8	60.8

Experiment #1 is located on the same area each year while experiment #2 is planted following a non-lupin crop. No significant difference in yield as a response to a fertility treatment have been observed to date. Observed differences in yield are attributed to population variables.

Table 2. Nutrient content of Lupin Beans, Staples Station, Staples, MN 1987. Experiment #1, continous lupins.

Treatment	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B	Fe
	%							ppm			
1	5.51	.27	.41	1.11	.26	.20	.106	43.2	3.42	14.6	32.2
2	5.53	.27	.41	1.13	.26	.20	.092	41.8	3.18	13.8	29.2
3	5.33	.28	.41	1.20	.25	.20	.105	44.0	3.46	14.5	30.1
4	5.56	.29	.44	1.28	.24	.20	.117	45.8	3.72	13.6	33.8
5	5.63	.29	.47	1.24	.26	.21	.084	41.5	2.49	11.4	30.9
6	5.51	.29	.45	1.26	.26	.21	.101	55.8	3.37	24.3	34.7

Table 3. Nutrient Content of Lupin Beans, Staples MN 1987. Experiment #2 (1st year lupins).

Treatment	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B	Fe
	%							ppm			
1	5.04	.268	.529	1.25	.264	.202	.130	56.1	5.51	19.6	35.6
2	5.06	.277	.506	1.25	.273	.203	.117	55.8	5.10	19.7	36.5
3	4.97	.296	.558	1.35	.274	.211	.134	61.2	5.68	18.9	37.6
4	4.84	.279	.584	1.38	.285	.214	.114	58.8	5.77	19.7	35.4
5	4.82	.302	.576	1.38	.292	.218	.094	62.7	5.04	19.0	37.4
6	4.85	.299	.575	1.39	.285	.211	.122	63.4	5.84	25.5	36.0

Table 4. Lupin Bean (Grain) Nutrient Removal, Staples, MN 1987. Experiment #1, Continuous Lupins.

Treatment	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B	Fe
	-lbs/A-										
1	163.5	8.11	12.3	32.8	7.81	5.84	3.12	.128	.010	.043	.095
2	155.6	7.62	11.6	31.9	7.29	5.61	2.60	.118	.009	.039	.082
3	137.9	7.31	10.7	31.2	6.55	5.04	2.71	.115	.009	.038	.078
4	163.4	8.52	13.0	37.5	7.22	5.81	3.44	.134	.011	.040	.099
5	138.0	7.12	11.5	30.5	6.49	5.15	2.06	.102	.006	.028	.076
6	156.7	8.14	12.8	35.7	7.28	5.87	2.85	.158	.010	.069	.098

Table 5. Lupin Bean (Grain) Nutrient Removal, Staples, MN 1987. Experiment #2 (1st year Lupins).

Treatment	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B	Fe
	lbs/A										
1	161.5	8.54	17.0	40.2	8.48	6.51	4.07	.180	.018	.063	.114
2	164.8	9.03	16.5	40.9	8.91	6.61	3.86	.181	.017	.064	.119
3	159.6	9.50	17.9	43.2	8.80	6.77	4.28	.196	.018	.061	.121
4	155.4	8.98	18.7	44.1	9.13	6.87	3.53	.188	.018	.063	.114
5	140.6	8.82	16.8	40.3	8.55	6.37	2.75	.184	.015	.056	.110
6	152.9	9.43	18.2	44.0	8.97	6.68	3.84	.201	.018	.081	.114

Table 6. Lupin Bean (Grain) Test Weight, lbs/bu., Staples, MN 1987.

Treatment	Exp #1	Exp #2
1	63.1	64.3
2	62.9	64.1
3	62.2	64.2
4	62.2	63.8
5	62.4	61.3
6	63.4	64.8

LUPIN LIME AND SULFUR AMENDED STUDY

H. Meredith, Mel Weins, Greg Cremers and Andy Scobbie

Elemental sulfur (flower of sulfur) and finely ground limestone were applied to lupin plots to determine effects on concentration and yield of various nutrients in the seed.

Table 1. Nutrient Concentration of Lupins Grown on Lime Amended Soils, Staples 1987.

Treatment #	lbs Lime Per Acre	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
		%						ppm				
1	0	5.6	.27	.40	1.1	.26	.20	32	888	45	3.0	15
2	500	5.7	.27	.43	1.2	.26	.21	34	914	46	3.4	16
3	1000	5.8	.27	.41	1.2	.27	.21	33	903	42	2.9	15
4	2000	5.6	.29	.43	1.2	.27	.21	35	947	46	3.6	16

Table 2. Nutrient Uptake of Lupins Grown on Lime Amended Soil, Staples 1987

Treatment #	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lbs/A										
1	161	7.8	12	33	7.3	5.8	.09	2.5	.13	.009	.04
2	142	6.7	11	30	6.4	5.2	.08	2.4	.12	.008	.04
3	164	7.6	12	33	7.6	5.9	.09	2.5	.12	.008	.04
4	155	8.0	12	33	7.4	5.7	.10	2.7	.13	.010	.04

Table 3. Nutrient Concentration of Lupins Grown on Sulfur Amended Soils, Staples 1987

Treatment #	lbs Sulfur (S) per acre	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
		%						ppm				
1	0	5.8	.32	.40	1.1	.27	.19	32	931	52	3.1	18
2	500	5.7	.37	.40	1.2	.26	.19	33	1138	57	4.4	18
3	1000	5.8	.38	.40	1.2	.26	.20	32	1010	59	4.0	18
4	2000	5.6	.39	.38	1.2	.29	.18	30	1102	53	4.0	18

Table 4. Nutrient Uptake of Lupins Grown on a Sulfur Amended Soil, Staples 1987

Treatment #	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------	----------	----------	----------	----------	Lbs/A	----------	----------	----------	----------	----------
1	168	9.3	12	33	7.8	5.6	.09	2.6	.15	.009	.05
2	189	12.0	13	40	8.5	6.3	.11	3.7	.19	.015	.06
3	194	12.6	13	41	8.7	6.6	.11	3.4	.20	.013	.06
4	195	13.5	13	41	10.1	6.4	.11	3.8	.19	.014	.06

Table 5. Yield and Test Weight of Lupins Grown on Lime and Sulfur Amended Plots, Staples 1987

	Sulfur Amended		Lime Amended	
Treatment #	Yield bu/A	Test Wt. lbs/bu	Yield bu/A	Test Wt. lbs/bu
1	55.4	63.4	55.2	63.0
2	63.4	63.4	47.6	62.8
3	63.8	63.6	54.6	62.8
4	67.4	64.6	53.4	62.2

Conclusions: The primary objective was to determine if amendments of lime or sulfur would alter nutrients accumulated in the seed, especially manganese. It appears concentration of most elements remained similar. Sulfur uptake and concentration in the seed was increased with addition of sulfur. Boron, copper, zinc and manganese were increased with the sulfur addition. Potassium uptake appeared to increase with the sulfur addition as well.

Yield increase appeared to be the most dramatic difference between the two treatments of about 10 bushels per acre. This may be reflective of the lower pH brought about by addition of the elemental sulfur.

This study will be continued to follow this trend.

Table 6. Soil Test Data, Staples Station, Staples MN 1987. Experiment #1, Continuous Lupins

Treatment	Depth Inches	pH	P	K	S
Check	0-6	7.7	80	110	5
	6-12	7.6	70	77	6
Sulfur(s)	0-6	7.7	88	102	5
	6-12	7.6	74	90	
S + K	0-6	7.2	90	183	4
	6-12	6.7	85	83	4
SK + P	0-6	7.6	75	297	5
	6-12	7.3	77	263	
SKP + Zn	0-6	7.6	137	317	8
	6-12	7.6	95	309	
SKP Zn + B	0-6	7.5	122	420	7
	6-12	7.5	87	306	

Sulfur: 100 lbs elemental sulfur/A
Potassium: 300 lbs K_2O/A
Phosphorus: 60 lbs P_2O_5/A
Zinc: 10 lbs Zn/A
Boron: 2 lbs B/A

Table 7. Soil Test Data from Lime Additions, Staples Station, 1987.

Treatment	Depth Inches	pH	P	K	S
Check	0-6	7.5	56	97	6
	6-12	7.4	57	78	
500# Lime	0-6	7.5	56	131	6
	6-12	7.4	54	83	
1000# Lime	0-6	7.5	57	86	5
	6-12	7.4	55	71	
2000# Lime	0-6	7.5	63	102	8
	6-12	7.5	59	96	

Table 8. Soil Tests Data from Sulfur Additions, Staples Station, Staples, MN 1987.

Treatment	Depth Inches	pH	P	K	S
Check	0-6	7.5	67	114	5
	6-12	7.2	58	72	5
500# S	0-6	6.9	55	108	23
	6-12	6.8	50	66	13
1000# S	0-6	6.7	55	110	27
	6-12	6.8	53	65	21
2000# S	0-6	6.3	63	124	40+
	6-12	6.5	53	74	40+

S - elemental sulfur, lbs/A

SOUTHERN EXPERIMENT STATION
WASECA, MINNESOTA

WEATHER DATA - 1987

Month	Period	Precipitation 1987	Precipitation Normal 1/	Avg. Air Temp. 1987	Avg. Air Temp. Normal 1/	Growing Degree Days 1987	Growing Degree Days Normal 2/
		---- inches ----		------ °F -----			
January	1-31	0.96	0.84	18.0	10.0		
February	1-28	0.12	0.99	29.1	16.4		
March	1-31	1.23	1.99	35.8	27.6		
April	1-30	0.41	2.64	50.0	44.7		
May	1-10	0.09		59.1		119.5	
	11-20	1.10		66.3		157.5	
	21-31	0.87		63.3		160.0	
	Total	2.06	3.76	62.9	57.7	437.0	334
June	1-10	0.05		69.2		184.5	
	11-20	1.23		74.5		225.0	
	20-30	2.20		68.6		186.0	
	Total	3.48	4.48	70.8	67.1	595.5	518
July	1-10	2.40		71.1		211.0	
	11-20	2.63		71.3		210.0	
	21-31	2.24		79.1		300.5	
	Total	7.27	4.02	73.8	71.2	721.5	641
August	1-10	4.06		71.8		205.5	
	11-20	0.74		70.0		198.0	
	21-31	0.57		60.6		130.5	
	Total	5.37	3.99	67.1	68.8	534.0	579
September	1-30	2.03	3.36	61.3	59.8	374.5	311
October	1-31	1.76	2.08	42.5	48.9	20.0	38
November	1-30	1.90	1.43	37.0	32.5		
December	1-31	2.34	1.02	22.1	18.0		
Year	Jan-Dec	27.97	30.60	47.6	43.6	2682.5 2/	2421
Growing Season	May-Sep	20.21	19.61	67.2	64.9	2662.5	2383

1/ 30-year normal from 1951 - 1980.
2/ 50 to 86°F base, May 1 until first fall frost.

Notes:
1) Highest temperature on June 14 and 15 -- 98°.
2) Highest 24-hour precipitation on August 9 -- 1.90".
3) Highest 48-hour precipitation on August 8-9 -- 2.20".
4) Last spring frost -- April 8.
5) First fall frost -- October 3.
6) Warmest year since 1939, 5th warmest in 73 years of records.
7) Driest year since 1976.

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

Waseca, 1987

Gyles W. Randall, Gary L. Malzer and Brian W. Anderson

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

EXPERIMENTAL PROCEDURES

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

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

Anhydrous ammonia was applied at a rate of 135 lb/A for all N treatments while N-Serve was applied at 0.5 lb/A. Fall treatments were applied on October 21. Average soil temperature at the 4" depth on that date was 44°F with an average of 43°F over the following 10-day period. Spring preplant treatments were applied on April 23. The sidedress portion (60%) of the split treatments was applied at the V-7 stage on June 15.

No primary or secondary tillage was done on the soybean area that was planted to corn in 1987. The corn area, however, was fall chiseled and spring disked once prior to planting soybeans. Surface residue accumulation estimated by the line-transect method on April 6 showed an average of 21 and 53% for the areas that were planted to corn and soybeans, respectively, in 1986. Because of high soil P and K tests no broadcast nor starter fertilizer was used.

Corn (Pioneer 3737) was planted at 30,800 plants/acre on May 6 with a JD Max-Emerge planter equipped with waffle coulters. A corn rootworm insecticide was not used. Weeds were chemically controlled with a preemergence application of Lasso (3.5 lb/A) plus Bladex (3 lb/A).

Soybeans (Hardin) were planted in 30" rows at 9 beans per foot of row on May 6. Weeds were chemically controlled with a preemergence application of Lasso (3½ lb/A) plus Amiben (3 lb/A).

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

Stand counts were taken at the V-7 stage and plots were thinned to a uniform population. Eight randomly selected plants were removed from the center rows at silk initiation (July 16) and were chopped, dried, weighed and ground for total dry matter accumulation and analyzed for total N

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concentration. Stover and grain samples were taken at physiological maturity by hand harvesting 30' of row for stover yields and 60' of row for grain yields and moisture. Chemical analyses of whole plant, stover and grain samples were performed by the Research Analytical Laboratory, University of Minnesota.

Tile line flow rates were determined daily and were recorded when flow exceeded 10 ml/minute (0.01"/day). Samples were collected for NO_3-N analysis on an every-other-day basis. Periodic samples were collected for alachlor (Lasso) and cyanazine (Bladex) analyses.

Soil samples for NO_3-N analysis were taken in 1-foot increments to a depth of 8 feet from three corn plots and three soybean plots on April 9. The same technique was used to sample all corn plots after harvest on October 13.

RESULTS AND DISCUSSION

Plant

Whole plant N concentration and DM accumulation at the silking stage were greatly increased over the check by all of the N treatments with little difference among the six N treatments (Table 1). Stover N concentrations and yield at physiological maturity (PM) were affected similarily by the treatments (Table 1). Slight differences in final population were significant due to the extremely low CV (1.9%).

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

N application		Whole Plant Silk Stage		Stover		
Time	N-Serve	N	DM	N	Yield	Final Population
		%	g/plt	%	TDM/A	ppA x 10^3
Primary trts						
Fall (Oct.)	No	1.60	125	.49	2.79	29.2
Fall (Oct.)	Yes	1.51	129	.46	3.29	28.8
Spr. (April)	No	1.52	128	.42	2.97	29.6
Split[1/]	No	1.59	130	.44	3.19	28.9
Additional trts						
Check	-	.86	96	.31	2.37	30.2
Spr. (April)	Yes	1.66	134	.54	2.76	29.1
Split[1/]	Yes	1.63	130	.46	3.12	29.0
		Statistical Analysis				
Latin square (Prim. Trts)						
Signif. Level (%):		76	42	68	82	59
CV (%) :		4.5	3.9	11.	9.6	2.3
Completely randomized (7 trts)						
Signif. Level (%):		99	99	99	99	97
BLSD (.05) :		.14	8	.11	.36	.9
CV (%) :		7.3	4.6	15.	8.4	1.9

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

Grain yield, N concentration, and N removal (product of grain yield times N conc.) were all increased significantly over the control by the N treatments (Table 2). Although statistically not significant, yields from the fall applications, regardless of N-Serve, trailed the yields from the spring and split applications. Silage yields were also increased significantly over the check by all of the N treatments (Table 2). In addition, the addition of N-Serve to the fall application resulted in a significant silage yield increase. Silage yield differences were not significant among the spring and split treatments.

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

N application		Grain					Total N
Time	N-Serve	Yield	H_2O	N	N removal	Silage	uptake
		bu/A	%	%	lb/A	TDM/A	lb/A
Primary trts							
Fall (Oct.)	No	179.2	16.8	1.39	117.6	7.52	144.6
Fall (Oct.)	Yes	182.3	18.4	1.40	120.5	8.45	150.7
Spr. (April)	No	184.5	17.5	1.40	121.6	7.78	146.4
Split[1/]	No	194.8	17.2	1.34	123.7	8.22	151.5
Additional trts							
Check	-	106.8	21.3	.98	49.4	5.39	63.9
Spr. (April)	Yes	191.9	19.7	1.34	122.1	7.92	151.9
Split[1/]	Yes	188.7	18.8	1.30	116.0	8.27	144.9
Statistical Analysis							
Latin square (Prim. trts)							
Signif. Level (%):		73	63	68	59	75	64
CV (%) :		5.6	6.7	3.1	4.0	7.8	4.0
Completely randomized (7 trts)							
Signif. Level (%):		99	99	99	99	99	99
BLSD (.05) :		12.8	2.1	.07	8.8	.67	12.6
CV (%) :		5.5	7.5	4.0	6.0	6.4	6.9

1/ 40% preplant + 60% sidedress.

Total N removal in the grain ranged from 116.0 to 123.7 lb/A but was not different among the six treatments (Table 2). Nitrogen efficiency (N removed by a treatment - N removed in the check ÷ 135 lb N/A) ranged from 49.3 to 55.0%. Total N uptake by the above-ground portion of the plants ranged from 144.6 to 151.9 lb/A but was not different among the six treatments. Nitrogen efficiency based on total plant uptake ranged from 59.8 to 65.2%. These efficiency values were quite good considering soybeans were the previous crop.

Total N uptake by the plant prior to silking (Fodder N yield at silking ÷ total N uptake at PM) shows that from 84 to 94% of the N was accumulated by the plants prior to silking (Table 3). Surprisingly, the highest amounts of pre-silk accumulation were with the spring and split applications with N-Serve. NEW N in the grain (assumed to be taken up by the plant after silking and translocated to the grain) ranged from only 8% to 19%, but because of the high experimental error this difference was not significant at the P = 90% level. Under these experimental conditions spring and split applications of N with N-Serve definitely did not lead to greater amounts of late-season N accumulation.

Water

April through June conditions were dry and warm and resulted in very favorable conditions for soil mineralization and rapid early season plant growth. July rainfall totaled 7.27" (3.25" above normal) and recharged much of the soil profile moisture. Rainfall during August was 1.38" above the normal of 3.99". Tile flow of slightly over 1.5" occurred in the 14-day period from August 3 thru the 17th (Table 4).

Flow-weighted nitrate-N concentrations averaged from 5.7 to 7.7 mg/L but were not significantly different for the N treatments (Table 4). These values were quite low probably due to the large amount of N taken up by the plants as well as the low amount of residual soil N in the profile at the beginning of the season (Table 5). Nitrate-N losses via the tile lines were almost negligible (<3 lb N/A). It is interesting to note that average NO_3-N concentrations were over twice as high (17.2 mg/L) from the two fallow plots.

Table 3. Influence of time of N application and N-Serve on time of N uptake.

N application		Fodder N Yield at[1/]		Grain N Yield at PM			
Time	N-Serve	Silk	PM	Total	OLD[2/]	NEW[3/]	NEW[3/]
		lb N/A					%
Primary trts							
Fall (Oct)	No	128.5	27.0	117.6	101.5	16.1	13
Fall (Oct)	Yes	127.3	30.2	120.5	97.1	23.4	19
Spr (April)	No	126.5	24.9	121.6	101.7	19.9	16
Split[4/]	No	132.0	27.8	123.7	104.2	19.5	16
Additional trts							
Check	-	55.7	14.5	49.4	41.2	8.2	17
Spr (April)	Yes	142.0	29.8	122.1	112.3	9.8	8
Split[4/]	Yes	135.6	28.9	116.0	106.7	9.3	8
Statistical Analysis							
Latin square (Prim. trts)							
Signif. Level (%):		58	98	59	64	32	36
BLSD (.05) :		-	3.0	-	-	-	-
CV (%) :		3.6	6.2	4.0	5.1	42.	42.
Completely randomized (7 trts)							
Signif. Level (%):		99	99	99	99	80	35
BLSD (.05) :		11.4	6.3	8.8	11.3	-	-
CV (%) :		7.1	16.	6.0	8.9	64.	78.

1/ Silk = silk stage, PM = physiological maturity.
2/ OLD N = N in stover at silk - N in stover at PM; the difference is assumed to be translocated to the grain.
3/ NEW N = Total N in grain - Old N; the difference is assumed to be absorbed from the soil and/or translocated from the roots after silking.
4/ 40% preplant + 60% sidedress.

Table 4. Influence of N application time and N-Serve on NO_3-N concentration in NO_3-N loss to tile lines.

N Application		Tile Flow[1/]	NO_3-N	
Time	N-Serve		Concentration	Loss
		acre-inches	mg/L	lb N/A
Fall	No	1.86	6.9	2.49
Fall	Yes	1.63	5.7	1.91
Preplant	No	1.64	7.3	2.74
Split	No	1.71	7.7	2.64
None (Fallow) [2/]	-	1.55	17.2	4.78

1/ Tile flow occurred August 3rd to August 17th.
2/ Average of 2 replications.

Soil

Nitrate-N amounts in the 0-8' soil profile following soybeans were very low prior to planting (Table 5). Higher amounts were found in the area planted to corn in 1986; especially at the 3 to 5' depth near the tile lines.

Table 5. Nitrate-N in the soil profile in April, 1987 as influenced by previous crop.

Profile depth	1986 Crop	
	Soybean	Corn
feet	lb/A	
0-1	34.0	24.3
1-2	9.5	9.7
2-3	4.1	16.1
3-4	4.0	23.9
4-5	5.1	23.3
5-6	7.3	13.5
6-7	6.9	7.7
7-8	7.5	7.7
Total in		
0-5' profile	56.7	97.3
0-8' profile	78.4	126.2

Residual NO_3-N remaining after the 1987 crop was considerably higher than in April (Table 6). The exact reasons for this are not clear at this time. Differences among treatments are slight except that markedly higher levels were found following the split application with N-Serve and in the fallow plots.

Table 6. Residual NO_3-N remaining in the 0-8' soil profile after harvest as influenced by time of N application and N-Serve.

Profile depth	Fallow[1/]	Check[1/]	Application Time					
			N-Serve			No N-Serve		
			Fall	Preplant	Split	Fall	Preplant	Split
ft.	lbs NO_3-N/A							
0-1	85.6	68.8	60.0	69.6	94.0	68.4	55.2	62.4
1-2	63.2	53.6	32.0	43.6	53.6	42.8	39.2	37.2
2-3	62.8	35.2	26.0	28.8	40.8	27.6	26.4	33.6
3-4	48.4	26.8	28.4	30.0	36.0	32.0	22.8	26.4
4-5	37.6	28.8	31.2	34.4	33.6	27.2	29.6	25.6
5-6	34.0	37.6	31.6	32.8	34.8	30.4	30.0	28.8
6-7	31.2	30.0	29.6	34.0	29.2	30.4	27.2	29.2
7-8	28.8	28.8	28.0	32.4	31.2	30.4	27.6	31.2
Total in 0-8' profile	392	310	267	306	353	289	258	274

1/ Avg. of 2 replications

CONCLUSIONS

Corn yields were improved significantly with all of the N treatments with little difference among the times of application or the addition of N-Serve. Nitrogen uptake and efficiency were high; however differences did not exist among the time of application or N-Serve treatments. Approximately 90% of the N accumulated by the corn was taken up by silking. Tile flow occurred over only a 14-day period in August. Nitrate-N concentrations and losses in the tile water averaged only about 7 mg/L and 2.5 lb/A, respectively, and were not affected by time of N application. Nitrate-N concentrations in the tile water from the fallowed plots averaged 17 mg/L. Residual NO_3 in the soil profile at the end of the growing season was highest in the fallow plots and in the plots that received the split application with N-Serve.

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SPLIT APPLICATION OF N FOR CORN ON A WEBSTER SOIL

Waseca, 1987

G. W. Randall and B. W. Anderson

Improved nitrogen (N) efficiency is a goal of many corn producers because of the enhanced economic return to their fertilizer dollar. One potential method of improving the efficiency of N is to apply it closer to the period of greatest demand by the plant. For corn this is the period from three weeks prior to three weeks after tasseling. Applying N closer to this period limits the potential for N loss due to leaching or denitrification. Split applications of N have been shown to be quite beneficial on coarse-textured soils where leaching losses are common. The primary purpose of this study was to evaluate split applications of N to a naturally, poorly drained Webster clay loam where leaching is thought not to be a problem.

EXPERIMENTAL PROCEDURES

A poorly drained Webster clay loam soil with lateral tile lines at 75-foot spacings was the experimental site. Corn, which had been fall moldboard plowed, was the previous crop. Soil tests of the site showed a pH = 6.9, OM = High, Bray P_1 = 56 lb/A (VH), and exchangeable K = 461 lb/A (VH).

Sixteen N treatments were applied in a randomized, complete-block design with five replications (Table 1). Each plot measured 10' wide (4 - 30" rows) by 60' long. Split treatments consisted of either a 1/3-rate applied preplant with the remaining 2/3 sidedressed or 2/3 applied preplant and 1/3 sidedressed. Preplant treatments of anhydrous ammonia (AA) and urea-ammonium nitrate solution (UAN) were applied on April 17 and April 22, respectively. Anhydrous ammonia was injected while the UAN was broadcast applied on the soil surface. The entire experimental area was field cultivated on April 27.

Corn (Pioneer 3906) was planted at 30400 ppA on May 6. No starter fertilizer was used. Furadan was used at a rate of 1 lb(ai)/A to control rootworms. Weeds were chemically controlled with a preemergence application of Lasso (3½ qt/A) plus Atrazine (3 qt/A). Rootworm and weed control were excellent.

The sidedress portions of the split treatments were applied at the 8-leaf stage (June 16). The AA was injected while the UAN was applied either dribbled in bands on the soil surface 12" from the row or injected 4 to 6" deep using Yetter coulters and thin-profile knives. All plots were cultivated two days later (June 18) to incorporate the surface-applied UAN. On June 18 and 23, 0.35 and 1.37 inches of rain occurred, respectively, to saturate the surface 1-foot for a few days.

Six randomly selected whole plants were harvested from the center two rows at the silk initiation stage (July 16), were chopped, dried and weighed for dry matter accumulation, and were analyzed for total N concentration. Stover and silage yields were obtained at physiological maturity (PM) (Sept. 3) by hand harvesting 15' of row. Grain yields were determined on October 1 by harvesting the center two rows with a modified JD3300 plot combine. Chemical analyses of the whole plants, stover, and grain were performed by the Research Analytical Laboratory, University of Minnesota.

RESULTS

Whole plant N at silking

Distinct N deficiency symptoms were evident on the plants from the control plots at the silking stage. Whole plant N concentrations given in Table 1 show all N treatments except the 60-lb rate as UAN (PP) + UAN (SD dribble) with significantly more N than the control. Factorial comparisions of the treatments show a linear response to N rate when averaged over source-time of application. When averaged over N rates significantly less whole plant N was found with the split application of 1/3 UAN (PP) + 2/3 UAN (SD dribble) compared to all other N treatments. The significant N rate x method of application interaction (P = 95%) was due to a general increase in N concentration with increasing N rate for all methods of application except the split application where AA was the SD source of N. Apparently much of this late-applied N had not been absorbed into the plant at this time.

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Whole plant dry matter at silking

Total dry matter accumulation at silking was increased significantly over the control by some of the N treatments (Table 1). Factorial comparison of the treatments shows a response through the 120-lb rate of N when averaged over method of application. Highest DM accumulation occurred with the preplant AA and the 2/3 AA + 1/3 UAN split treatments.

Table 1. Whole plant N, stover N, stover yield, and final population as influenced by split applications of N.

Nitrogen Rate	Nitrogen Time[1/]	Nitrogen Source[2/]	Whole plant at silk N	Whole plant at silk DM	Stover N	Stover Yield	Final population
lbN/A			%	g/pl	%	TDM/A	ppA x 10^3
0	--	CHECK --	.98	116	.37	2.52	27.3
60	PP	AA	1.40	120	.39	3.12	28.1
120	"	"	1.50	130	.48	3.66	28.2
180	"	"	1.79	121	.63	3.78	27.6
60	1/3PP+2/3SD	UAN(PP)+AA(SD)	1.52	111	.49	3.00	27.1
120	"	"	1.45	133	.48	3.36	27.4
180	"	"	1.51	122	.51	3.45	27.4
60	"	UAN(PP)+UAN(Drib.SD)	1.04	111	.41	2.40	28.0
120	"	"	1.19	118	.38	2.91	27.2
180	"	"	1.21	121	.39	2.87	28.1
60	"	UAN(PP)+UAN(Inj.SD)	1.45	114	.44	2.98	27.6
120	"	"	1.58	121	.51	3.22	27.4
180	"	"	1.61	120	.53	3.48	26.8
60	2/3PP+1/3SD	AA(PP)+UAN(Drib.SD)	1.52	122	.44	3.10	28.1
120	"	"	1.60	130	.50	3.20	27.9
180	"	"	1.68	131	.52	3.81	27.9
Signif. Level (%):[3/]			99	99	99	99	87
BLSD (.05) :			.14	12.	.07	.39	-
CV (%) :			8.1	7.1	12	11	2.8
FACTORIAL COMPARISONS							
Main Factors							
N Rate (lb/A)							
60			1.40	115	.43	2.90	27.8
120			1.48	123	.47	3.27	27.6
180			1.56	126	.51	3.48	27.6
Signif. Level (%):[3/]			99	99	99	99	35
BLSD (.05) :			.06	5	.03	.20	-
Method (N Time-Source)							
PP - AA			1.57	124	.50	3.52	28.0
PP/SD - UAN/AA			1.50	122	.49	3.27	27.3
PP/SD - UAN/UAN (Dribble)			1.15	116	.39	2.73	27.8
PP/SD - UAN/UAN (Inject)			1.54	118	.49	3.22	27.3
PP/SD - AA/UAN (Dribble)			1.60	128	.49	3.37	28.0
Signif. Level (%):[3/]			99	99	99	99	97
BLSD (.05) :			.08	7	.04	.25	.6
Interaction			Significance Level (%)[3/]				
N Rate x Method			95	57	99	32	60

1/ PP = preplant, SD = sidedress applied at the 8-leaf stage.
2/ AA = anhydrous ammonia, UAN = 28-0-0, Inj = injected 4 to 5" deep, Drib = dribbled in a band next to row.
3/ Probability level of significance.

Stover N

Nitrogen concentrations in the stover at PM were increased linearly by the N rates when averaged over method of application (Table 1). Lowest stover N concentrations were found with the split application of UAN when the SD treatment was dribbled on the surface and cultivated in. Stover N concentrations were not different among the other application methods averaged over N rates. The highly significant N rate x method interaction was due to no influence of N rate on stover N with the split applications when UAN was the sole N source compared to the linear effect of N rate with the other application methods.

Stover Yield

Stover yield was increased signficantly over the check by all of the N treatments except split application of UAN that was dribbled on the surface (Table 1). There was a linear effect of N rate when averaged over methods of application. Stover yields were significantly lower with the split application of UAN when the SD treatment was dribbled on the soil surface compared to all other methods of application.

Table 2. Corn grain and silage production as influenced by split applications of N.

Nitrogen			Grain				Silage	Total N
Rate	Time	Source	Yield	H_2O	N	N Removal	Yield	Uptake
lb/A			bu/A	---	% ---	lb/A	TDM/A	lb/A
0	--	CHECK --	87.3	16.2	1.25	51.9	5.54	70.8
60	PP	AA	118.2	16.9	1.34	75.0	7.04	98.6
120	"	"	147.1	18.1	1.49	103.3	7.98	138.5
180	"	"	152.9	18.2	1.54	111.6	8 36	159.3
60	1/3PP+2/3SD	UAN(PP)+AA(SD)	130.8	16.5	1.36	84.7	7.24	114.1
120	"	"	152.6	16.4	1.44	103.9	8.11	136.6
180	"	"	154.8	16.7	1.52	111.6	8.52	147.0
60	"	UAN(PP)+UAN(Drib.SD)	98.4	16.5	1.27	59.0	5.66	78.6
120	"	"	108.2	16.2	1.28	65.8	6.56	88.2
180	"	"	123.1	15.8	1.30	75.4	6.77	95.9
60	"	UAN(PP)+ UAN(Inj.SD)	123.3	16.7	1.34	78.1	6.98	104.4
120	"	"	148.7	17.0	1.43	100.5	7.72	133.0
180	"	"	154.3	17.4	1.47	107.2	8.38	144.2
60	2/3PP+1/3SD	AA(PP)+UAN(Drib.SD)	127.5	17.4	1.34	81.0	6.75	106.3
120	"	"	146.9	17.8	1.43	99.7	7.52	130.9
180	"	"	149.5	18.1	1.55	109.3	8.55	149.2
Signif. Level (%):			99	99	99	99	99	99
BLSD (.05) :			8.8	1.0	.06	6.7	.76	10
CV (%) :			5.9	4.6	3.6	6.7	8.8	7.8
FACTORIAL COMPARISONS								
Main Factors								
N Rate (lb/A)								
60			119.6	16.8	1.33	75.6	6.74	101.0
120			140.7	17.1	1.41	94.6	7.58	125.5
180			146.9	17.2	1.47	103.0	8.12	139.6
Signif. Level (%):			99	89	99	99	99	99
BLSD (.05) :			4.0	-	.03	3.0	.31	4.4
Method (N Time - Source)								
PP - AA			139.4	17.7	1.46	96.7	7.79	132.4
PP/SD - UAN/AA			146.1	16.5	1.44	100.1	7.96	132.6
PP/SD - UAN/UAN (Dribble)			109.9	16.2	1.28	66.7	6.33	88.3
PP/SD - UAN/UAN (Inject)			142.1	17.0	1.41	95.2	7.69	127.2
PP/SD - AA/UAN (Dribble)			141.3	17.8	1.44	96.7	7.61	129.6
Signif. Level (%):			99	99	99	99	99	99
BLSD (.05) :			5.2	.5	.03	3.9	.41	5.7
Interaction					Significance Level (%)			
N Rate x Method			80	68	99	99	8	99

Final Population

Final populations were not affected by N rate and were only slightly different among the methods of application (Table 1).

Grain Yield

Grain yields were increased significantly over the control by all N treatments (Table 2). Highest yields were obtained at the 180-lb rate for all application methods. When averaged over N rates, the highest yield was with the split application of UAN (PP) + AA (SD). This yield was significantly higher (6.7 bu/A) than with the single PP application of AA. Yields from the split UAN/UAN (injected) and AA/UAN (dribbled) treatments were not different from the single PP application of AA. Similar to 1986, yields were about 23% less with the split application of UAN/UAN (dribble) even though the dribbled SD application was cultivated in 2 days after application. Injecting the side-dressed UAN significantly improved grain yields over the dribbled application method by 32.2 bu/A. These results indicate that significant losses of N must have occurred with the dribbled sidedress application of UAN to the soil surface.

Grain Moisture

Significant differences in grain moisture at harvest occurred among the treatments, but no consistent trends were established (Table 2).

Grain N

Grain N was increased significantly over the control by all of the treatments except all rates of UAN/UAN (dribble) and was increased linearly at N rates from 0 to 180 lb/A when averaged over methods of application (Table 2). The split treatment using UAN for both PP and SD applications resulted in significantly lower N concentrations when the SD application was dribbled. The highly significant N rate x method interaction was due to no response to increasing N rate with the UAN/UAN (dribble) treatment while other methods showed increasing grain N with increasing N rates.

Grain N Removal

Grain N removal (product of grain yield times grain N concentration) was increased significantly over the check by all N rates (Table 2). Highest N removals were associated with the 180-lb rate for all methods of application except the UAN/UAN (dribble) treatment. When averaged over N rates, N removal was significantly lower with the UAN/UAN (dribble) treatment with little difference among the other four methods of application.

Nitrogen efficiency based on grain N removal minus that removed by the check averaged 40, 36, and 28% for the 60, 120, and 180-lb rates, respectively. When averaged over N rates, methods of application ranked according to highest efficiency were: split with UAN + AA (40%), single with preplant AA (37%), split with AA + UAN (37%), split with UAN both PP and SD injected (36%), and split with UAN both PP and SD dribbled (12%). This ranking was identical to 1986.

Silage Yield

Silage yields were increased significantly by all N treatments except the 60-lb rate of UAN/UAN (dribble) and continued to increase up through the 180-lb N rate (Table 2). Application of AA either all PP or 2/3 PP resulted in yields significantly higher than the other treatments. Lowest silage yields occurred with the split application of UAN/UAN (dribble).

Total N Uptake

Total N uptake by the corn was calculated by multiplying the stover N concentration times stover yield and adding it to grain N removal. Results of total N uptake were almost identical to those of grain N removal.

Nitrogen efficiency based on total N uptake minus that removed in the check averaged 50, 46, and 38% for the 60, 120, and 180-lb rates, respectively. When averaged over N rates, efficiency was 51, 52, 15, 47 and 49% for the single PP application of AA, split UAN + AA, split UAN + UAN (dribble), split UAN + UAN (injected), and split AA + UAN (dribble) treatments, respectively.

Time of N Uptake

To determine the effect of delayed/split applications of N on the time of N uptake relative to silking, whole plants (above-ground portions) were analyzed for total N at the silking stage and at PM (both grain and stover). Nitrogen uptake at the time of silking was increased over the check by all N treatments except the 60-lb rate of UAN/UAN (dribble) (Table 3). Pre-silk N uptake was optimized at the 120-lb rate when averaged over all methods of application. Highly significant differences in pre-silk N uptake were found among the application methods. Single and split PP applications of AA resulted in higher uptake than split applications where UAN was the PP source of N. This was especially true when UAN was the sole source of N and the SD application was dribbled on the surface.

Stover N yield at PM was increased over the check by all of the 120 and 180-lb rates except the UAN/UAN (dribble) treatment (Table 3). Stover N yield was optimized with the 180-lb N rate when averaged over application methods. Significantly less stover N yield was found for the UAN/UAN (dribble) application method compared to the other methods. The significant interaction between N rate and method was due to the lack of rate effect with the UAN/UAN (dribble) treatment in contrast to the significant rate effect with the other treatments. The difference between N yield at silking minus that at PM was assumed to be translocated to the grain and is termed OLD N. The amount of OLD N was increased up to the 120-lb N rate and was affected significantly by method of application (time-source). OLD N was significantly higher with the split AA/UAN treatment, intermediate with the single PP application of AA and split applications of UAN/UAN (inject) and UAN/AA, and significantly lower with the UAN/UAN (dribble) treatment.

NEW N is assumed to be that N taken up into the above-ground portion of the plant after silking and is calculated by substracting the OLD N from the total N in the grain at PM (Table 3). New N as a percent of the total N in the grain averaged 5% from the check treatment. This low amount was due to the large proportion of soil N taken up prior to silking under very favorable conditions. With higher than normal rainfall after silking, and a rather large plant biomass, the demand for additional N post-silk N (NEW N) was high but apparently was not met because of a low pool of available soil N. NEW N was increased significantly with increasing rate of application and averaged 3, 13 and 23% with the 60, 120 and 180-lb rates, respectively. The method of application (time-source) had a highly significant effect on the time of N uptake. Averaged over N rates, NEW N ranged from a high of 22% with the UAN(PP) + AA(SD) treatment to a low of 2% with the AA/UAN (dribble) treatment. Highest NEW N levels were found with the treatments that contained sidedress applications of AA or UAN injected. Injecting the sidedressed UAN resulted in significantly higher levels of NEW N compared to the dribbled application. Split applications of N resulted in greater amounts of late-season N uptake (NEW N) than the preplant AA treatment only when AA was the sidedressed N source. These data further substantiate the poor efficiency of the split applications of UAN especially when dribbled on the soil surface of these high OM, clay loam soils.

Residual Soil NO_3-N

Soil samples were taken in 1-foot increments to a depth of 5' from the check plots and all 180-lb N treatments to determine the effect of method (time-source) of N application on the amount of NO_3-N remaining in the soil after harvest. The data shown in Table 4 indicate substantially more NO_3-N left in the 5-foot profile with the single PP application of AA than with any of the split applications. On the other hand, NO_3-N amounts remaining from the UAN/UAN (dribble) treatment were not different from the 0-lb control treatment. Part of the reason for the higher concentrations associated with the injected treatment could be due to the soil sampling pattern used. Cores were taken midway between the rows; the same zone where the AA and UAN were injected. However, one would think that higher NO_3-N concentrations in the injection band would have dissipated throughout the profile in the 6-month interval between application and sampling.

N Recovery

A partial N budget can be obtained by adding the total N uptake shown in Table 2 to the residual NO_3-N shown in Table 4 for each 180-lb treatment, and then subtracting out the uptake plus residual from the check treatment. From this one can calculate the percent recovery at the end of the season by dividing by the rate of N application. At the optimum 180-lb N rate, the percent recovery averaged: preplant AA (88%), UAN + AA (64%), UAN + dribbled UAN (10%), UAN + injected UAN (58%), and AA + dribbled UAN (56%).

Table 3. Time of N uptake as influenced by rates and split applications of N.

Nitrogen Rate	Nitrogen Time	Nitrogen Source	Stover N Yield[1/] Silk	Stover N Yield[1/] PM	Grain N Yield at PM Total	Grain N Yield at PM OLD[2/]	Grain N Yield at PM NEW[3/]	Grain N Yield at PM NEW[3/]
lb/A			lb N/A					% of total
0	--	CHECK --	68.4	18.9	51.9	49.5	2.4	5
60	PP	AA	103.6	24.2	75.0	79.4	-4.3	-6
120	"	"	122.1	35.2	103.3	86.9	16.4	16
180	"	"	132.0	47.9	111.6	84.1	27.5	24
60	1/3PP+2/3SD	UAN(PP)+AA(SD)	100.7	29.4	84.7	71.2	13.4	14
120	"	"	115.5	32.7	103.9	82.9	21.0	20
180	"	"	111.4	35.4	111.6	76.0	35.6	32
60	"	UAN(PP)+UAN(Drib.SD)	71.9	19.6	59.0	52.3	6.6	10
120	"	"	83.1	22.5	65.8	60.6	5.2	8
180	"	"	90.2	21.5	75.4	68.7	5.7	6
60	"	UAN(PP)+UAN(Inj.SD)	99.9	26.3	78.1	73.6	4.5	5
120	"	"	115.9	32.4	100.5	83.4	17.1	17
180	"	"	113.1	37.1	107.2	76.0	31.1	29
60	2/3PP+1/3SD	AA(PP)+UAN(Drib.SD)	114.2	27.4	81.0	86.7	-5.7	-8
120	"	"	127.5	31.7	99.7	95.8	3.8	3
180	"	"	135.4	39.8	109.3	95.6	13.8	12
Signif. Level (%):			99	99	99	99	99	99
BLSD (.05) :			12.7	6.9	6.7	13.4	16.3	19
CV (%) :			10	19	6.7	14.6	103	114
FACTORIAL COMPARISONS								
Main Factors								
N Rate (lb/A)								
60			98.0	25.4	75.3	72.6	2.9	3
120			112.8	30.9	94.6	81.9	12.7	13
180			116.4	36.6	102.8	79.8	23.2	23
Signif. Level (%):			99	99	99	98	99	99
BLSD (.05) :			5.8	3.0	3.2	6.6	6.8	7
Method (N Time - Source)								
PP - AA			119.2	35.8	96.7	83.4	13.2	12
PP/SD - UAN/AA			109.2	32.5	100.1	76.7	23.3	22
PP/SD - UAN/UAN (Dribble)			81.7	21.6	66.4	60.1	6.6	9
PP/SD - UAN/UAN (Inject)			109.6	31.9	95.2	77.7	17.6	17
PP/SD - AA/UAN (Dribble)			125.6	32.9	96.2	92.7	4.0	2
Signif. Level (%):			99	99	99	99	99	99
BLSD (.05) :			7.3	4.0	4.1	7.7	9.5	10
Interaction			Significance Level (%)					
N Rate x Method			28	97	98	8	61	52

1/ Silk = silk stage, PM = physiological maturity.
2/ OLD N = N in stover at silk - N in stover at PM; the difference is assumed to be translocated to the grain.
3/ NEW N = Total N in grain - OLD N; the difference is assumed to be absorbed from the soil after silking and/or translocated from the roots.

Table 4. Residual soil NO_3-N after harvest in 1987 as influenced by N application method.

Profile depth	Check	Preplant AA	Split UAN+AA	Split UAN+UAN(D)	Split UAN+UAN(I)	Split AA+UAN(D)
	Application method 1/					
feet	lb NO_3-N/A					
0 - 1	38.4	53.6	47.2	32.8	47.2	43.2
1 - 2	13.2	52.4	30.0	10.4	24.8	22.8
2 - 3	9.6	20.0	18.0	9.6	13.6	12.8
3 - 4	10.0	12.4	13.6	10.8	12.8	11.6
4 - 5	12.0	13.6	13.6	12.0	15.2	14.8
Total in 0 - 5' profile	83.	152.	122.	76.	114.	105.

1/ 180 lb N/A

CONCLUSIONS - 1987

Corn production was improved slightly (6.7 bu/A) in 1987 by the split application of UAN (PP) + AA (SD) compared to the single PP application of AA. Split applications of N where UAN was the SD source of N did not improve corn production over the single PP application of AA. Split applications of UAN where the SD application was injected were superior to the surface dribble applications. Highest post-silk uptake (NEW N) of N occurred with the split applications when AA was sidedressed (22%) and UAN injected (17%). Lowest post-silk N uptake occurred when the sidedressed UAN was dribbled (9% and 2%). These results indicate greatest production and N efficiency when AA is used regardless of single or split application or when sidedressed UAN is injected.

THREE-YEAR SUMMARY

Average continuous corn yields for the 3-year period showed a consistent response to N up through the 180-lb rate (Table 5) regardless of application method. At the 60- and 120-lb N rates, slightly higher yields (5 bu/A), grain N removal, and total N uptake were obtained with the split application of UAN (PP) + AA (SD). This is also shown by the higher efficiency values based on N removed in the grain and total N taken up by the plant. There was no difference between the single PP application of AA and the split application of UAN (PP) + AA (SD) at the optimum N rate (180 lb/A). Split application of UAN/UAN when the sidedress application was dribbled on the surface resulted in yield depressions of 16, 19 and 12% at the 60, 120 and 180-lb N rates, respectively. Based on these results, sidedress application of UAN dribbled on the surface and cultivated in at the 8-leaf stage is not recommended on these soils. Sidedress applications at the 8-leaf stage should be injected at least 4 to 6" deep for maximum benefit.

Table 5. Three-year average grain yield, grain N removal, and total N uptake as influenced by split applications of N at Waseca.

Nitrogen Rate	Nitrogen Time	Nitrogen Source	Grain yield	Grain Removal	GNR 1/ Eff.	Total N Uptake	TNU 2/ Eff.
lb/A			bu/A	lb/A	%	lb/A	%
0	--	CHECK --	68.1	39.1	-	54.2	-
60	PP	AA	109.1	65.0	43	85.6	52
120	"	"	138.3	90.4	43	117.1	52
180	"	"	149.4	107.9	38	145.1	50
60	1/3PP+2/3SD	UAN(PP)+AA(SD)	114.0	71.6	54	93.6	66
120	"	"	143.4	98.9	50	125.3	59
180	"	"	150.8	109.1	39	138.6	47
60	"	UAN(PP)+UAN(Drib.SD)	93.6	57.2	30	75.7	36
120	"	"	113.7	71.6	27	93.5	33
180	"	"	131.7	88.4	27	112.3	32

1/ GNR Efficiency = (Grain N Removal - Grain N Removed from check) ÷ N rate applied.
2/ TNU Efficiency = (Total N Uptake - Total N Removed from check) ÷ N rate applied.

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NITROGEN LOSS TO TILE LINES AS AFFECTED BY TILLAGE

Waseca, 1987

G. W. Randall and B. W. Anderson

Nitrogen losses to tile lines have been documented in a number of research studies including some conducted at Lamberton and Waseca, Minnesota. These studies primarily showed that N losses were a function of the N application rate and amount of precipitation. To some degree the time of application and crop grown have been shown to influence NO_3-N loss to tile lines. The purpose of this long-term study is to determine if tillage has an effect on N utilization, accumulation of NO_3-N in the soil profile, and the subsequent loss of NO_3-N to tile lines.

EXPERIMENTAL PROCEDURES

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

In the fall of 1981, eight plots with the most uniform tile flow rates over the 1975-81 period were selected. Two tillage treatments (fall moldboard plow and no tillage) were replicated four times and randomized over the previous plot histories. Corn was grown on these plots in 1982 through 1986. The stalks were chopped in October, 1986 and moldboard plots plowed.

On April 23, 180 lb N/A as ammonium nitrate was broadcast applied to the surface of all plots. The moldboard treatment was then field cultivated. Corn (Pioneer 3732) was planted on April 27 at a population of 27700 plants/A with a John Deere Max-Emerge planter equipped with ripple coulters. Starter fertilizer was not used because of the high soil tests. Furadan was applied at 1 lb (ai)/A to control rootworms. Weeds were controlled with a preemergence application of Lasso (3½ lb/A) and atrazine (3 lb/A) applied May 8. Weed and insect control were excellent. Percent surface residue was measured on May 15 and averaged 10 and 89% for the MP and NT systems, respectively.

The leaf opposite and below the ear was taken from 10 randomly selected plants per plot at silking (July 10) and was analyzed for N. Silage and grain yields were taken at physiological maturity by hand harvesting 20 and 80' of row, respectively, from each plot.

Tile lines flowed from only August 4 to August 24. When tile lines were flowing, flow rates were measured daily and samples taken on a daily basis for the first week and then on a M-W-F basis thereafter for NO_3 analysis. All analyses were done by the Research Analytical Lab.

Soil NO_3-N in the 0-8' profile was determined from two cores/plot taken in 1-foot increments on October 14, 1987.

RESULTS

Although yields and N removal tended to be consistently higher with the moldboard plow (MP) system compared to the no tillage (NT) system, differences between the two tillage systems were not significant at the P = 90% level (Table 1). Leaf N was not influenced by tillage system but grain N concentration was significantly higher with MP tillage. The dry conditions during and after planting resulted in some stand loss with the MP system.

Please refer to title page of this publication for information regarding application and use of this article.

Table 1. Influence of tillage system on corn production and N utilization at Waseca in 1987.

Tillage system	Final population	Leaf N	Silage Yield	Silage N uptake	Grain Yield	Grain N	Grain N removal
	x10^3	%	T DM/A	lb N/A	bu/A	%	lb N/A
Moldboard Plow	25.1	2.75	8.35	160.2	157.6	1.45	107.8
No Tillage	26.6	2.66	8.43	158.2	152.8	1.36	97.9
Signif. Level (%):1/	99	50	14	13	41	98	88
CV (%) :	1.5	6.2	7.3	9.3	7.2	2.2	6.4

1/ Probability level of significance.

Precipitation for February through June totalled 6.56" below normal and tile water did not flow during this period. However, rainfall in July and August was 4.65" above normal which resulted in slightly more than 1.6" of tile flow in August (Table 2). Tile flow was not affected by tillage, but average NO_3-N concentration and total NO_3-N loss were slightly higher with the MP system. These NO_3-N concentrations average 5 mg/L less than in 1986; perhaps due to the short duration of flow shortly after the period of maximum N uptake by the plants.

Table 2. Influence of tillage system on tile flow, NO_3-N concentration and NO_3-N loss in 1987.

Tillage system	Tile flow	Nitrate-N Concentration 1/	Nitrate-N Loss
	acre inches	mg/L	lb N/A
Moldboard Plow	1.66	9.2	3.76
No Tillage	1.64	7.8	3.19

1/ Flow-weighted

Residual NO_3-N in the soil profile at the end of the 1987 growing season showed about 45 lb/A more N remaining with the MP system (Table 3). The largest differences between the two tillage systems occurred above 4' where substantially more NO_3 accumulated with MP. These results are different from 1986 when about 80 lb more N remained under the NT system.

Table 3. Influence of tillage systems on residual NO_3-N in the soil profile in Oct., 1987.

Profile depth	Tillage System: Mb. Plow	Tillage System: No Tillage
feet	NO_3-N (lb/A)	
0-1	36.2	18.3
1-2	16.5	7.6
2-3	25.3	11.7
3-4	26.3	16.7
4-5	26.0	24.7
5-6	25.6	26.5
6-7	23.0	26.4
7-8	20.6	22.9
Total (lb NO_3-N/A 0-8')	199.5	154.8

Eight soil cores per plot were taken on July 28 and divided into 0-1", 1-2", 2-4", 4-6", and 6-9" increments to evaluate the effect of the 6-years of continuous tillage on soil pH, Bray P_1 and exchangeable K. Results shown in Table 4 indicate a marked acidification of the surface 1" with NT (pH = 5.2 compared to 6.4 with MP). Some surface accumulation and stratification of P and K also occurred with NT while a uniform distribution was noted with MP.

Table 4. Soil test properties in the 0 to 9-inch profile as influenced by 6 years of continuous tillage.

	Moldboard plow			No Tillage		
Depth	pH	Ext. P	Exch. K	pH	Ext. P	Exch. K
inches		------ ppm	------		------ ppm	------
0-1	6.4	30	138	5.2	41	157
1-2	6.5	27	125	6.2	24	137
2-4	6.7	26	131	6.5	22	115
4-6	6.7	26	135	6.4	21	116
6-9	6.7	21	121	6.5	16	107

SIX-YEAR SUMMARY

The cumulative totals for the 6-year period (1982-1987) are shown in Table 5. Corn yields over this period have averaged 7.5 bu/A better with moldboard plow tillage. Approximately 10% more N has been removed in the grain with moldboard plow tillage. This has been due to both higher yields and slightly higher grain N concentrations with the moldboard tillage system some years. Even so, very little difference in applied N removed in the grain exists between the two treatments (50% vs 46% for MP vs NT, respectively). Even though total water flow and NO_3-N lost through the tile lines was about 7% higher with no tillage, this small difference is considered to be insignificant when considering tile flow variability among the eight plots over this 6-year period.

Table 5. Cumulative effects of the two tillage systems over the 6-year period.

Parameter	Tillage System	
	Mb. plow	No tillage
Fert. N applied (lb/A)	1080	1080
Corn grain removed (bu/A)	831	786
N removed in grain (lb/A)	544	494
N removed in grain as a percent of applied N (%)	50	46
Tile flow (acre inches)	58.6	62.7
Nitrate-N lost in tile (lb/A)	140.4	152.5
N lost via tile lines as a percent of applied N (%)	13	14

SOIL TEST COMPARISON STUDY

Waseca, 1987

G. W. Randall and B. W. Anderson

Soil testing is one of the best and most economical methods of ascertaining the nutrient status of the soil. The test then serves as the basis for fertilizer recommendations for crops. Many private and public laboratories provide that service to Corn Belt farmers. The purpose of this study is to compare the soil analyses and fertilizer recommendations given by five regional laboratories for corn production in Southern Minnesota. Working with the laboratories in this comparison study we should be able to improve and standardize fertilizer recommendations for corn and soybean production.

PROCEDURES

Two experimental sites measuring 150' by approximately 300' were selected for sampling in October, 1979. One of the sites had a history of high P and K fertilization while the other had not received P or K since 1974. The soil type in the former is a Nicollet clay loam while that in the latter is primarily Webster clay loam with some Nicollet clay loam. Tile lines spaced at 75' intervals provide excellent drainage at both sites. Neither site can be irrigated.

Four samples consisting of approximately 35 cores each from a 0-7" depth were taken from each site. All samples were oven dried at 95°F, crushed and mixed thoroughly. The samples were then subdivided and sent to five laboratories which test the majority of the soil samples from Southern Minnesota. The laboratories were: A & L Agricultural Laboratories, Inc., Omaha, NE; Harris Laboratories, Inc., Lincoln, NE; Minnesota Valley Testing Laboratories, Inc., New Ulm, MN; AMOCO/Cropmate Co., Reinbeck, IA; and University of Minnesota Soil Testing Laboratory, St., Paul, MN. Soil anslyses requested consisted of pH, OM, extractable P, exchangeable K, extractable S and the micronutrients generally tested by each laboratory. Based on the results from the U of M laboratory these two sites were then classified as being initially "very high" and "medium-high". The fertilizer recommendations given by the five laboratories were then applied as five treatments in the spring of 1980 for corn. An additional check (no fertilizer) treatment was included in the randomized, complete-block design with six replications. Each plot measures 15' wide and 55' long.

After the 1980 crop, soil samples (5 cores/plot times 6 replications yielding 30 cores per treatment) were taken yearly from each treatment and sent to the respective laboratory. This allowed us to follow the buildup or decline of nutrients in the soil as affected by the recommendations of a particular laboratory over time. After 6 years (1980-85) the "very high" fertility site was terminated.

Fertilizer amounts based on the analyses and recommendations from the summer 1986 soil samples were applied October 22 to the appropriate plots before chisel plowing. Nitrogen was broadcast applied as urea on April 22 and incorporated with a field cultivator. These fertilizer recommendations were based on a corn yield goal of 160 bu/A following soybeans. Corn (Pioneer 3732) was planted in 30" rows on April 27. Chemical weed control consisted of 3½ qt. Lasso and 3 qt. Bladex/A applied preemergence to all plots (May 4).

Grain yield and moisture were determined by harvesting each plot with a modified JD 3300 plot combine. Yields were converted to 15.5% moisture.

In August, 1987, 0-7" soil samples were taken from each treatment and were sent to the U of M laboratory to determine the effect of the labortories' recommendations on the soil test values at the conclusion of the 8-year study.

Medium-high testing site

The soil test results and the accompanying recommended fertilizer program of each laboratory are shown in Table 1. While the numeric values of the four laboratories were somewhat similar the corresponding interpretation (whether the soil tested high, low, medium, deficient etc.) varied substantially. Nitrogen recommendations from the three private laboratories were considered excessive. Phosphorus and K recommendations among the labs were quite different. The Harris recommendations continued to be very high. Also, sulfur was recommended by two private labs.

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Table 1. Soil test results and the recommended fertilizer program from each laboratory on the medium-high testing site at Waseca in 1987.

Test	Soil Test Laboratory A&L	Harris	MVTL	U of M
	Soil Test Results[1/]			
pH	6.7	6.9	6.3	6.7
pH (buffer)	---	---	6.8	---
Phosphorus	22 H	17 D	18 H	16 H
Potassium	208 H	142 D	125 H	117 MH
Organic matter (%)	5.1 H	4.3 A	5.3 H	H
Calcium	3060 H	4335 E	5550	---
Magnesium	555 VH	489 A	775	---
Sulfur	7 L	3 L	11 H	2 L
Iron	61 VH	36 E	24.1 S	---
Manganese	24 H	15 E	14.9 S	---
Zinc	3.2 H	5.8 E	1.4 H	1.0 M
Copper	1.6 H	1.0 A	1.8 S	---
Boron	1.4 H	---	1.4 S	---
ENR (lb/A)	100	---	---	---
C.E.C. (meq/100 g)	20.5	26.2	36.5	---

1/ All soil test results are stated in ppm unless noted otherwise.

Nutrient	A&L	Harris	MVTL	U of M
	Recommended Fertilizer Program[2/]			
Nitrogen	180	155	198	130
Phosphorus (P_2O_5)	55	110[3/]	78[3/]	10
Potassium (K_2O)	80	215[3/]	72[3/]	80
Sulfur	14	20	--	--
Iron	--	--	--	--
Manganese	--	--	--	--
Zinc	--	--	--	--
Lime (T/A)	--	--	--	--

2/ All values indicate pounds of nutrients recommended per acre for a yield goal of 160 bushels of corn per acre.

3/ Value includes maintenance recommendation, plus 50% of the buildup recommendation which was to be applied over a two-year period.

The treatments that received fertilizer yielded significantly more than the unfertilized check (Table 2). However, there were no significant yield differences among the fertilizer treatments (recommendations). Yields from the plots with the residual fertility remaining from the Cropmate recommendations were surprisingly high.

Table 2. Effect of fertilizer recommendations on corn yield on the medium-high testing site at Waseca in 1987.

Lab	Fertilizer Recommendations	Grain Yield	Grain Moisture
	lb/A[1]	bu/A	%
A&L	180 N + 55 P + 80 K + 14 S	163.2	16.1
Harris	155 N + 110 P + 215 K + 20 S	167.9	16.5
MVTL	198 N + 78 P + 72 K	162.5	15.9
Residual[2]	---	147.2	16.4
U of M	130 N + 10 P + 80 K	164.9	16.0
Check		120.2	17.6
	Signif. Level (%):[3]	99	99
	BLSD (.05) :	9.1	.5
	CV (%) :	5.4	2.8

1/ P and K expressed on oxide basis.
2/ Cropmate recommendations applied 1980-86, no fertilizer applied in 1987.
3/ Probability level of significance.

Soil test P and K levels resulting from the laboratories 8-year fertilizer recommendations are shown in Table 3. Fertilizer P recommendations by all labs increased soil test P over the initial 18 lb Bray P_1/A. Soil test P was related closely to the amount of fertilizer P applied. Both soil test P and K were considerably higher for the Harris recommendations. Based on these soil test values and the amount of P_2O_5 applied over the 8-year period, 23 lb P_2O_5/A was required to raise soil test P by 1 lb Bray P_1/A. Because of substantial year to year soil test K variability, it was not possible to make this calculation for K.

Table 3. Soil tests and the amount of fertilizer applied after 8 years with the four laboratories recommendations.

Laboratory	Soil pH	Bray Ext. P	Exch. K	Fertilizer applied P_2O_5	Fertilizer applied K_2O
		lb/A			
A & L	6.6	35	244	535	775
Harris	6.8	62	337	744	1542
MVTL	6.4	35	240	479	585
U of M	6.7	26	246	390	490
Check (No fert.)	6.8	15	211	0	0

Initial tests in 1979 were pH = 6.4, P = 18, and K = 294.

SUMMARY - 1987

Substantial differences again existed among the laboratories fertilizer recommendations. High amounts of P and K were recommended by the Harris lab. Sulfur was recommended by two of the three private labs.

Differences in grain yield were not observed among the four laboratories' recommendations. Yields were excellent.

Fertilization resulted in highest profit from the U of M recommendations and no profit from the Harris recommendations (Table 4). Fertilizer costs ranged from $32/A with the U of M recommendation to $73/A with the Harris recommendation.

Table 4. Effect of fertilizer recommendations on yield, value, fertilizer cost and economic return on the medium-high testing site at Waseca in 1987.

Lab	Yield	Value @ 1.52/bu	Fert[1/] cost	Return[2/]
	bu/A	$/A		
A&L	163.2	248	52	13
Harris	167.9	255	73	-1
MVTL	162.5	247	57	7
U of M	164.9	251	32	36
Check	120.2	183	--	--

1/ Using May, 1987 prices for each nutrient expressed as dollars/lb as follows: N, .17; P_2O_5, .22; K_2O, .09; S, .16.
2/ Return yield value @1.52/bu - (fertilizer cost & value of check trt).

EIGHT-YEAR SUMMARY

Yield responses paid for the fertilizer recommendations made by all four laboratories (Table 5). However, net return was highest with the lowest cost fertilizer recommendations. The higher cost recommendations given by A&L and Harris resulted in lowest economic return. It is interesting to note the very narrow range in crop value among the four laboratories over this 8-year period (a low of $2657/A to a high of $2676/A).

Table 5. Effect of fertilizer recommendations on total crop value, total fertilizer cost and resulting economics on the medium-high testing site at Waseca from 1980-87.

Lab	8-Yr Total Crop Value[1/]	8-Yr Total Fertilizer cost	Return[2/]
	$/A		
A&L	2657	436	+212
Harris	2676	547	+120
MVTL	2659	344	+306
U of M	2666	295	+362
Check	2009	0	---

1/ 3.00, 2.40, 3.00, 2.07 and $1.52/bu used for corn in 1980, 1981, 1983, 1985 and 1987, respectively, and 5.50, 6.00 and $4.57/bu used for soybeans in 1982, 1984 and 1986, respectively, for a seven-year total crop value.
2/ Return over 8-year period = crop value - (fertilizer cost & value of check treatment).

CONSERVATION TILLAGE FOR CORN AND SOYBEAN PRODUCTION

Waseca, 1987

G. W. Randall and J. B. Swan

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.

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.

Ridges for the ridge plant treatment in 1987 were built in June, 1986. After the 1986 corn harvest stalks were chopped and the moldboard and chisel plow treatments were performed. On May 5 the moldboard and chisel plow treatments were field cultivated once with the chiseled plots receiving a prior disking. The spring disk treatment was disked twice. Ridges for 1987 corn were prepared in October.

Soybeans (Hardin) were planted in 30" rows at a rate of 200,000 plants/A on May 8. All treatments except no-till 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. Because of high surface soil density with no tillage, seeding depth was not adequate with this planter. Thus, a JD 7000 planter was used to get better seeding depth on this tillage treatment. Ten gallons/A of 7-21-7 was used as the starter treatment.

Broadcast P and K were not applied for the 1987 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 Amiben 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 (both Poast and non-Poast) during herbicide spraying to prevent the application of herbicide onto the soil surface. Weed counts (grass and broadleaf) were taken on June 10 from sprayed and unsprayed areas. On June 12 one-half of each replicate was treated with a postemergence application of Poast at a rate of ¼ lb/A with 1 qt of oil concentrate for grass control. Treatments 2, 3, 4, and 5 were cultivated on June 18.

Surface residue coverage was measured by the line-transect method on April 6 prior to spring tillage and on May 12 after planting. Yields were taken by combine harvesting the center two rows from each plot.

Please refer to title page of this publication for information regarding application and use of this article.

Statistical interpretation of the data throughout this report is based on the percent probability (significance levels) of obtaining a response. A significance level of 95 indicates that we could expect a reeal difference to occur 19 times out of 20 and only 1 time out of 20 due to chance. A significance level below 50 would indicate less than 50:50 odds of being real.

RESULTS

Significant differences in population and soybean yields were found among the tillage treatments (Table 1). Even though the planters had been previously calibrated to plant about 200,000 seeds/A, the 1987 populations were considerably higher; perhaps due to slightly smaller soybean seeds. Due to the density of the surface soil and the dry conditions following planting, plant population with the no tillage (NT) treatment was significantly lower than with the other tillage treatments. Even though a heavier planter was used, seeding depth was rather shallow and germination was not as good. Starter fertilizer had no effect on plant population, seed moisture, and seed yield.

A significant tillage x Poast interaction was found for seed moisture. Seed moisture at harvest was slightly lower for the Poast treatment when applied to the NT and spring disk (SD) systems where grass weed pressure was highest (Table 1). Seed moisture was not affected by Poast in the moldboard plow (MP), chisel plow (CP), or ridge-plant (RP) systems.

Yields were significantly higher for the moldboard plow (MP) treatment compared to the CP, RP, and SD treatments when averaged over starter fertilizer and Poast treatments. Identical yields were found among the CP, RP, and SD tillage systems. Yields with NT were approximately 40% lower than the other tillage systems. A highly significant tillage x Poast interaction existed. Yields from the Poast application to the NT, SD and CP tillage systems were significantly higher than the non-Poast treatments. This response was directly related to the high incidence of grasses in these tillage systems compared to the RP and MP systems (Tables 4 and 5). Yields for the NT, CP and SD systems were increased 149%, 10% and 12% by the Poast application. Poast applied to the MP and RP systems did not increase yields by more than 5%. Thus, the primary reason for the reduced yields with NT appears to be largely due to weed infestation, but other unidentified factors also appear to be having an effect on yield.

Percent surface residue cover measured before spring tillage showed highest amounts with the NT (98%) and SD (76%) systems (Table 2). The RP system also had a high level of coverage (56%) and an intermediate level with CP (25%). Almost no residue was left on the surface with the moldboard plow (3%). After planting, residue coverage decreased substantially with the RP and SD systems. Only the NT, CP, and RP systems met the strict conservation tillage definition of 30% residue coverage.

The rate of seedling emergence was determined by counting the number of plants whose cotyledons had emerged in 40'feet of row/plot from the 6th through the 18th day following planting. Emergence as a percent of final stand, shown in Table 3, indicates a rather slow but fairly uniform emergence among all tillage systems. Emergence was delayed approximately 1 day with MP. Ninety percent emergence was reached 12 days after planting (DAP) with the SD system, 13 DAP with the NT, CP and RP systems and 14 DAP with the MP system.

Weed counts (broadleaf and grass) were taken between the 4th and 5th rows from 1 ft^2 sections/plot from both the previous (1985) Poast and non-Poast sections 26 days after preemergence herbicide application (Table 4). 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. Considering the extremely high population of grasses with NT when no herbicide was used, weed counts were reduced by 85% and 88%, respectively, with the Lasso & Amiben combination. Grass weed control was least adequate with the NT tillage system.

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 and 1985. The purpose of these measurements was to evaluate the effect of these previous applications on the grass pressure prior to Poast application in 1987. Data shown in Table 5 indicate: (1) a tremendous affect of tillage on grass density, (2) a substantial improvement in weed control with the preemergence herbicide, and (3) a marked decrease in weed pressure resulting from the 1983 and 1985 applications of Poast. Even though most farmers would use a herbicide program for general weed control somewhat similar to the Lasso + Amiben program, it is quite apparent that post emergence applications of materials such as Poast would be especially helpful for long-term grass management in the NT and SD tillage systems.

Table 1. Influence of tillage methods, starter fertilizer and Poast herbicide on soybean production at Waseca in 1987.

Treatment				Seed	
Tillage	Starter[1/] fertilizer	Poast[2/] herbicide	Population	Moisture	Yield
			ppA x 10^3	%	bu/A
No tillage	S	P		8.5	44.2
"	S	NP	247	8.9	16.8
"	NS	P		8.5	45.2
"	NS	NP	205	8.6	19.1
Fall plow, f. cult.	S	P		8.8	59.1
" "	S	NP	297	8.8	53.2
" "	NS	P		8.4	54.1
" "	NS	NP	300	8.4	55.9
Fall chisel, d., f. cult.	S	P		8.4	52.5
" "	S	NP	300	8.2	49.3
" "	NS	P		8.5	51.9
" "	NS	NP	287	8.4	45.9
Ridge plant	S	P		8.5	51.8
" "	S	NP	318	8.4	46.4
" "	NS	P		8.4	51.4
" "	NS	NP	292	8.4	51.9
Spring disk (2x)	S	P		8.5	52.1
" "	S	NP	283	8.9	47.7
" "	NS	P		8.4	53.8
" "	NS	NP	278	8.8	46.6
Individual Factors					
Tillage					
No tillage			226	8.6	31.3
Fall plow			299	8.6	55.6
Fall chisel			293	8.4	49.9
Ridge plant			305	8.5	50.4
Spring disk (2x)			280	8.7	50.1
Significance Level (%):[3/]			99	54	99
BLSD (.05) :			32		5.1
Starter Fertilizer					
Starter			289	8.6	47.3
No starter			272	8.5	47.6
Significance Level (%):[3/]			89	87	21
Poast Herbicide					
Poast				8.5	51.6
No Poast				8.6	43.3
Significance Level (%):[3/]				83	99
Interactions			Significance Levels (%)[3/]		
Tillage x SF			37	72	33
Tillage x Poast				98	99
SF x Poast				09	60
Tillage x SF x Poast				08	56
CV (%)			11	3.4	10.4

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

Table 2. Influence of tillage methods for soybeans after corn on surface residue before spring tillage and after planting at Waseca in 1987.

Treatment	Surface Residue	
	Before spr. tillage	After planting
	%	%
No tillage	98	90
Fall plow	3	10
Fall chisel	25	38
Ridge plant	56	37
Spring disk (2x)	76	28
Significance Level (%):	99	99
BLSD (.05) :	8	14
CV (%) :	11.	24.

Table 3. Influence of tillage methods on the emergence progress of corn following soybeans at Waseca in 1986.

Treatment	Days Post Planting									
	6	7	8	9	10	11	12	13	14	18
	% emerged									
No tillage	0	0	8	23	60	69	83	92	98	100
Fall plow	1	1	10	22	41	52	70	88	97	100
Fall chisel	1	1	15	37	64	74	85	91	96	100
Ridge plant	0	0	7	28	50	63	81	91	97	100
Spring disk	1	1	11	30	62	78	91	96	98	100

Table 4. Weed populations on June 10 as affected by tillage and herbicide for soybeans following corn at Waseca in 1987.

Treatment	Herbicide[1/]		No Herbicide	
	Grasses	Broadleaves	Grasses	Broadleaves
	plants/10 sq. ft.[2/]			
No tillage	78	0	527	1
Fall plow	2	1	15	6
Fall chisel	9	8	126	4
Ridge plant	1	0	2	3
Spring disk	31	5	265	6

1/ 3 lb Amiben and 3½ lb Lasso/A, preemergence
2/ Average over 4 replications from both the previous Poast and non-Poast plots

Table 5. Grass populations on June 10 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	49	267	108	787
Fall Plow	0	11	4	19
Fall Chisel	6	25	11	228
Ridge Plant	0	0	1	4
Spr. Disk (2 X)	16	192	45	338

1/ Applied in 1983 and 1985.
2/ Avg. of 4 replications.

SUMMARY - 1987

This was the third crop of soybeans grown following corn in this long-term study with continuous corn from 1975 through 1982 and soybeans in 1983 and 1985. Surface residues prior to planting were greater than 50% with the NT, RP, and SD tillage and remained at 30% or greater after planting with the NT, CP, and RP tillage. Plant emergence among tillage systems was quite uniform with only about a 1-day delay with the MP system due to dry soil surface conditions. Weed pressure was reduced considerably with the Lasso + Amiben preemergence application. Lowest weed pressure was noted with the RP and MP tillage systems. Highest weed counts were with the NT and SD systems. Yields averaged about 5 bu/A higher with MP tillage compared to the CP, RP, and SD systems. Yields were reduced about 40% with NT. This decrease was most likely due to the high weed pressure. The application of Poast to the NT, CP and SD treatments increased yields by 149%, 10% and 12%, respectively, but did not increase yields on the MP and RP treatments because of low grass weed pressure.

THIRTEEN-YEAR YIELD SUMMARY

Grain yields were obtained from the five tillage systems where starter fertilizer was used from 1975-1982 (Table 6.) 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 6). Corn and soybean yields in this sequence averaged about 3 and 8% higher, respectively, with the moldboard plow system compared to the chisel plow, ridge plant, or spring disk system with virtually no difference among the latter three systems.

Table 6. 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
		bu/A			
No tillage	Yes	129.2	140.6	34.5	145.6
"	No		136.0	34.3	133.4
Fall plow	Yes	154.5	170.9	51.0	159.3
"	No		170.8	50.2	160.5
Fall chisel	Yes	144.4	161.8	47.7	156.3
"	No		155.5	45.5	148.3
Ridge plant	Yes	149.2	161.5	46.9	158.6
"	No		156.4	47.2	147.8
Till plant (flat) 1/	Yes	144.9	154.8	46.8	163.2
"	No		157.4	47.1	158.0

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

TILLAGE SYSTEMS FOR CORN AND SOYBEAN CROP SEQUENCES

Waseca, 1987

G. W. Randall, B. W. Anderson and R. R. Allmaras

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, 1986 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 28.

Nitrogen was broadcast applied as ammonium nitrate prior to secondary tillage to all 1987 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 1 at a rate of 27700 ppA with a John Deere Max-Emerge 4-row planter equipped with 2" fluted coulters. Furadan (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 3½ qts Bladex/A applied preemergence on May 7 with no further row cultivation.

Soybeans (Hardin) were planted in 30" rows with the aforementioned planter at a rate of 9 beans/foot on May 11. Weeds were controlled with a preemergence application of Lasso (3½ qts/A) + Amiben (6 qts/A) on May 12 with no additional cultivation.

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.

Results and Discussion

Corn yields were quite good and in contrast to 1986 were affected significantly (P = 98% level) by tillage (Table 1.). Yields were 6 and 15% higher for the CP and NT tillage systems, respectively, compared to the MP system. Contrary to 1986, yields were not affected significantly (P = 90% level) by the crop sequence. An interaction between tillage and crop sequence was not found.

The primary reason for the yield differences with tillage was the delayed and uneven emergence due to the dry surface soil conditions caused by secondary tillage. Statistical analysis of the emergence data collected on June 12 indicates a significant tillage x sequence interaction (P = 93%). For continuous corn 27 and 31% of the plants were at least 4 leaf-stages behind the early (normal) emerging plants with the MP and CP systems, respectively, while only 12% were delayed in the NT system (Table 1). Moldboard plowing and field cultivation following soybeans resulted in 20% of the plants delayed in their emergence. Delayed emergence was negligible with the CP and NT systems following soybeans. Regression analysis of late corn emergence on yield showed the highly significant

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relationship: Yield (bu/A) = 165.4 - 0.62 * (% late emergence) with R^2 = .304** (N = 24).

Grain moisture at harvest was significantly affected by tillage and crop sequence and was closely related to the degree of late/uneven emergence.

Soybean yields also were extremely good and were not affected by tillage (Table 2). The 13% yield reduction found with continuous soybeans compared to soybeans following corn was highly significant. Seed moisture content at harvest was not influenced by either tillage or crop sequence. Neither soybean yield nor seed moisture showed an interaction between 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	Late Emergence 1/
		bu/A	%	x 10^3	%
MP	C-C	140.7	18.4	25.8	27
"	C-Sb	150.1	16.4	25.7	20
CP	C-C	150.1	16.8	26.1	31
"	C-Sb	157.2	15.0	26.5	4
NT	C-C	162.7	16.1	25.7	12
"	C-Sb	172.5	15.4	26.2	1
FACTORIAL COMPARISONS					
Tillage					
MP		145.4	17.4	25.8	24
CP		153.7	15.9	26.3	18
NT		167.6	15.8	25.9	7
Signif. Level (%): 2/		98	99	98	99
BLSD (.05) :		14.5	0.8	.34	6
Crop Sequence					
C-C		151.2	17.1	25.8	24
C-Sb		160.0	15.6	26.1	8
Signif. Level (%): 2/		89	99	46	99
Tillage x Sequence Interaction					
Signif. Level (%): 2/		3	69	24	93
CV (%) :		7.7	5.0	3.6	48

1/ Plants that were ≥4 leaf stages behind the normal emerging plants on June 12.

2/ Probability level of significance.

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

Tillage	Crop Sequence	Soybean Yield	Soybean Moisture
		bu/A	%
MP	Sb-Sb	52.1	8.8
"	Sb-C	54.9	8.8
CP	Sb-Sb	51.4	8.8
"	Sb-C	61.2	8.7
NT	Sb-Sb	49.3	8.7
"	Sb-C	59.1	8.8
FACTORIAL COMPARISONS			
Tillage			
MP		53.5	8.8
CP		56.3	8.7
NT		54.2	8.7
Signif. Level (%):		65	30
Crop Sequence			
Sb-Sb		51.0	8.7
Sb-C		58.4	8.7
Signif. Level (%):		99	11
Tillage x Sequence Interaction			
Signif. Level (%):		81	22
CV (%) :		7.3	1.7

Conclusions

These second-year results indicate a significant effect of tillage on the yield of corn but not soybeans regardless of crop sequence. Corn yields were depressed with the MP and CP systems because secondary tillage with these systems caused the seedbed to dry excessively. As a result corn emergence was uneven with up to 31% of the plants showing a growth delay of 4 or more leaf stages by mid-June. Corn emergence and growth were more uniform with NT. The effect of cropping sequence remained consistent with previous years results. Continuous corn and continuous soybean yields were depressed by 6% (not statistically significant) and 13%, respectively, compared to a corn-soybean rotation.

PLANTING DATE, NITROGEN FERTILIZER, AND PLANT POPULATION INTERACTIONS IN PROCESSING SWEET CORN

C.Rosen and V.Fritz

Processing sweet corn is usually planted over a period of 6 to 8 weeks in May and June. Because of this extended planting schedule, questions concerning whether nitrogen fertilizer requirements vary with planting date are frequently asked. Previous work suggests that fertilizer rates can be lowered at the later planting dates, although a detailed analysis could not be found. In addition to nitrogen needs, proper plant populations should be selected to optimize sweet corn yield and quality. Depending on end use of the product (eg. cut corn vs corn on the cob), optimum plant populations may vary. Little research dealing with the interactions of planting date, nitrogen fertilizer, and plant populations has been conducted. Therefore, the objective of this experiment was to evaluate the effects of these factors on various yield components and nitrogen nutrition of sweet corn.

Procedures

The experiment was conducted at the Southern Experiment Station in Waseca, MN. The soil is characterized as a Nicollet-Webster clay loam with medium to high organic matter and had the following chemical properties prior to planting (0-6"): pH, 6.7; (lb/A): P, 60; K, 358. Because of the high P and K soil tests levels, potash and phosphate fertilizer were not applied. Treatments included 4 nitrogen rates (0, 60, 120, and 180 lb N/A), 3 planting dates (May 7, May 21, and June 4), and 3 plant populations (17,000, 22,000 and 27,000). Nitrogen was applied as urea and broadcast/incorporated two or three days prior to planting. Sweet corn seeds ('Jubilee') were planted at 30,000 plants/A and then thinned to the desired population. The previous crop was corn. A factorial treatment arrangement was used in a split-spilt plot design with 4 replications. Planting date and nitrogen rate were main plots and plant population was the subplot. Whole plants were sampled at the 10 - 12 leaf stage and ear leaves were sampled at mid- silking. Samples were dried, ground and analyzed for Kjeldahl nitrogen. Plots were harvested when the average kernel moisture content was 73 - 74%. At harvest, total ear weight, husked ear weight, cut corn weight, and number of usable ears were recorded.

Results

Due to the relatively dry conditions during the spring of 1987, nitrogen loss through leaching or denitrification during the season was minimal. Sweet corn response to nitrogen and plant populations at the three planting dates is provided in Table 1. Yields were depressed at the third planting date because of a serious infestation of northern and western corn rootworm (adult stage). Earfill and number of usable ears were greatly reduced by this insect. Statistical analyses of the main effects and interactions are presented in Table 2. Care should be taken when interpreting the main effects without taking into account the significant interactions.

Nitrogen application increased yield at all planting dates. As in previous years the greatest increment of response was from 0 to the 120 lb N/A rate. Response to N was greatest during the first two planting dates compared to the third planting date. This was because of the severe insect damage at the third date which negatively affected crop growth. Surprisingly, plant population had little effect on sweet corn yields. The only advantage of going to a higher plant population was for an increase in number of usable ears. A population of 22,000 plants/A yielded a greater number of usable ears than 17,000 plants/A provided that at least 120 lb N/A was available. Populations of 27,000 plants/A did not yield more usable ears than 22,000 plants/A. Ear length tended to increase with nitrogen rate up to 120 lb N/A and decrease with increasing plant populations.

Nitrogen in whole plant samples and in the ear leaf sampled at mid-silk increased with increasing N rate. An ear leaf N concentration of about 2.75 seemed to be optimum for maximum yields under the conditions of this experiment. Increasing plant populations tended to lower ear leaf N levels.

Conclusions:

1. Sweet corn yields increased with nitrogen fertilizer up to 120 lbs N/A. There was only a slight increase (less than 5%) in cut corn yields by increasing nitrogen from 120 lb/A to 180 lb/A.

2. Unless rainfall, diseases, and insects are controlled, it is difficult to assess the effect of planting date on N response.

3. Based on results of this experiment maximum cut corn yields were obtained with a population of 17,000 plants/A and a nitrogen rate of 120 lb N/A. Maximum number of usable ears/A were obtained with 22,000 plants/A provided that at least 120 lb N/A was applied.

Table 1. Effects of nitrogen rate, plant population and planting date on various yield components and nitrogen nutrition of sweet corn.

Planting Date	Plant Population	N rate	Green Yield	Husked Yield	Cut Corn Yield	Ears Useable	Ear Length	-Tissue Nitrogen- Whole plant at 10 leaf stage	Ear leaf at silking
	plants/A x 1000	lbs/A	--------- T/A		----------	ears/A x 1000	inches	-------- %	-------
May 7	17	0	4.13	3.08	1.50	8.3	7.3	2.52	2.12
7	17	60	7.05	5.03	3.04	15.9	7.8	2.95	2.83
7	17	120	8.89	6.26	3.86	18.8	8.1	2.87	2.94
7	17	180	9.49	6.26	3.86	16.9	8.0	3.06	3.06
7	22	0	4.28	3.26	1.58	9.6	7.1	2.50	2.34
7	22	60	7.28	5.36	3.19	18.1	7.6	2.86	2.42
7	22	120	8.70	6.11	3.71	19.3	7.9	2.91	2.90
7	22	180	8.78	6.41	4.05	19.9	7.9	3.26	2.97
7	27	0	3.71	2.59	1.39	7.8	6.7	2.47	2.07
7	27	60	7.39	5.36	3.15	16.6	7.6	3.03	2.49
7	27	120	9.11	6.56	4.09	21.5	7.6	3.14	2.74
7	27	180	9.79	6.56	3.98	17.9	7.8	3.15	2.94
May 21	17	0	4.43	3.53	2.06	11.0	7.3	2.24	2.42
21	17	60	6.30	4.91	3.04	15.5	7.6	2.36	2.41
21	17	120	7.65	5.93	3.71	17.4	8.0	2.43	2.76
21	17	180	9.98	6.45	3.98	20.0	7.9	2.76	2.98
21	22	0	3.98	3.04	1.65	7.1	6.9	2.11	2.32
21	22	60	6.64	5.14	3.04	15.2	7.6	2.46	2.74
21	22	120	7.69	6.00	3.71	21.0	7.6	2.70	2.72
21	22	180	8.36	6.41	3.98	19.8	7.6	2.65	2.83
21	27	0	3.75	2.85	1.54	6.5	6.5	1.76	2.43
21	27	60	6.56	5.06	2.96	15.6	7.3	2.41	2.59
21	27	120	7.88	6.19	3.79	21.2	7.4	2.52	2.55
21	27	180	7.99	6.23	3.86	20.0	7.8	2.83	3.84
June 4	17	0	4.31	2.48	1.24	1.9	7.2	2.69	2.50
4	17	60	4.84	2.78	1.35	2.2	7.3	2.98	2.83
4	17	120	5.51	3.23	1.73	2.6	7.4	3.09	2.78
4	17	180	5.96	3.34	1.61	2.7	7.2	3.18	2.94
4	22	0	3.75	2.21	1.05	1.4	7.2	2.73	2.46
4	22	60	5.55	3.38	1.65	2.2	7.2	2.92	2.69
4	22	120	5.70	3.68	2.03	3.9	7.4	2.93	2.71
4	22	180	5.44	3.19	1.65	3.6	7.2	3.22	2.68
4	27	0	4.05	2.36	1.05	1.9	7.1	2.79	2.40
4	27	60	5.21	3.23	1.61	3.1	7.3	3.05	2.48
4	27	120	5.93	3.60	1.80	2.9	7.1	2.99	2.68
4	27	180	5.89	3.71	1.95	4.9	7.2	3.14	2.84

Table 2. Statistical analysis of nitrogen rate, plant population, planting date and interactive effects on sweet corn yield and nutrition.

	Green Yield	Husked Yield	Cut Corn Yield	Useable Yield	Ear Length	-Tissue Nitrogen- whole plant at 10 leaf stage	ear leaf at silking
Main Effects	---------- T/A		----------	ears/A x 1000	inches	-------- %	-------
N rate							
0	4.04	2.81	1.45	6.2	7.0	2.42	2.35
60	6.31	4.47	2.56	11.6	7.5	2.78	2.61
120	7.45	5.29	3.17	14.1	7.6	2.84	2.75
180	7.80	5.40	3.21	14.0	7.6	3.03	2.90
Significance	**	**	**	**	**	**	**
BLSD (0.05)	0.76	0.38	0.27	1.6	0.2	0.16	0.44
Planting Date							
May 7	7.38	5.24	3.12	15.9	7.6	2.89	2.66
May 21	6.64	5.14	3.11	15.7	7.5	2.43	2.63
June 4	5.18	3.11	1.56	2.8	7.2	2.97	2.66
Significance	**	**	**	**	**	**	NS
BLSD (0.05)	0.67	0.33	0.23	1.4	0.2	0.14	----
Plant Population							
17,000	6.42	4.44	2.58	11.1	7.6	2.76	2.72
22,000	6.33	4.51	2.61	11.6	7.4	2.77	2.65
27,000	6.44	4.53	2.60	11.6	7.3	2.77	2.59
Significance	NS	NS	NS	NS	**	NS	*
BLSD (0.05)	----	----	----	----	0.2	----	0.12
Interactions							
N rate x planting	**	**	**	**	**	NS	NS
N rate x Population	NS	*	NS	*	NS	NS	NS
Planting Date x Population	NS	NS	NS	NS	*	NS	NS
N rate x Planting Date x Population	NS	NS	NS	NS	NS	NS	NS

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

WATER QUALITY RESEARCH WITH NITROGEN AT THE HERMAN ROSHOLT IRRIGATION FARM, WESTPORT, MN

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In 1987 three phases of nitrogen research were started at the Herman Rosholt Irrigation 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. Results from the lysimeter phase are being evaluated and will be reported at a later time. Results from the groundwater phase are being summarized by the department of Agricultural Engineering. This report is a summary of the results obtained from the nitrogen management/crop production phase.

The soil at the Rosholt farm is an Estherville sandy loam with 35-70 cm of sandy loam soil overlying glacial outwash composed mainly of coarse sand and gravel. Because of the course nature of these soil 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 nitrogen. Improper fertilizer nitrogen 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 nitrogen and crop management practices on both the crop yield/nitrogen utilization and their resulting impacts on groundwater quality.

Experimental Procedures

Two separate nitrogen experiments were established at the Rosholt farm in 1987. The previous cropping history on the experimental area consisted of nonirrigated oats.

Experiment 1 consisted of 25 nitrogen treatments randomized within a split plot design with three replications. The main plot consisted of two cropping sequences (continuous corn and corn following beans) with the sub-plots being tillage (ridge till and chisel plow). Ridges were constructed in the fall of 1986. In 1987 both corn and soybeans were planted. In 1988 the entire experiment will be in corn. The 25 nitrogen treatments within each sub-plot consisted of a control (zero N) plus four nitrogen 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 nitrogen 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. Soybeans (Pioneer 9601) were planted on May 18th at a rate of 70 kg/ha in 0.76m rows. A tank mix of Amiben (2.24 kg/ha), Lasso (2.24 kg/ha) and Roundup (1.12 kg/ha) was applied on May 19th for weed control.

Experiment 2 consisted of 16 nitrogen treatments randomized within a split plot design with three replications. The main plots variable was tillage (ridge till and chisel plow). The 16 nitrogen treatments within each sub-plot consisted of two nitrogen rates (120 an 180 kg N/ha), two nitrogen sources (anhydrous ammonia and urea) and two nitrification inhibitor treatments (no and yes) at two times of application (early-4 leaf and late-8 leaf). Nitrification inhibitor treatments consisted of 0.56 kg/ha of N-Serve applied with anhydrous ammonia or 7% DCDN with urea. The DCD urea was supplied by TVA. Urea treatments were injected at a depth of 15 cm and positioned approximately 16 cm away from the row similar to the anhydrous ammonia treatments.

Experiments 1 and 2: Corn (Funks G 4100 - 90 day R.M.) was planted on May 1 in 0.76 cm rows at a population of 78,600 seeds/ha using a four-row Hiniker planter. Starter fertilizer was applied at the rate of 250 kg/ha of 9-23-30 as a side banding. A tank mix of Atrazine (2.24 kg/ha), Lasso (3.36 kg/ha) and Roundup (1.12 kg/ha) was used on May 7th for weed control. For additional weed control both experiments were cultivated twice. For the ridge till treatment the second cultivation and the ridge

building were done simultaneously. Nitrogen treatments were applied on June 4th (early-4 leaf) and on June 18th (late-8 leaf). The irrigation program (traveling boom) was started on May 7th and continued through August 30th with 14.4 cm of water being applied through irrigation and an additional 37.8 cm of water coming through rainfall during the growing season.

Grain yields were obtained on October 8th by hand harvesting 9.3 m^2 of plot area. All grain yields were adjusted to 15.5% moisture.

General Results

Experiment 1 When no fertilizer nitrogen was applied grain yields were approximately 98 bu/A (6.2 mt/ha). Fertilizer treatments increased grain yields about 45 bu/A. No yield increases were obtained with fertilizer nitrogen rates over 60 kg/ha (54 lbs/A). Fertilizer nitrogen rates in excess of 60 kg/ha resulted in increased concentrations of residual nitrate-N remaining in the soil at the end of the season (data not presented. In 1987 delayed applications of fertilizer nitrogen did not increase yield, but did reduce the concentration of nitrogen in the grain at harvest. Nitrification inhibitors had no influence on grain yield or nitrogen utilization by the crop. 1987 results would suggest that nitrogen losses during the growing season were relatively low. The dry early spring and the general lack of large rainfall events during the growing season would support the fact that leaching losses would be expected to be minimal. Although nitrogen loss from the soil profile was limited during the growing season in 1987 the high residual nitrate remaining in the soil at the end of the year when nitrogen rates were in excess of plant need provide some environmental concern. The fall and early spring rainfall when no crop is present could move some of these residual nitrates to the groundwater. Soil samples will be collected in the spring of 1988 to assess nitrate loss from the soil profile during the non-crop portion of the year.

Experiment 2 There was no yield increase or increased N removal with the grain when the nitrogen rates were increased from 120 to 180 kg/ha. This would suggest that the lower rate was more than adequate for plant growth in 1987. This would support the results of experiment 1. The nitrification inhibitor treatments had no influence on yield or N removal with the grain. Anhydrous ammonia resulted in increased yields and more N removal with the grain than urea. Both of these experiments will be continued in 1988.

Table 1. Influence of N-Rates, nitrification inhibitors, method of application and tillage on corn grain yields Westport,MN 1987.

Total N-Rate kg/ha	First Split	Inh.	Second Split	Tillage	Grain Bu/A	Grain % N	Grain mt/ha	N-Removal kg/ha
Control	-----	---	-----	C	98.7	1.19	6.12	62.36
60	60	---	-----	C	125.0	1.42	7.86	94.50
60	-----	---	60	C	126.5	1.40	7.96	93.84
60	40	---	20	C	124.9	1.52	7.86	100.37
60	60	NS	-----	C	123.0	1.60	7.74	104.31
60	-----	NS	60	C	136.5	1.55	8.59	111.91
60	40	NS	20	C	131.0	1.58	8.24	110.06
120	120	---	-----	C	131.8	1.67	8.29	116.73
120	-----	---	120	C	133.9	1.52	8.43	108.02
120	80	---	40	C	134.7	1.54	8.47	109.95
120	120	NS	-----	C	124.4	1.59	7.83	104.64
120	-----	NS	120	C	136.5	1.52	8.59	110.05
120	80	NS	40	C	130.2	1.58	8.19	109.11
180	180	---	-----	C	126.0	1.69	7.93	113.14
180	-----	---	180	C	134.8	1.53	8.48	109.28
180	120	---	60	C	132.9	1.59	8.36	112.26
-180	180	NS	-----	C	130.8	1.61	8.23	111.87
180	-----	NS	180	C	131.9	1.61	8.30	112.31
180	120	NS	60	C	127.2	1.62	8.00	109.01
240	240	---	-----	C	134.1	1.64	8.43	116.57
240	-----	---	240	C	119.1	1.52	7.49	94.89
240	160	---	80	C	126.9	1.65	7.98	110.92
240	240	NS	-----	C	134.2	1.62	8.45	115.44
40	-----	NS	240	C	135.1	1.59	8.50	113.63
240	160	NS	80	C	145.8	1.62	9.17	124.80
Control	-----	---	-----	R	98.6	1.17	6.20	61.28
60	60	---	-----	R	127.9	1.44	8.05	97.56
60	-----	---	60	R	132.0	1.48	8.31	103.35
60	40	---	20	R	126.9	1.53	7.99	103.08
60	60	NS	-----	R	127.9	1.52	8.04	102.98
60	-----	NS	60	R	137.7	1.50	8.66	109.45
60	40	NS	20	R	130.4	1.47	8.20	101.32
120	120	---	-----	R	128.8	1.60	8.10	108.66
120	-----	---	120	R	136.4	1.48	8.58	106.77
120	80	---	40	R	140.3	1.54	8.83	114.74
120	120	NS	-----	R	134.3	1.48	8.45	105.68
120	-----	NS	120	R	133.6	1.63	8.41	115.53
120	80	NS	40	R	134.7	1.63	8.48	116.21
180	180	---	-----	R	144.4	1.59	9.09	122.05
180	-----	---	180	R	127.4	1.61	8.02	108.42
180	120	---	60	R	128.3	1.56	8.07	106.28
180	180	NS	-----	R	134.7	1.59	8.47	113.58
180	-----	NS	180	R	139.9	1.52	8.80	112.39
180	120	NS	60	R	137.7	1.55	8.67	113.27
240	240	---	-----	R	148.0	1.59	9.31	124.49
240	-----	---	240	R	144.3	1.52	9.08	115.96
240	160	---	80	R	122.8	1.61	7.73	104.52
240	240	NS	-----	R	134.1	1.58	8.44	112.12
240	-----	NS	240	R	131.9	1.52	8.30	106.32
240	160	NS	80	R	141.1	1.63	8.88	122.09