A Report on
Field Research in Soils
(Soil Series 118)

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A Report on Field Research in Soil Science

The 1988 edition of the "Bluebook" is a compilation of data collected and analyzed throughout Minnesota. Information was contributed by personnel of the Department of Soil Science including Extension Soil Specialists, Soil Scientists at the branch stations of Crookston, Lamberton, Morris, and Waseca; Becker and Staples experimental sites; and Soil and Crop area agents. Associated personnel from the Soil Conservation Service, and the Soil and Water Research group of the ARS-USDA, the Tennessee Valley Authority, the Departments of Agriculture and Natural Resources also contributed information.

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The investigators also greatly appreciate the cooperation of many farmers, county agents, technical assistants, secretaries and the representatives of the various firms and businesses who contributed time, land, machinery, and materials and without whose support many of the results reported here would not have been possible.

Some of the results are from 1987 experiments and should be regarded on this basis. Since most data are from only 1987 studies, conclusions may not be conclusive and thus are not for further publication without the written consent of the individual researchers involved.

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SPRING 1988 SOIL MOISTURE SITUATION

Prepared by G.J. Spoden, Ass't. State Climatologist, Dept. Natural Resources,
and D.L. Ruschy, R.R. Swerman and D.G. Baker, Soil Science Department, Univ. of MN

The generally very good crop season of 1987 was not the result of the 1987 precipitation, which was below average in many areas, see Fig. 1, but rather can be attributed to the soil moisture reserves remaining from the wet autumn of 1986. Due to the good crops and low 1987 rainfall amounts, the current soil moisture reserves have been seriously depleted in many parts of the state. Thus the 1988 growing season precipitation will assume a greater than usual importance.

The soil moisture situation for May 1, 1988, will almost surely show a drastic change from that of the recent past. For example, during the last 8-10 years Minnesota has been unusually wet, with many areas receiving 120 - 130% of their normal annual precipitation each year. The precipitation patterns shown in Fig. 2 are for the departure of the 1982-1986 annual total precipitation from the 1951-1980 normal. The wet period that Fig. 2 illustrates came to an abrupt end in late September, 1986, over many parts of the state.

Of consequence to the recharge of lakes and streams is what happens with respect to the hydrologic year precipitation, the 12-month period October 1986 - September 1987, which is shown in Fig. 3 as the departure from normal. The precipitation in the southern two-thirds of the state was at least 4-inches below normal, while in a large area in central and east-central Minnesota the precipitation was at least 8-inches below normal. The only large area having above normal precipitation occurred in the middle of the northern part of the state. Within this area are a few small areas that received about 4-inches above normal precipitation. The remainder of this area is only just above normal.

The soil moisture outlook for most of the northern part of the state can be characterized as normal to somewhat above average. No problems are foreseen as long as 1988 precipitation is near normal.

Due to low soil moisture reserves the southern one-half of the state, with the general exception of the extreme southeast, will be highly dependent upon spring and summer rains. Their amount and timing will be critical. The estimated amount of water that will be added to the soils between November 1, 1987 and April 30, 1988 is shown in Fig. 4. Except for the far north, the smallest addition to soil moisture reserves, about 2.0 - 2.5 in. will be added in the west central and Red River Valley regions. It is in west central Minnesota where the fall 1987 soil moisture reserves were generally the lowest.

The amounts shown in Fig. 4 include the following sources of water: November rains; 15% of the measured water content of December - February snows; 15% of the normal March precipitation (this article is prepared in February 1988 so estimates are required); and the April precipitation that is expected with a 50% probability.

Only 15% of the over-winter precipitation enters the soil on the average, as most of it runs off before the soils have thawed in early spring. The April precipitation amount was estimated to be the median or 50% value of the historical total. There is one chance in three that the April amount would be about 0.75 in., 1.50 in., and 2.5 in. higher in the northwest, the center, and the southern part of the state, respectively. There is also one chance in three that the April rains will be lower by the same amounts.

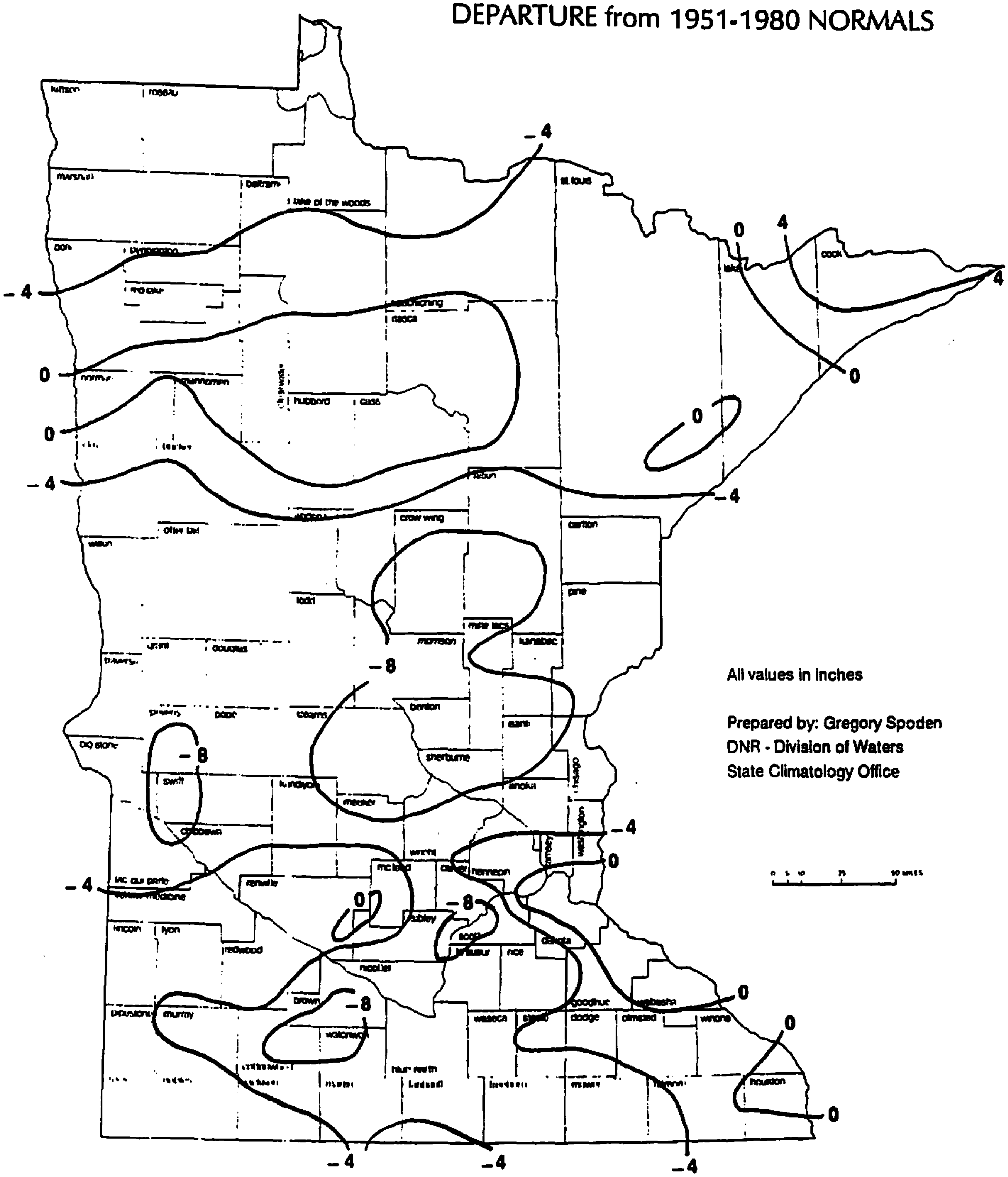
The November 1987 rains that occurred were generally sufficient to wet only the top 6-12 inches of the soil before the soils froze. As a result the subsoils in many areas remain extremely low in moisture. And until the soils are completely thawed in the spring, the rains that occur will largely run off.

As most people realize, weather forecasts beyond a few days are most unreliable. Thus, no statement can be made with any confidence about the 1988 season. It can be stated, however, that the wet period of about 8-10 years that we have experienced was most unusual and cannot be expected to continue. Thus, as a result of the unusually low soil moisture reserves in some areas of the state, particularly the west central and parts of the south-central and southwest, the spring and summer rains will be more critical than usual.

FIGURE 1

ANNUAL PRECIPITATION FOR 1987

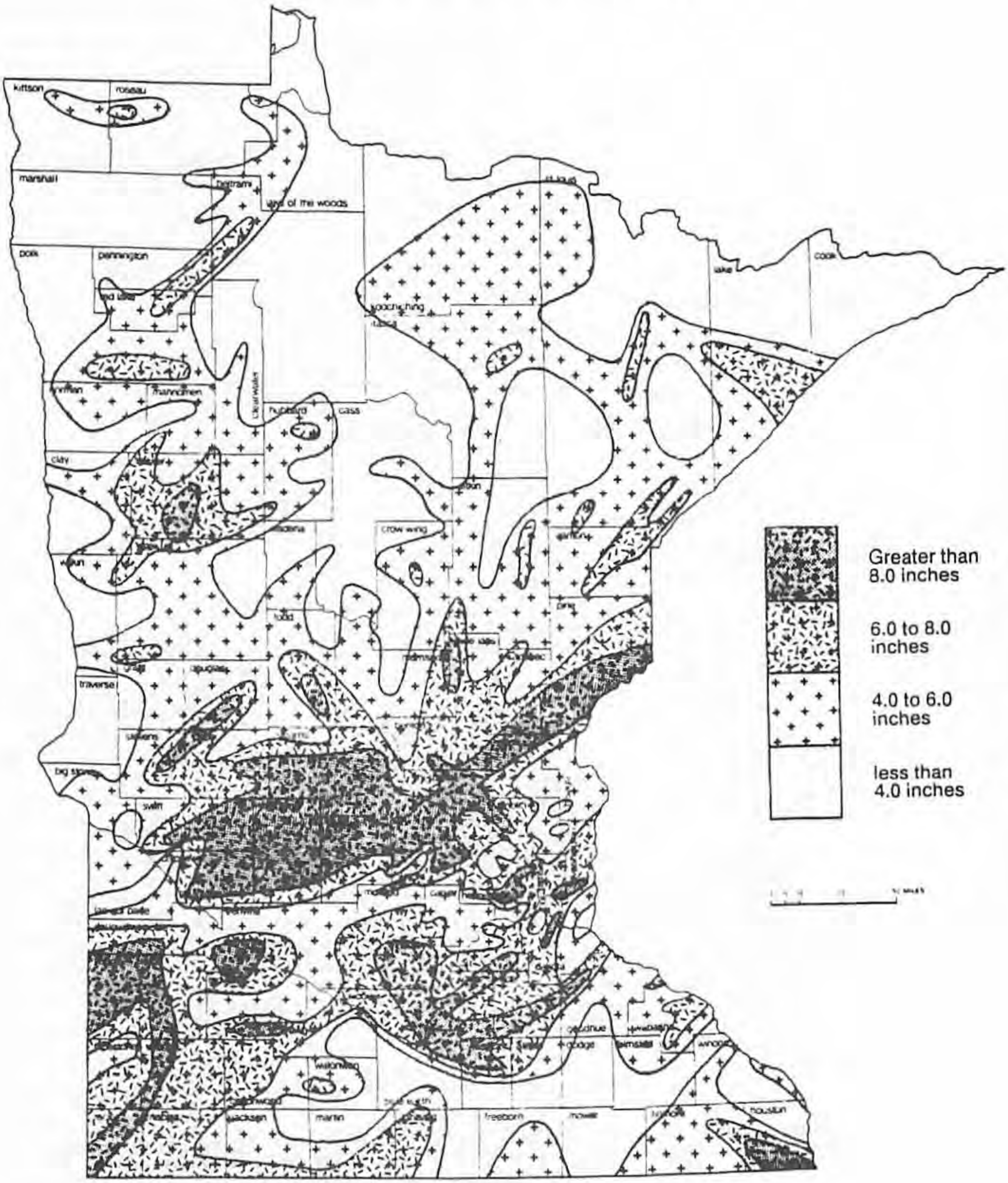
DEPARTURE from 1951-1980 NORMALS



Data: National Weather Service, Soil & Water Conservation Service, DNR Forestry, Metropolitan Mosquito Control, Backyard Raingage Network, Future Farmers of America, KSTP-TV, Deep Portage Conservation Reserve, Minnesota Association of Watersheds

FIGURE 2

AVERAGE ANNUAL DEPARTURE FROM NORMAL PRECIPITATION FOR 1982 - 1986 (5 YEARS)

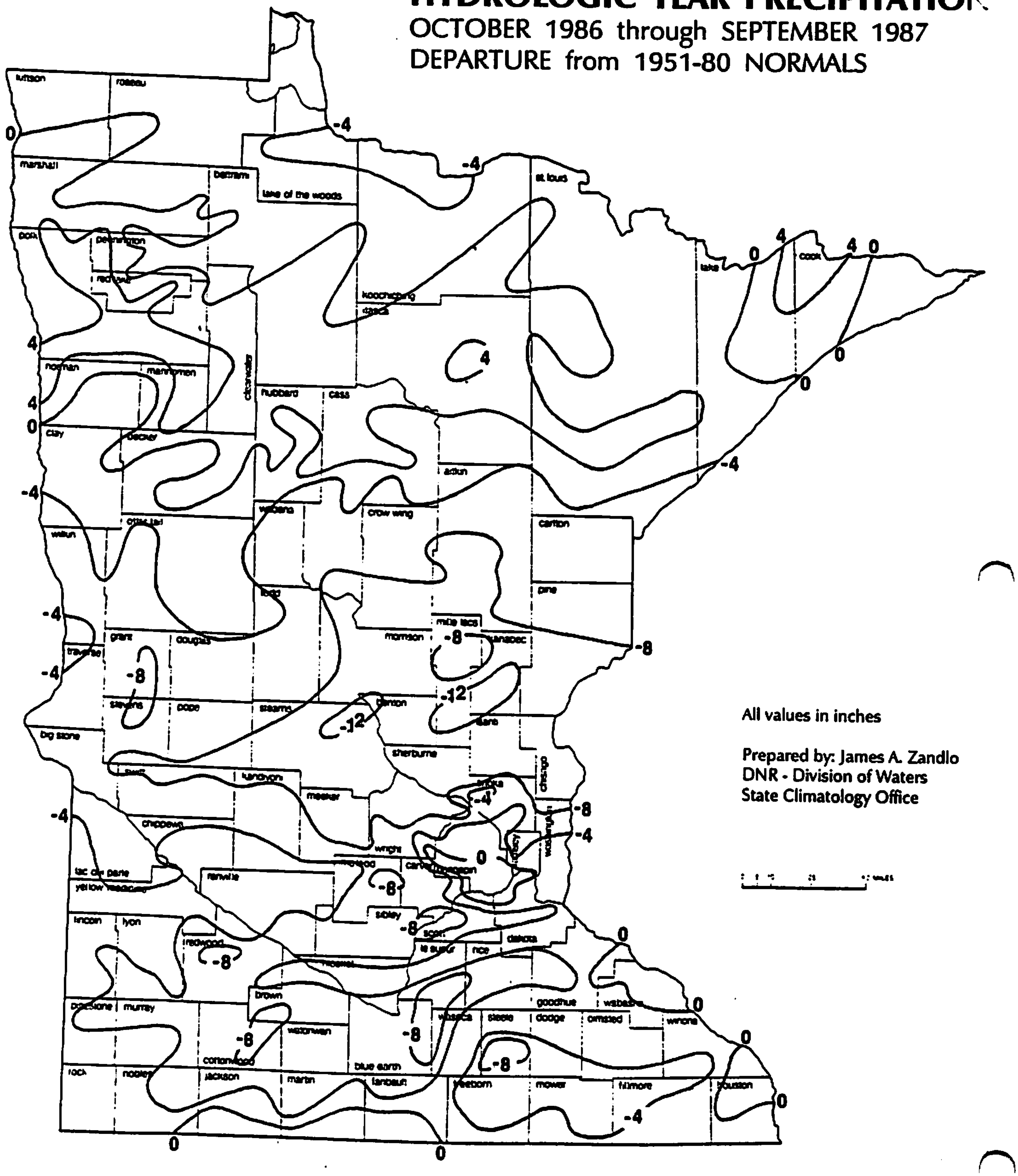


Prepared by: DNR, Division of Waters, State Climatology Office

FIGURE 3

HYDROLOGIC YEAR PRECIPITATION

OCTOBER 1986 through SEPTEMBER 1987
DEPARTURE from 1951-80 NORMALS

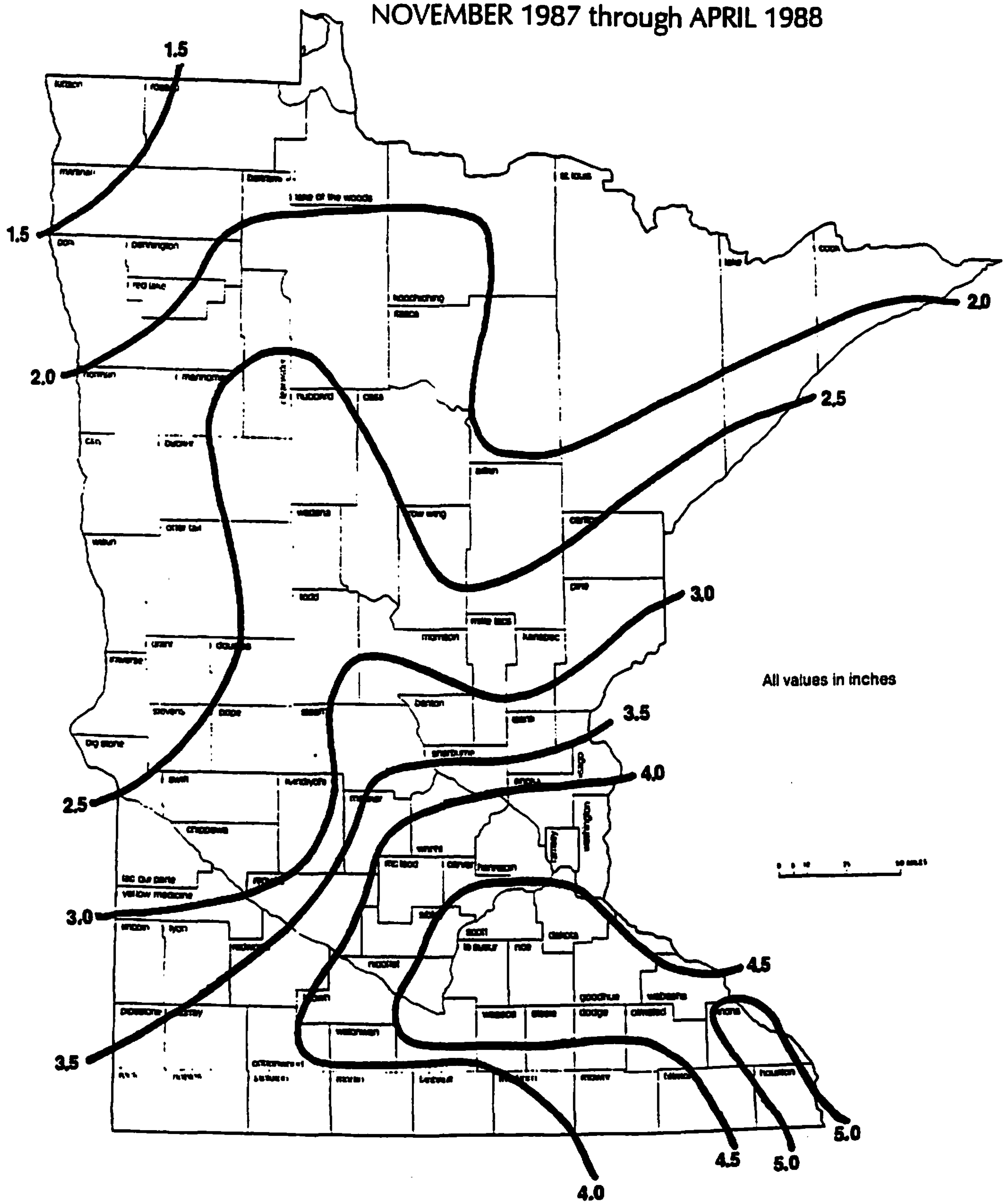


Data: National Weather Service, Soil & Water Conservation Service, DNR Forestry, Metropolitan Mosquito Control, Backyard Raingage Network, Future Farmers of America, KSTP-TV, Deep Portage Conservation Reserve, Minnesota Association of Watersheds

FIGURE 4

POTENTIAL SOIL MOISTURE RECHARGE

NOVEMBER 1987 through APRIL 1988



THE DENSITY OF FRESHLY FALLEN SNOW AND THE SNOWPACK

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and D.B. Wall, Minnesota D.N.R.

In the course of modeling soil frost depth and duration, a series of snow density measurements were taken of both freshly fallen snow and the snow that had accumulated. Some interesting results were obtained which will be of interest to those concerned with water supplies and the insulating value of snow. It might also be of interest to little boys and girls who make snowballs and snowmen (snowwomen?).

The objectives are two-fold. One objective is to determine how the density of snow varies with the air temperature at the time the snow falls. The second, and more important objective, is to find how the snowpack density changes with time. The initial density (that is, the water content) varies with the atmospheric temperature at the time of the snowfall. Upon reaching the earth's surface a change or metamorphosis in the crystalline structure of the snow begins. The rate of this change (or metamorphosis) is primarily a function of the temperature and wind conditions during the life of the snowpack.

Snow sampling devices not unlike large cookie cutters were constructed. The shallow-snow sampler measured 23 cm (9.1 in) on a side and was 20 cm (8 in) deep. A larger one was made for deeper snow. Each density measurement consisted of at least 3 subsamples. Freshly fallen snow was sampled as close to the end of the snowfall as possible. No measurement was made more than 24 hours after the snowfall.

The first year, 1984-85, had little snow cover and did not result in many good measurements of the accumulated snow. However, the 1985-86 winter was one of a deep and persistent snow cover which provided excellent opportunities for both the newly fallen snow and snowpack density measurements. The 1987-88 winter (still incomplete as this is written) has not been very satisfactory in terms of fresh snow densities. However, it has been quite satisfactory in terms of the accumulated snow, since there have been extended periods of sufficient snow depth and continuity to provide a marked metamorphosis of the snow structure.

In Fig. 1 it is shown how the density of freshly fallen snow varies with the air temperature. The least dense snow is associated with a temperature of about 10°F (-12°C). The density increases with temperatures that are both higher and lower than 10°F. Snow with the highest water content (maximum density) is right at the freezing point. Almost every child knows this snow is the best to work with. For reasons that are not clear at this time the greatest variability in the density measurements apparently occurs at about 21°F.

Snow density is a function of the kind of snow crystals that are formed within particular temperature ranges. Snow crystals that typically form at about 10°F (-12°C) have a fern-like dendritic structure and make the fluffiest of snows.

The density of the snowpack during each of the three winters is shown in Fig. 2. In general an increase in the density occurs as the snow ages. However, density changes during any one season are quite irregular, since the deposition of new snow on aged snow will result in a temporary decrease in the overall density. But as the fresher snow undergoes a metamorphosis, along with the continuing one in the underlying older snow, the entire snowpack increases in density. As indicated earlier this change is due to wind action and partial melting. Both change the physical structure. An additional factor is the compression of the snowpack caused by successive snowfalls on the earlier deposits.

During the 3 years the mean change in density has been 300 kg/m^3 (14.4 lbs/ft^3) over the 122 days between Nov. 20 and March 22. At a density of about 14.4 lbs/ft^3 the snowpack is no longer snow-like, but it resembles a loosely packed pile of dry shelled corn. For this reason one observer calls snow in this physical state "corn snow". At greater densities than this the snow no longer resembles snow but various states of ice.

It is our intention to correlate the change in the snowpack density with melting degree days, or a similar factor, in order to obtain a better predictor of the ageing process than simply the duration (in days) of the snowpack.

Fig. 1. Density of fresh snows measured at St. Paul, 1984-85, 1985-86, and 1987-88. The curved line represents the mean density for the indicated temperatures.

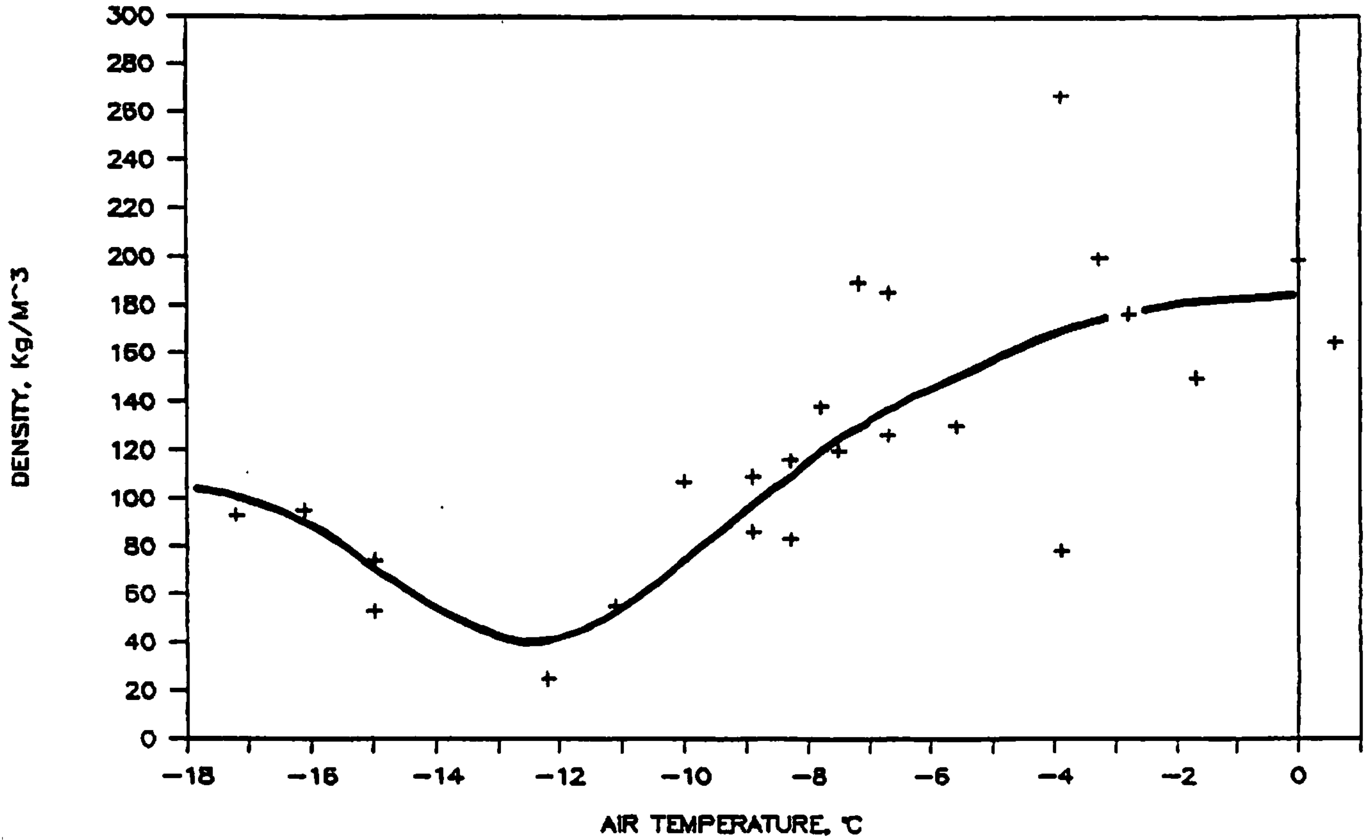
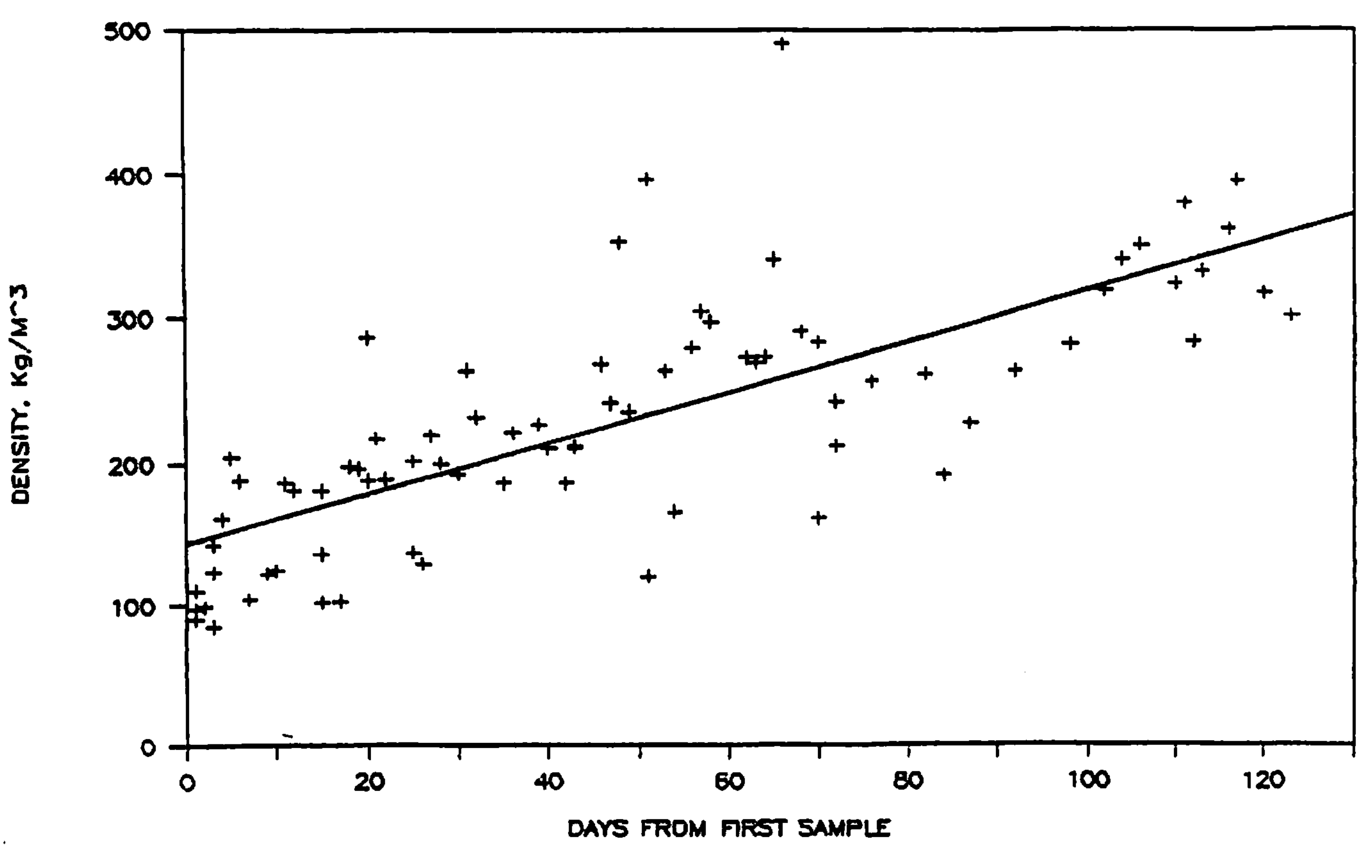


Fig. 2. The change in the density of the snowpack (accumulated snow) with time during the three winters of 1984-85, 1985-86, and 1987-88. The straight line is the mean of the indicated measurements.



MANAGEMENT OF UAN ON THE COARSE TEXTURED IRRIGATED SOIL OF MINNESOTA FOR EFFICIENT CORN PRODUCTION BECKER, MN 1987

G.L. Malzer and T. Graff

Nitrogen (N) fertilizer management decisions are major considerations that all producers must address. These management decisions include many aspects of N fertilization including rates, forms, methods and time of application, equipment, and additives. Although these factors are important for all corn producers, they become especially important for the producers on the coarse textured irrigated soils. Since these soils are highly responsive to fertilizer N, and highly susceptible to N loss, poor management can result in significant yield reductions, reduced profits, and increased nitrate contamination of ground water. The use of nitrification inhibitors in the management programs should also be considered as a management tool to minimize the N loss and add flexibility to the overall N management program. Although most nitrification inhibitors are applied with anhydrous ammonia, they can also be applied with other fertilizer products such as urea, or urea-ammonium nitrate solution (UAN). The objectives of these experiments are to evaluate several aspects of UAN management including: timing of application, method of application, split vs. single applications and the contribution of nitrification inhibitors in these possible management combinations.

Experimental Procedures

Two separate experiments were established at the Sand Plain Research Farm near Becker, Minnesota in 1985 this is the third and final year of these experiments.

Experiment 1 consisted of 25 treatments with four replications arranged in a randomized complete block design. Treatment variables included factorial combinations of six N rates of UAN (100, 134, 168, 202, 235, and 269 kg/ha) and four methods of application (2/3 of N rate early 1/3 late, all late, 2/3 early with DCD 1/3 late, and 2/3 early with N-Serve 1/3 late), plus a zero N control. Early N treatments were applied at the 4-5 leaf growth stage (May 28) while late applications were made at the 8-9 leaf growth stage (June 11). All treatments were injected into the soil on 76 cm centers approximately 8 cm deep and 18 cm away from the row. Nitrification inhibitors were mixed with the UAN prior to application and were applied at rates of 7.84 kg/ha for DCD and 0.56 kg/ha a.i. for N-Serve.

Experiment 2 consisted of 19 treatments with four replications in a randomized complete block design. Treatment variables included factorial combinations of three rates of N as UAN (100, 168, and 235 kg/ha), two methods of application (broadcast vs. injected), and two times of application (4-leaf and 8-leaf growth stages). Nitrification inhibitor (DCD and N-Serve similar to above) treatments were included to provide comparisons for all injected N treatments at the four-leaf growth stage.

Experiment 1 and 2: Prior to planting, broadcast applications of potassium-magnesium-sulfate (336 kg/ha 0-0-22), and (280 kg/ha 0-14-42) were made and incorporated by plowing. Corn (Pioneer 3906 - 95 day relative maturity) was planted on April 27th in 0.76 m rows at a population of 75,800 seeds/ha. Starter fertilizer was applied at the rate of 185 kg/ha 8-10-30, side banded at planting. A tank mix of Atrazine (2.24 kg/ha) and (Dual 1.68 kg/ha) was applied on April 30th for weed control.

Leaf samples from opposite and below the ear at mid-silking were obtained on July 13th, dried and analyzed for N. Total dry matter production and grain yields were determined on September 15 and 16th by hand harvesting 9.29 m^2 of plot area. Ears were separated from the stalks, field weights obtained, and samples removed for moisture and N determination. Grain yields were adjusted to 15.5% moisture.

The irrigation program was started on May 2nd and continued through August 25th with a total of 32.6 cm being applied through irrigation. An additional 36.3 cm of water was obtained during the growing season as rainfall.

General Results

The 1987 growing season provided excellent conditions for high yields. The distribution of precipitation in 1987 could be characterized as being relatively dry during the months of May and June with no single rainfall at any time during the growing season in excess of one inch. With this rainfall distribution significant nitrate leaching would not be expected to occur. Likewise, the impacts of nitrogen management techniques such as time of application, placement, and use of nitrification inhibitors would be expected to have minimal influence on grain yield and N utilization. The results of experiment 1 are presented in tables 1 and 2 and experiment 2 are presented in tables 3 and 4.

Experiment 1 Yield increases in excess of 90 bu/A were associated with fertilizer nitrogen application. The optimum rate of fertilizer N application was 150 lbs/A (168 kg/ha), similar to what was found in both 1985 and 1986. Time of N application (split vs. all late sidedressed) had no influence on grain yield, but the all late N application did reduce stover yield and total dry matter production by the crop. Although time of N application did not influence N concentration in the plant tissue it did result in a reduced amount of N contained in the stover and a trend for reduced total N removal by the total crop. The use of nitrification inhibitors had no influence on crop yield, nitrogen concentrations in the tissue, or total N removal by the crop.

Experiment 2 The apparent optimum N rate in experiment 2 was similar to that obtained in experiment 1 (150 lbs/A). Nitrification inhibitors had no influence on grain yields, but did increase total dry matter production and N concentration in the tissue. The result was an increase in N uptake by the crop. The nitrification inhibitor DCD appeared to be more effective than N-Serve in this respect. Time of N application had no influence on grain yield or N removal suggesting that early season N losses were minimal. Injected applications of UAN increased grain yields, N concentration in the tissue and overall N removal by the crop. Since leaching losses appeared to minimal, the decreased efficiency associated with the broadcast application of UAN could be due to volatilization, increased immobilization of N in the soil, or positional unavailability. Although it is not possible to differentiate these processes in this experiment, previous experimental results at this location under similar experimental conditions would suggest that volatilization losses are minimal.

Table 1. Influence of N-Rates, nitrification inhibitors and method of application on grain yield, and dry matter production on irrigated corn Becker, MN 1987.

Treatments N-Rates	Split 1	Inh.	Split 2	Meth.	Grain Yield		Dry Matter Production Grain	Stover	Total
kg/ha	kg/ha		kg/ha		Bu/A	mt/ha	---------mt/ha---------		
Control	----	---	----	---	96.2	6.0	5.08	6.14	11.24
100	67	---	34	1	171.7	10.8	9.09	8.36	17.45
100	----	---	100	2	168.6	10.6	8.94	7.97	16.91
134	90	---	44	1	183.1	11.5	9.70	8.74	18.44
134	----	---	134	2	177.6	11.1	9.41	8.27	17.67
168	112	---	56	1	185.7	11.6	9.83	9.54	19.40
168	---	---	168	2	180.3	11.3	9.54	8.69	18.26
202	134	---	68	1	185.1	11.6	9.81	9.39	19.20
202	----	---	202	2	179.2	11.2	9.50	8.06	17.56
235	157	---	78	1	184.4	11.6	9.77	9.14	18.93
235	----	---	235	2	184.2	11.5	9.74	8.98	18.75
269	179	---	90	1	188.1	11.8	9.97	9.27	19.24
269	----	---	269	2	183.2	11.5	9.70	8.74	18.44
100	67	DCD	34	3	176.4	11.1	9.34	8.65	17.99
100	67	NS	34	4	171.8	10.8	9.09	8.15	17.27
134	90	DCD	44	3	175.2	11.2	9.30	9.09	18.39
134	90	NS	44	4	184.4	11.6	9.30	8.89	18.88
168	112	DCD	56	3	181.7	11.4	9.77	9.27	18.52
168	112	NS	56	4	186.3	11.7	9.63	9.61	19.15
202	134	DCD	68	3	180.1	11.3	9.88	8,87	19.15
202	134	NS	68	4	181.6	11.4	9.54	9.34	18.50
235	157	DCD	78	3	184.9	11.6	9.61	9.16	19.13
235	157	NS	78	4	183.1	11.5	9.79	9.16	18.88
269	179	DCD	90	3	188.6	11.8	9.70	9.30	19.29
269	179	NS	90	4	184.4	11.6	9.99	9.16	19.22
P-Value					99	99	99	93	99
BLSD (.05)					12.1	0.7	0.62		1.28
Main Effects									
Rates kg/ha									
100					172.1	10.8	9.11	8.28	17.40
134					180.1	11.3	9.54	8.73	18.34
168					183.5	11.5	9.72	9.09	18.83
202					181.5	11.4	9.60	9.04	18.61
235					184.1	11.5	9.74	9.16	18.90
269					186.1	11.7	9.85	9.18	19.04
P-Value					99	99	99	99	99
BLSD (.05)					5.5	0.3	0.29	0.19	0.49
Methods	Early	Late							
1	2/3	1/3			183.0	11.5	9.69	9.07	18.77
2	---	3/3			178.9	11.2	9.58	8.44	17.94
3	2/3 + DCD	1/3			181.2	11.3	9.58	9.13	18.74
4	2/3 + NS	1/3			181.9	11.4	9.69	9.00	18.63
P-value					67	67	67	99	99
BLSD (.05)								0.14	0.22
Rate X Method					4	4	3	49	13

Table 2. Influence of N-Rates, nitrification inhibitors and method of application on leaf,grain, and stover N content and total N removal by irrigated corn Becker, MN 1987.

Treatments					N-Concentration			N-Removal		
N-Rates	Split 1	Inh.	Split 2	Meth.	Leaf	Grain	Stover	Grain	Stover	Total
kg/ha	kg/ha		kg/ha							
Control	----	---	----	---	1.55	1.18	0.45	60.6	29.1	89.7
100	67	---	34	1	2.95	1.53	0.64	139.9	53.7	193.6
100	----	---	100	2	3.11	1.55	0.55	138.8	44.4	183.2
134	90	---	44	1	3.36	1.62	0.56	157.7	49.5	207.3
134	----	---	134	2	3.19	1.68	0.54	158.7	45.1	203.8
168	112	---	56	1	3.29	1.67	0.59	164.7	57.2	221.9
168	---	---	168	2	3.35	1.58	0.61	151.3	53.6	205.0
202	134	---	68	1	3.31	1.68	0.61	164.8	58.2	223.1
202	----	---	202	2	3.19	1.67	0.57	159.3	46.0	205.4
235	157	---	78	1	3.35	1.68	0.62	164.7	57.1	221.8
235	----	---	235	2	3.20	1.65	0.63	161.2	56.9	218.1
269	179	---	90	1	3.25	1.67	0.56	166.8	53.0	219.8
269	----	---	269	2	3.17	1.72	0.65	167.3	57.1	224.0
100	67	DCD	34	3	3.10	1.55	0.51	145.5	44.7	190.2
100	67	NS	34	4	2.99	1.55	0.51	141.2	41.7	182.9
134	90	DCD	44	3	3.12	1.60	0.63	148.9	57.3	206.2
134	90	NS	44	4	3.23	1.64	0.53	161.0	48.7	209.8
168	112	DCD	56	3	3.29	1.66	0.59	160.0	53.0	213.0
168	112	NS	56	4	3.35	1.66	0.59	164.4	54.8	219.3
202	134	DCD	68	3	3.42	1.67	0.65	160.1	62.9	223.1
202	134	NS	68	4	3.33	1.70	0.61	163.8	54.0	217.9
235	157	DCD	78	3	3.24	1.71	0.64	167.5	60.2	227.8
235	157	NS	78	4	3.31	1.72	0.64	166.9	59.1	226.0
269	179	DCD	90	3	3.39	1.73	0.68	173.1	63.7	236.9
269	179	NS	90	4	3.30	1.73	0.61	169.4	57.8	227.2
P-Value					99	99	99	99	99	99
BLSD (.05)					0.21	0.09	0.11	13.2	11.2	19.4
Main Effects										
Rates kg/ha										
100					3.04	1.54	0.50	141.3	46.1	187.4
134					3.22	1.63	0.56	156.5	50.1	206.7
168					3.32	1.64	0.59	160.0	54.6	214.8
202					3.31	1.68	0.61	161.9	55.3	217.8
235					3.27	1.69	0.63	165.8	58.2	223.4
269					3.28	1.71	0.62	169.1	57.9	227.0
P-Value					99	99	99	99	99	99
BLSD (.05)					0.10	0.04	0.04	6.3	5.2	9.2
Methods	Early	Late								
1	2/3	1/3			3.25	1.64	0.60	159.7	54.7	214.5
2	---	3/3			3.20	1.64	0.59	156.1	50.5	206.6
3	2/3 + DCD	1/3			3.26	1.65	0.62	159.1	57.0	216.1
4	2/3 + NS	1/3			3.25	1.66	0.58	161.0	52.6	213.8
P-value					47	40	73	66	97	90
BLSD (.05)									4.7	
Rate X Method					66	20	86	14	68	7

Table 3. Influence of N rates, nitrification inhibitors, method, and time of application on grain yield and dry matter production on irrigated corn Becker MN 1987.

	Treatments			Grain		Dry Matter Productoin		
N-Rate	Method	Inh.	Time	Yields		Grain	Stover	Total
kg/ha				Bu/A	mt/ha	---------mt/ha---------		
Control	------	----	---	90.7	5.7	4.79	6.25	10.74
100	Broadcast	----	1	159.5	10.0	8.44	7.82	18.92
100	Broadcast	----	2	164.9	10.3	8.74	7.77	19.57
100	Injected	----	1	175.4	11.0	9.30	8.51	20.82
100	Injected	----	2	176.7	11.1	9.36	8.65	20.97
100	Injected	DCD	1	178.9	11.2	9.48	8.58	21.22
100	Injected	NS	1	172.8	10.8	9.14	8.42	20.47
168	Broadcast	----	1	179.2	11.2	9.50	8.60	21.27
168	Broadcast	----	2	181.8	11.4	9.63	8.00	21.58
168	Injected	----	1	185.2	11.6	9.81	8.80	21.98
168	Injected	----	2	181.4	11.4	9.61	7.59	21.53
168	Injected	DCD	1	188.8	11.8	10.01	9.34	22.43
168	Injected	NS	1	189.5	11.9	10.04	9.43	22.48
235	Broadcast	----	1	179.8	11.3	9.52	8.65	21.32
235	Broadcast	----	2	173.3	10.9	9.18	8.29	20.57
235	Injected	----	1	191.4	12.0	10.15	9.43	22.73
235	Injected	----	2	181.8	11.4	9.63	8.85	21.58
235	Injected	DCD	1	186.5	11.7	9.88	9.43	22.13
235	Injected	NS	1	196.7	12.3	10.42	9.45	23.33
P-Value				99	99	99	99	99
BLSD (.05)				10.7	0.7	0.56	0.18	1.09
Factorial Arrangement (N-Rate X Inhibitor DCD and N-Serve)								
N-Rate								
100				175.9	11.0	9.31	8.53	17.87
168				186.2	11.7	9.85	9.09	18.97
235				189.1	11.8	10.01	9.29	19.30
P-Value				99	99	99	99	99
BLSD (.05)				4.4	0.2	0.20	0.12	0.40
Inhibitor								
None				182.0	11.4	9.63	8.84	18.48
DCD				184.4	11.6	9.78	9.11	18.90
N-Serve				186.3	11.7	9.87	9.11	18.99
P-Value				87	87	88	91	95
BLSD (.05)								0.09
N-Rate X Inhibitor				92	92	93	73	88
Factorial Arrangement (N-Rate X Method X Time)								
N-Rate								
100				169.1	10.6	8.96	8.19	17.15
168				181.9	11.4	9.63	8.55	18.18
235				181.6	11.4	9.60	8.80	18.43
P-Value				99	99	99	99	99
BLSD (.05)				5.2	0.3	0.26	0.35	0.56
Method								
Broadcast				173.1	10.8	9.16	8.19	17.36
Injected				182.0	11.4	9.63	8.48	18.48
P-Value				99	99	99	99	99
Time								
Early				178.4	11.2	9.45	8.62	18.09
Late				176.7	11.1	9.34	8.40	17.76
P-Value				56	56	58	89	83
Rate X Method				86	86	87	26	65
Rate X Time				88	88	87	63	82
Method X Time				68	68	68	46	11
Rate X Method X Time				5	5	4	46	15

Table 4. Influence of N rates, nitrification inhibitors, method, and time of application on leaf, grain, and stover N content and N removal by irrigated corn Becker MN 1987.

Treatments				N-Concentration			N-Removal		
				------------%-----------			----------kg/ha----------		
N-Rate	Method	Inh.	Time	Leaf	Grain	Stover	Grain	Stover	Total
Control	------	----	---	1.53	1.23	0.40	58.9	24.9	83.9
100	Broadcast	----	1	2.81	1.39	0.44	117.6	35.0	152.7
100	Broadcast	----	2	2.83	1.33	0.46	117.0	36.1	153.1
100	Injected	----	1	3.08	1.48	0.50	138.7	43.3	182.0
100	Injected	----	2	3.09	1.51	0.58	142.4	50.3	192.8
100	Injected	DCD	1	3.09	1.57	0.54	149.1	47.0	196.1
100	Injected	NS	1	3.17	1.53	0.48	140.1	40.6	180.8
168	Broadcast	----	1	3.05	1.65	0.55	157.8	47.52	205.3
168	Broadcast	----	2	3.13	1.60	0.53	148.6	42.1	190.8
168	Injected	----	1	3.27	1.66	0.56	158.0	47.1	205.1
168	Injected	DCD	1	2.84	1.71	0.62	160.2	49.5	209.7
168	Injected	NS	1	3.40	1.73	0.54	171.1	58.1	229.3
235	Broadcast	----	1	3.28	1.60	0.55	173.7	51.9	225.7
235	Broadcast	----	2	3.33	1.62	0.55	152.7	48.1	200.9
235	Injected	----	1	3.11	1.66	0.55	148.9	46.1	195.0
235	Injected	----	1	3.22	1.70	0.56	169.3	52.1	221.4
235	Injected	----	2	3.26	1.70	0.67	164.4	50.4	214.8
235	Injected	DCD	1	2.84	1.63	0.59	168.5	63.4	231.9
235	Injected	NS	1	3.33	1.36	0.47	170.5	56.0	226.6
P-Value				99	99	99	99	99	99
BLSD (.05)				0.37	0.11	0.10	13.5	9.0	18.2
Factorial Arrangement (N-Rate X Inhibitor DCD and N-Serve)									
N-Rate									
100				3.11	1.52	0.53	142.5	45.8	187.0
168				3.19	1.67	0.56	165.7	51.6	217.5
235				3.16	1.67	0.59	168.1	55.4	223.6
P-Value				23	99	99	99	99	99
BLSD (.05)					0.04	0.04	5.4	4.3	7.7
Inhibitor									
None				3.13	1.60	0.55	155.4	48.7	204.2
DCD				3.11	1.66	0.61	162.8	56.2	219.0
N-Serve				3.26	1.63	0.54	161.3	49.5	211.0
P-Value				51	93	99	97	99	99
BLSD (.05)						0.04	6.7	4.7	8.9
N-Rate X Inhibitor				80	82	81	79	87	79
Factorial Arrangement (N-Rate X Method X Time)									
N-Rate									
100				2.95	1.43	0.50	128.9	41.2	170.1
168				3.07	1.61	0.54	156.1	46.4	202.8
235				3.23	1.64	0.55	158.8	49.1	208.0
P-Value				99	99	99	99	99	99
BLSD (.05)				0.18	0.05	0.04	7.6	4.2	10.4
Method									
Broadcast				3.04	1.52	0.51	140.4	42.4	183.0
Injected				3.13	1.60	0.55	155.4	48.7	204.2
P-Value				75	99	97	99	99	99
Time									
Early				3.13	1.56	0.52	148.9	45.4	194.5
Late				3.04	1.56	0.54	146.9	45.6	192.7
P-Value				75	14	70	46	10	32
Rate X Method				79	77	95	88	86	91
Rate X Time				43	55	40	26	69	48
Method X Time				46	85	94	53	82	46
Rate X Method X Time				90	17	58	25	34	33

Influence of Nitrogen Application Time and Nitrification Inhibitor Rate on Sweet Corn Production on an Irrigated Sand

C. J. Rosen

With excessive rainfall, coarse-textured soils are subject to leaching of nitrate-N from the root-zone. Because N loss through the growing season can depress yields and contaminate groundwater, the practice of sidedressing and/or use of nitrification inhibitors are important considerations for growers on the central sand plains of Minnesota. Maintaining N in the relatively nonleachable ammonium form through use of a nitrification inhibitor may be one means of reducing nitrate-N leaching and N fertilizer inputs. Another factor to consider is whether hybrids respond differently to ammonium-N compared to nitrate-N. Selecting hybrids that respond to ammonium nutrition may enhance the effectiveness of nitrification inhibitors. The objectives of this study were to 1) determine the effects of N fertilizer application time and nitrification inhibitor rate on soil levels of nitrate-N and ammonium-N and 2) compare the response of two sweet corn hybrids to these treatments. Results presented here are from the second year of the study.

EXPERIMENTAL PROCEDURES

The experiment was conducted at the Sand Plains Research Farm in Becker, MN. Prior to planting and fertilizer application, the soil (Hubbard loamy sand) had the following test values (0-6"): pH, 6.3; Bray P1, 105 lb/A; ammonium acetate extractable K, 234 lb/A. The previous crop at this site was rye. Prior to planting 150 lb/A potassium-magnesium sulfate (0-0-22) was broadcast and incorporated.

Treatments consisted of two hybrids 'Code 5' (early season maturing) and 'Jubilee' (mid-season maturing), 150 lb N/A as anhydrous ammonia either preplant or split applied (75 lb N/A preplant and 75 lb N/A sidedressed) and three rates of N-Serve (0, 0.5, or 1.0 lb ai/A). For both hybrids, a control, which did not receive N or an inhibitor, was also included. A split-plot design with four replications was used with timing and inhibitor rate as main plots and hybrid as subplots. Preplant treatments were applied April 24, 1987. Both hybrids were planted April 29 with a banded application of 150 lb/A 0-14-42. Stands were thinned to approximately 24,000 plants/A with spacing set at 30" rows. The sidedress treatments were applied June 9 (10-12 leaf stage). The split N treatments had half the inhibitor applied preplant and the remainder applied with the sidedress. Soil samples were collected in the anhydrous ammonia bands (samples bulked over hybrid) May 27, July 10 and August 5 and stored moist at 4°C until extracted with 2N KCl for nitrate-N and ammonium-N determination. Whole plant samples collected at the 10-12 leaf stage (before sidedress application) and leaf samples opposite and above the ear at mid-silking were dried and ground for subsequent nutrient determination. From May through July, precipitation totalled 12.3". This rainfall was supplemented with an overhead irrigation system to supply 1 inch of water per week.

Code 5 was harvested on July 22 and Jubilee was harvested July 30. Total green yield, husked yield and stover yield were obtained by harvesting two 15 ft center rows within each plot. Subsamples of ears, husk, and stover were taken to determine % moisture for N uptake calculations. As a measure of product quality, % kernel moisture and % usable ears (5.5" or greater with unfilled tip removed - CCC eligible) were determined.

RESULTS

Both N timing and nitrification inhibitor rates had significant effects on levels of soil ammonium-N (Table 1) and nitrate-N (Table 2). Because samples were taken in the anhydrous ammonia band, values presented are valid for that area and do not represent average levels through the field. The control plot, as expected, had relatively low levels of nitrate-N and ammonium-N at all sampling dates and depths. Differences in the N treated plots were most apparent at the second and third sampling date. Ammonium-N increased significantly with split applications and with increasing inhibitor rate at the 0-6" depth. At times it was difficult to locate the band from the preplant applications. Therefore, some samples from the preplant applications may not have been entirely from the band. In contrast to ammonium-N, nitrate-N levels decreased with inhibitor rate at the 6-12" and 12-14" depths at the second and third planting dates. Nitrate-N increased when applications were split. This may have been in part due to the inability to locate the band in some of the preplant treatments. Overall, these data indicate that N-Serve suppressed nitrification which resulted in relatively high ammonium-N soil levels in N-Serve treated plots.

Yield of Jubilee was greater than that of Code 5 regardless of treatment (Table 3). This hybrid difference was due in part to earlier maturity of Code 5 and a higher % moisture at time of harvest of Code 5. As expected, both hybrids yielded poorly when nitrogen was omitted. Split application of nitrogen resulted in greater unhusked (green), husked yield and % CCC eligible ears compared to preplant application. Nitrification inhibitor rate had no effect on green yield, but husked yield tended to increase with inhibitor rate. The significant interaction between hybrid and inhibitor rate was due to a more linear response to inhibitor rate by Jubilee compared to a more quadratic response by Code 5. Inhibitor rate had no effect on the % CCC eligible ears. This is in contrast to the results from last year where Code 5 had a greater number of eligible ears with increasing inhibitor rate. Except for a hybrid difference, there was no treatment effect on ear length.

Nitrogen composition of and uptake by the two hybrids are presented in Table 4. Nitrogen concentration and uptake was significantly reduced when nitrogen was not applied. Concentrations of N in plants sampled at the 8-10 leaf stage were not significantly affected by inhibitor rate or N timing. Concentrations of N in stover, husk and ears were not affected by inhibitor rate or split applications. Total N removed in ears, husk and stover was not consistently affected by inhibitor rate and split application. Mid-silk leaf elemental concentrations are presented in Table 5. Except for the control plots, all leaf N levels were in the optimum range for sweet corn production. In general, increasing inhibitor rate decreased leaf Ca, Mg, Fe and Mn.

GENERAL COMMENTS

Overall responses this year to inhibitor and split application were much less than those of the previous year. Precipitation during this growing season was about half that of the previous season. In addition, none of the rainfall events this year exceeded more than one inch over a 24 hour period. It is probable that there was less leaching of nitrate this year compared to last year. Extractable ammonium levels significantly increased with inhibitor rate; however, hybrids responded similarly to the different treatments. These results suggest that unless significant leaching of nitrate occurs during the season, the probability of a response to inhibitor or split N applications is low.

The assistance of Tom Graff with inhibitor and nitrogen applications is gratefully acknowledged.

Table 1. Influence of timing of N fertilizer application (150 lb. N/A) and rate of nitrification inhibitor on soil ammonium - N levels at three depths. The control did not receive any nitrogen or inhibitor treatment.

		Sampling Data								
		May 27			July 10			August 5		
Timing	NI rate (lb. ai/A)[1]	0-6"	6-12"	12-24"	0-6"	6-12"	12-24"	0-6"	6-12"	12-24"
		ppm-NH_4-N								
control	0	1.0	0.2	0.3	0.8	0.6	1.0	0.8	0.8	1.0
preplant	0	31.7	82.8	2.0	1.0	8.2	2.0	0.8	2.9	1.8
preplant	0.5	22.8	69.0	1.8	11.7	21.2	2.5	1.8	9.2	1.4
preplant	1.0	14.8	39.6	3.6	0.9	4.7	1.9	0.8	4.8	3.0
split	0	14.2	41.0	1.2	131.9	16.8	6.8	6.3	11.6	2.8
split	0.5	4.5	20.2	0.5	163.9	8.6	18.5	50.6	4.8	2.5
split	1.0	28.2	46.8	5.0	218.3	13.4	9.9	65.2	20.8	3.0

Statistics (not including control)	0-6"	6-12"	12-24"	0-6"	6-12"	12-24"	0-6"	6-12"	12-24"
Timing									
preplant	23.1	63.8	2.4	4.6	11.4	2.2	1.2	5.6	2.1
split	15.6	36.0	2.2	171.3	12.9	11.7	40.7	12.4	2.8
Significance	NS	NS	NS	**	NS	++	**	++	NS
NI Rate									
0	22.9	61.9	1.6	66.5	12.5	4.4	3.6	7.3	2.3
0.5	13.6	44.6	1.1	87.8	14.9	10.5	26.2	7.0	2.0
1.0	21.5	43.2	4.3	109.6	9.0	5.9	33.0	12.8	3.0
Significance	NS	NS	*	*	NS	NS	*	NS	NS
Linear	NS	NS	*	**	NS	NS	**	NS	NS
Quad	NS	NS	++	NS	NS	NS	++	NS	NS
Time x NI Rate									
Significance	+	NS	NS	*	*	NS	*	++	NS

[1] NI - nitrification inhibitor (N-Serve)
** = <.01, * = .01-.05, ++ = .05-.1, + = .1-.2, NS = >.2

Table 2. Influence of timing of N fertilizer application (150 lb. N/A) and rate of nitrification inhibitor on soil nitrate - N levels at three depths. The control did not receive any nitrogen or inhibitor treatment.

		Sampling Data								
		May 27			July 10			August 5		
Timing	NI rate(lb. ai/A)[1]	0-6"	6-12"	12-24"	0-6"	6-12"	12-24"	0-6"	6-12"	12-24"
		ppm-NO_3-N								
control	0	6.6	5.9	1.8	4.4	2.3	1.2	3.3	2.2	0.8
preplant	0	18.9	34.5	9.0	7.2	17.6	14.5	5.2	11.2	8.6
preplant	0.5	15.0	14.4	2.5	12.1	18.6	6.0	6.0	7.3	4.0
preplant	1.0	20.6	29.2	5.2	7.1	4.0	2.9	5.2	3.6	2.0
split	0	22.9	44.9	5.0	70.5	46.4	15.6	16.4	22.0	15.7
split	0.5	18.8	25.3	3.4	152.6	33.1	12.6	13.9	11.0	5.6
split	1.0	30.5	35.8	9.1	145.4	42.8	12.1	31.2	13.3	8.4

Statistics (not including control)

	0-6"	6-12"	12-24"	0-6"	6-12"	12-24"	0-6"	6-12"	12-24"
Timing									
preplant	18.2	26.0	5.6	8.8	13.4	7.8	5.5	7.4	4.9
split	24.1	35.3	5.8	122.8	40.8	13.4	20.5	15.4	9.9
Significance	NS	+	NS	*	**	**	++	**	**
NI Rate									
0	20.9	39.7	7.0	38.9	32.0	15.1	10.8	16.6	12.1
0.5	16.9	19.8	2.9	82.4	25.8	7.5	10.0	9.2	4.8
1.0	25.6	32.5	7.2	76.3	23.4	9.2	18.2	8.4	5.2
Significance	NS	++	+	NS	NS	**	NS	*	**
Linear	+	+	NS	NS	*	**	NS	*	**
Quad	*	**	*	NS	NS	+	NS	NS	*
Time x NI Rate									
Significance	NS	NS	NS	NS	+	+	NS	NS	+

[1] NI - nitrification inhibitor (N-Serve)

** = <.01, * = .01-.05, ++ = .05-.1, + = .1-.2, NS = >.2

Table 3. Nitrogen fertilizer timing (150 lb. N/A) and nitrification inhibitor rate effects on yield and quality of two sweet corn hybrids. The control did not receive any nitrogen or inhibitor treatment.

Timing	NI rate[1] (lb. ai/A)	Hybrid	Yield Green	Yield Husked	Ear Length	Kernal Moisture	OOC Eligible
			-----(T/A)-----		(inches)	(%)	(%)
control	0	Code 5	0.6	0.3	2.2	82.7	00.0
preplant	0	Code 5	7.6	4.7	8.2	82.6	91.0
preplant	0.5	Code 5	7.8	4.7	8.0	83.6	75.8
preplant	1.0	Code 5	7.5	4.6	8.4	84.7	90.0
split	0	Code 5	7.6	4.7	8.4	84.1	89.8
split	0.5	Code 5	8.4	5.3	8.4	82.1	90.0
split	1.0	Code 5	7.8	5.0	8.5	83.0	91.2
control	0	Jubilee	2.1	1.5	5.9	75.6	17.5
preplant	0	Jubilee	8.9	6.2	7.6	77.1	87.5
preplant	0.5	Jubilee	9.8	6.6	7.8	77.8	88.8
preplant	1.0	Jubilee	9.7	6.7	7.9	77.8	87.5
split	0	Jubilee	10.1	6.6	7.7	78.8	93.8
split	0.5	Jubilee	9.9	6.6	7.7	77.2	96.2
split	1.0	Jubilee	10.0	7.3	7.8	76.2	95.0

Statisitics (not including control)	Green	Husked	Ear Length	Kernal Moisture	OOC Eligible
Main Effects					
Hybrid					
Code 5	7.8	4.8	8.3	83.4	88.0
Jubilee	9.7	6.7	7.7	77.5	91.4
Significance	**	**	**	**	++
Timing					
preplant	8.5	5.6	8.0	80.6	86.8
split	9.0	5.9	8.1	80.2	92.7
Significance	*	**	NS	NS	*
NI Rate					
0	8.6	5.6	8.0	80.6	90.5
0.5	9.0	5.8	8.0	80.2	87.7
1.0	8.7	5.9	8.1	80.4	90.9
Significance	NS	*	NS	NS	NS
Linear	NS	**	NS	NS	NS
Quad	*	NS	NS	NS	+
Interactions					
Hybrid X Timing	NS	NS	NS	NS	NS
Hybrid X NI Rate	NS	*	NS	NS	+
Timing X NI Rate	NS	NS	NS	++	NS
Hybrid X NI Rate X Timing	++	*	NS	NS	NS

[1] NI - nitrification inhibitor (N-Serve)
** = <.01, * = .01-.05, ++ = .05-.1, + = .1-.2, NS = >.2

Table 4. Nitrogen fertilizer timing (150 lb. N/A) and nitrification inhibitor effects on N composition of and uptake by two sweet corn hybrids. The control did not receive any nitrogen or inhibitor treatment.

			---% N---				---N Content---			Total
Timing	NI rate (lb. ai/A)[1]	Hybrid	Whole Plant (6-8 leaf)	Ear -----Harvest-----	Husk	Stover	Ear ------lb N/A-----	Husk	Stover	N Uptake lb. N/A
control	0	Code 5	3.82	1.58	.70	0.68	1.8	7.5	35.9	45.1
preplant	0	Code 5	3.41	1.84	.80	1.72	38.7	8.1	90.6	137.4
preplant	0.5	Code 5	4.27	1.50	.77	1.73	29.1	5.3	85.7	120.1
preplant	1.0	Code 5	4.28	1.84	.74	1.72	35.6	6.4	97.2	139.2
split	0	Code 5	3.69	1.78	.60	1.43	28.8	14.6	72.0	128.9
split	0.5	Code 5	4.22	1.79	.73	1.78	43.5	5.4	85.9	134.8
split	1.0	Code 5	4.11	1.82	.78	1.72	39.4	6.3	87.0	132.7
control	0	Jubilee	3.89	1.34	.60	0.55	9.4	4.4	21.4	35.2
preplant	0	Jubilee	4.19	1.89	.94	1.40	55.5	10.5	78.8	144.8
preplant	0.5	Jubilee	4.10	1.84	.96	1.37	61.1	8.3	77.4	146.7
preplant	1.0	Jubilee	4.24	1.86	.82	1.36	63.8	6.6	82.2	152.6
split	0	Jubilee	4.13	1.86	.91	1.50	59.7	8.5	92.5	160.7
split	0.5	Jubilee	4.22	1.89	1.02	1.53	60.7	8.4	91.8	160.9
split	1.0	Jubilee	4.12	1.93	.90	1.34	71.4	7.5	78.4	157.4
Statisitics (not including the control)										
Main Effects										
Hybrid										
Code 5			4.10	1.76	.77	1.72	37.2	6.6	90.4	134.2
Jubilee			4.17	1.88	.93	1.41	62.0	8.3	83.5	153.8
Significance			NS	+	**	**	**	**	+	**
Timing										
preplant			4.08	1.79	.84	1.55	47.3	7.5	85.3	140.1
split			4.18	1.85	.86	1.59	51.9	7.4	88.6	147.9
Significance			NS	NS	NS	NS	*	NS	NS	+
NI Rate										
0			4.00	1.85	.87	1.57	47.7	8.8	89.4	145.9
0.5			4.20	1.75	.87	1.60	48.6	6.8	85.2	140.6
1.0			4.19	1.86	.81	1.53	52.6	6.7	86.2	145.5
Significance			NS	NS	++	NS	+	NS	NS	NS
Linear			NS	NS	*	NS	++	**	NS	NS
Quad			NS	NS	+	NS	NS	+	NS	NS
Interactions										
Hybrid X Timing			NS	NS	NS	NS	NS	NS	NS	NS
Hybrid X NI Rate			NS	NS	**	NS	+	NS	NS	NS
Timing X NI Rate			NS	NS	NS	NS	NS	NS	NS	NS
Hybrid X NI Rate X Timing			+	NS	NS	NS	++	NS	NS	NS

[1]NI - nitrification inhibitor (N-Serve)
** = <.01, * = .01-.05, ++ = .05-.1, + = .1-.2, NS = >.2

Table 5. Influence of timing of N fertilizer application (150 lb. N/A) and rate of nitrification inhibitor on leaf elemental concentration at mid-silking. The control did not receive any nitrogen or inhibitor treatment.

Timing	NI rate (lb. ai/A)[1]	Hybrid	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			%					ppm				
control	0	Code 5	1.75	0.30	2.25	0.45	0.33	56	30	13	4	10
preplant	0	Code 5	3.30	0.32	2.03	0.61	0.40	93	114	23	9	8
preplant	0.5	Code 5	3.20	0.31	2.03	0.54	0.36	86	102	28	9	8
preplant	1.0	Code 5	3.29	0.34	2.11	0.58	0.40	88	86	23	10	8
split	0	Code 5	3.20	0.32	2.02	0.59	0.40	89	112	23	10	8
split	0.5	Code 5	3.30	0.33	2.05	0.60	0.41	89	80	24	10	9
split	1.0	Code 5	3.13	0.32	2.02	0.58	0.39	84	77	26	9	9
control	0	Jubilee	1.22	0.29	2.45	0.46	0.40	57	25	10	3	8
preplant	0	Jubilee	2.72	0.30	2.09	0.72	0.51	87	129	32	9	9
preplant	0.5	Jubilee	2.84	0.30	2.06	0.70	0.49	83	115	37	9	10
preplant	1.0	Jubilee	2.73	0.31	2.14	0.65	0.48	84	100	29	9	10
split	0	Jubilee	2.93	0.31	2.14	0.74	0.56	86	108	23	10	9
split	0.5	Jubilee	2.86	0.31	2.13	0.71	0.53	83	87	27	10	10
split	1.0	Jubilee	2.68	0.31	2.12	0.65	0.49	84	80	27	9	9

Statisitics (not including the control)

	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
Main Effects										
Hybrid										
Code 5	3.23	0.32	2.04	0.58	0.39	88	95	24	9	8
Jubilee	2.79	0.31	2.11	0.70	0.51	84	103	29	9	9
Significance	**	*	*	**	**	*	++	**	NS	*
Timing										
preplant	3.01	0.31	2.08	0.64	0.44	87	107	29	9	9
split	3.02	0.32	2.08	0.64	0.46	86	91	25	9	9
Significance	NS	NS	NS	+	**	NS	**	++	NS	NS
NI Rate										
0	3.04	0.31	2.07	0.67	0.47	89	116	25	9	9
0.5	3.05	0.31	2.07	0.64	0.45	85	96	29	9	9
1.0	2.96	0.32	2.10	0.61	0.44	85	86	26	9	9
Significance	++	NS	NS	**	*	*	**	NS	NS	NS
Linear	NS	NS	NS	**	*	++	**	NS	++	NS
Quad	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
Interactions										
Hybrid X Timing	NS	NS	NS	NS	NS	NS	+	**	NS	NS
Hybrid X NI Rate	NS	NS	NS	++	+	NS	NS	NS	NS	NS
Timing X NI Rate	++	+	+	++	++	NS	NS	NS	++	NS
Hybrid X NI Rate X Timing	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] NI - nitrification inhibitor (N-Serve)

** = <.01, * = .01-.05, ++ = .05-.1, + = .1-.2, NS = >.2

1987 WEATHER DATA
NORTHWEST EXPERIMENT STATION, CROOKSTON, MN

T.E. Cymbaluk

The weather for 1987 will be known as a warm year when compared with the 90-year average. Ten of the 12 months were above normal in regard to temperature, accounting for the average annual temperature to be 4.8 degrees above normal. January, February, April, and December were well above normal, with the average monthly readings deviating 10.7, 16.7, 8.9, and 7.0 degrees, respectively. August and October were the only two months below normal. The highest temperature for 1987 occurred on July 16 at 97 degrees F. The lowest temperature for 1987 occurred on January 22 at -25 degrees F.

The last frost of the spring was April 21, 1987 (29 degrees F) and the first hard killing frost occurred October 1, 1987 (28 degrees F). This made a 162-day frost-free period for 1987, the second highest frost-free period on record. The highest frost-free period on record is 167 days set in 1922.

The ground frost reached a maximum depth of 30 inches by the end of February. Surface thaw had begun by the end of March, by mid to late April, the ground frost was gone.

The 1987 precipitation was 1.25 inches less than the 90-year average. Seven of the 12 months had precipitation below normal. The greatest amount of precipitation that occurred in a single day was received on May 20, accumulating 2.23 inches of rain.

With little snow, a warm winter and early warm spring temperatures made it possible for a early planting season in 1987. By the first of May, most of the small grain crops had been planted. Because of a lack of moisture there was little tillering in the small grain crops.

Table 1. Weather summary for 1987 with 90-year averages for precipitation and mean temperatures.

Month	Precipitation 1987	Precipitation 1890-1979	Mean Temperatures 1987	Mean Temperatures 1890-1979
	--------inches--------		--------degrees F------	
January	0.21	0.56	14.4	3.7
Febuary	1.07	0.59	24.8	8.1
March	0.45	0.84	28.0	22.9
April	0.29	1.57	50.3	41.4
May	4.37	2.59	60.0	54.6
June	1.04	3.56	67.5	64.4
July	5.20	3.09	72.5	69.6
August	3.13	2.90	64.7	67.4
September	1.64	2.16	58.1	57.5
October	0.36	1.43	40.4	45.3
November	0.55	0.78	30.8	26.7
December	1.11	0.60	18.5	11.5
Total	19.42	20.67	Mean 44.2	39.4

Table 2. Records broken or matched at the Northwest Experiment Station, Crookston, MN in 1987.

Highest Maximum Temperature			Highest Minimum Temperature		
Date	Old Record	New (1987)	Date	Old Record	New (1987)
	---------degrees F---------			------------degrees F---------	
Febuary 7	41 (1898)	42	January 5	27 (1902)	27
March 20	57 (1946)	58	April 18	55 (1931)	60
April 26	79 (1977)	79	December 7	32 (1935)	32
May 8	89 (1895)	89	December 8	30 (1952)	31
May 10	86 (1976)	92			
July 31	96 (1936)	96			

RESIDUAL SOIL N, FERTILIZER N, AND INOCULATION EFFECTS ON SOYBEAN PRODUCTION IN NORTHWESTERN MINNESOTA

J.A. Lamb and T.E. Cymbaluk

<u>OBJECTIVE</u>: The overall objective of this study is to measure the effect of residual NO_3^--N, fertilizer N and seed inoculation on soybean production in the Red River Valley of Minnesota.

<u>MATERIALS AND METHODS</u>: Two sites were located in 1987. The NO_3^--N (0-2') contents were 164 and 40 lbs A^{-1} for Marshall and West Polk County sites, respectively. The N fertilizer (urea) treatments (0, 30, 60, 90 and 120 lbs N A^{-1}) and inoculation treatment (none and inoculated) were applied and the plots planted to McCall soybean May 19 and June 1 at the Marshall and West Polk County locations, respectively. The most recent matured trifoliate leaves were sampled at 50% bloom for N analysis on July 30. The plots were harvested by plot combine September 14 and 21 at Marshall and West Polk locations, respectively.

<u>RESULTS AND DISCUSSION</u>: Table 1 lists the grain yield, trifoliate leaf N contents and statistical analyses for the 1987 locations. In 1987 we had two very different locations with regard to soil NO_3^--N contents. The West Polk location with soil NO_3^--N of 40 lb·A^{-1} (0-2') had a significant grain yield increase from fertilizer N which was not maximized by a 120 lb N A^{-1}. The use of inoculum did effect grain yield at the lower N rates but at 60 lb N A^{-1} there was no difference in grain yield from inoculum. The trifoliate leaf N concentrations were only effected by N fertilization and not by inoculum.

The Marshall County location had an extremely high soil NO_3^--N content of 164 lb A^{-1}. Because of this there was no yield response to N fertilization or inoculation. The trifoliate leaf N concentrations were increased (P=0.10) but no response occurred to inoculum treatment. These results support the use of a soil NO_3^--N test to determine if soybean plants will respond to N fertilization. Even though a visual examination of plants in the inoculated treatment indicated that nodules had been formed, evidently their ability to provide N to the plant is reduced by both high residual soil NO_3^--N contents and the addition of N fertilizer.

The authors would like to acknowledge the cooperation received from Curt Knutson, Dwight Anderson, and Ray Thompson in this study in 1987.

Table 1. Grain yields, trifoliate leaf N concentrations, and statistical analyses for 1987.

	West Polk			Marshall			West Polk			Marshall		
	NO	2X	$\bar{X}$	NO	2X	$\bar{X}$	NO	2X	$\bar{X}$	NO	2X	$\bar{X}$
	Grain Yield, bu A^{-1}						Leaf Concentration, %					
0	28.5	32.1	30.0	32.8	31.4	32.1	4.87	4.80	4.83	5.68	5.67	5.68
30	31.0	32.0	31.5	31.6	33.5	32.6	5.33	5.00	5.16	5.77	5.51	5.64
60	33.8	34.2	34.0	33.1	29.9	31.5	5.61	5.16	5.39	5.84	5.72	5.78
90	35.1	34.6	34.8	34.8	32.4	33.6	5.62	5.21	5.42	5.66	5.84	5.75
120	38.5	37.1	37.8	33.9	32.4	32.4	5.88	5.79	5.83	5.89	5.79	5.84
$\bar{X}$	33.4	34.0		33.2	31.6		5.46	5.19		5.77	5.70	
I		NS			NS			NS			NS	
N Rate		**			NS			**			NS	
Lin		**			NS			**			++	
Quad		NS			NS			NS			NS	
I * NR		*			NS			*			NS	
C.V.		4.7			6.9			7.2			3.6	

**, *, and ++ are 0.01, 0.05, and 0.10 significance levels, respectively.

USE OF ACID BASED FERTILIZERS FOR MORE EFFICIENT SOYBEAN PRODUCTION IN NORTHWESTERN MINNESOTA

J.A. Lamb, T.E. Cymbaluk, and G.W. Rehm

OBJECTIVES: The primary objective of this study is to evaluate low pH fertilizers as carriers for micronutrients for soybean production in northwestern Minnesota. Particular objectives include 1) determine if low pH fertilizer increases the uptake of Zn and Fe in soybeans grown on calcareous soils, 2) determine the effect on soybean nodulation by the addition of micronutrients in different fertilizer carriers, and 3) determine effect of acid fertilizer on soybean yields.

MATERIALS AND METHODS: This study was located at two sites; West Polk County - Knutson site, and Marshall County - Anderson site. The soil test information is reported in Table 1. McCall soybeans were planted on May 20, 1987, and June 1, 1987 at the West Polk County and Marhall County sites, respectively. The fertilizer treatments listed in Table 2 were applied as a starter placement 2" x 2" from the row. The treatments were in a randomized complete design with four replications. Whole plant samples and population counts were taken three weeks after emergence. The Marshall County and West Polk County plots were harvested September 14 and September 21, 1987, respectively.

RESULTS AND DISCUSSION: West Polk County Location: Even though the soil P test was 14 lb A^{-1}, there was not a positive grain yield response at this location, Table 3. Actually, the treated plants yielded significantly less than the check. Forage yield, population, Zn uptake, plant Fe concentration and Fe uptake were not effected by the treatments. Plant P was on the average negatively effected by the addition of zinc in either the acid or nonacid carriers. The treatments caused a trend in lower P uptakes when compared to the check (P=0.10). The plant Zn concentration was on the average significantly lower for the treated plant when compared to the untreated check plants.

Marshall County Location: This location had a very low phosphorus soil test of 9 lb A^{-1}, Table 4. Similar to the West Polk site, no grain yield response occurred. Forage yield and plant population were uneffected by the treatments. Both plant P concentration and uptake were significantly increased by the application of P by either carrier. There was no difference between carriers. Plant Zn concentration and uptake were increased when Zn was added to the carrier. Acid x Fe and Fe x zinc interactions occurred with the Zn concentration. The Zn by Fe interaction is interupted as without Fe in the fertilizer the increase in plant Zn concentration from the addition of Zn is greater than in the presence of Fe (11 ppm vs 5 ppm). The acid by Fe interaction reveals that when Fe is added to the acid carrier, the Zn concentration is decreased (6 ppm) and with the nonacid carrier it is increased 2 ppm. The plant Fe concentrations and uptakes were increased with the use of fertilizer when compared to the check. No fertilizer treatment significantly did better than the rest.

Originally the very acid fertilizers were developed to be used in higher pH soils to acidify the soil in a small area where nutrients such as P, Zn and Fe would be more available to the plant. This increased availability was then supposed to increase grain yields. From both 1986 and 1987 soybean studies over 4 locations in the Red River Valley, no grain yield increase has been documented. In fact, in 1987, one location had a yield decrease. The results from the nutrient data in 1987 were mixed. Of interest was the effect of the starter placement on population. Soybean seeds are sensitive to salt when it comes to germination. We did not see this effect with the 2" x 2" placement. The soils of the Red River Valley are so buffered with $CaCO_3$ that the amount of acid needed to neutralize them even in a band, would be larger than what could be economically supplied.

Table 1. Soil test information for soybean fertilizer carrier study, 1987.

	Depth	West Polk	Marshall
	--in.--		
OM %	0-6	4.5	4.7
NO_3^--N lb A^{-1}	0-24	40	104
$NaHCO_3$P lb A^{-1}	0-6	14	9
K lb A-1	0-6	530	230
pH		8.2	8.0
Zn ppm		0.5	0.6
Fe ppm		4	5

Table 2. Treatments for acid fertilizer experiment in 1986.

Carrier	Micronutrient
1. Acid fertilzier	-
2. (7-28-0-4) pH <0	1 lb A^{-1} Zinc
3.	1 lb A^{-1} Iron
4.	1 + 1 lb A^{-1} Zinc + Iron
5. Non Acid 10-34-0 + 12-0-0-26)	-
6. pH=5.4 (7-28-0-4)	1 lb A^{-1} Zinc
7.	1 lb A^{-1} Iron
8.	1 + 1 lb A^{-1} Zinc + Iron
9. Check (no fertilizer)	

Table 3. Treatment means and statistical analyses for grain yield, forage yield, small plant P, Zn, and Fe concentrations and uptakes and population for West Polk County location in 1987.

	Grain Yield bu A-1	Forage Yield lb A^{-1}	Plant P ppm	P Uptake lb A-1	Plant Zn ppm	Zn Uptake lb A-1	Plant Fe ppm	Fe Uptake lb A-1	Population plants A-1
Acid	29.8	132	2979	0.39	23.3	0.003	546	0.07	115,434
Acid + Zn	30.6	132	2601	0.34	19.6	0.003	504	0.07	114,345
Acid + Fe	31.2	122	2946	0.36	21.1	0.003	349	0.04	106,722
Acid + Zn + Fe	31.0	125	2471	0.31	19.5	0.002	600	0.08	112,167
Nonacid	30.6	127	2739	0.35	20.5	0.003	426	0.06	111,078
Nonacid + Zn	30.5	113	2458	0.27	18.8	0.002	395	0.05	107,811
Nonacid + Fe	31.5	120	2610	0.31	20.7	0.002	511	0.06	111,078
Nonacid + Zn + Fe	30.5	127	2772	0.35	21.9	0.003	565	0.07	103,455
Check	32.0	128	2888	0.37	23.2	0.003	416	0.05	109,626
Check vs Rest	*	NS	NS	NS	*	NS	NS	NS	NS
Acid	NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron	NS	NS	NS	NS	NS	NS	NS	NS	NS
Zinc	NS	NS	*	NS	NS	NS	NS	NS	NS
Acid * Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS
Acid * Zn	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fe * Zn	NS	NS	NS	NS	NS	NS	NS	NS	NS
Acid * Fe * Zn	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.	5.2	14.2	10.1	12.6	11.0	16.7	40.3	47.2	13.0

* is 0.05 significance level.

Table 4. Treatment means and statistical analyses for grain yield, forage yield, small plant P, Zn, and Fe concentrations and uptakes and populations for Marshall County location in 1987.

	Grain Yield bu A-1	Forage Yield lb A^{-1}	Plant P ppm	P Uptake lb A-1	Plant Zn ppm	Zn Uptake lb A-1	Plant Fe ppm	Fe Uptake lb A-1	Population plants A-1
Acid	28.7	177	3923	0.70	24.3	0.004	251	0.04	68,607
Acid + Zn	27.7	185	4212	0.78	39.6	0.007	423	0.08	72,963
Acid + Fe	27.8	199	4419	0.88	23.6	0.005	285	0.06	79,497
Acid + Zn + Fe	27.8	163	4338	0.72	27.6	0.005	267	0.04	64,251
Nonacid	29.4	157	4758	0.74	24.0	0.004	281	0.04	75,504
Nonacid + Zn	28.6	194	4105	0.79	30.4	0.006	240	0.05	74,052
Nonacid + Fe	30.0	175	4544	0.79	26.9	0.005	286	0.05	71,874
Nonacid + Zn + Fe	29.3	185	4053	0.75	32.2	0.006	275	0.05	76,230
Check	28.3	164	3580	0.59	25.1	0.004	223	0.04	75,141
Check vs Rest	NS	**	**	*	NS	*	*	NS	NS
Acid	NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron	NS	NS	NS	NS	NS	NS	NS	NS	NS
Zinc	NS	NS	NS	**	*	NS	NS	NS	NS
Acid * Fe	NS	NS	NS	**	NS	NS	NS	NS	NS
Acid * Zn	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fe * Zn	NS	NS	NS	*	NS	NS	NS	NS	NS
Acid * Fe * Zn	NS	NS	NS	NS	NS	*	NS	NS	NS
C.V.	9.3	19.7	11.7	22.7	13.1	27.4	25.5	36.4	13.1

** and * are 0.01 and 0.05 significance levels, respectively.

FOLIAR NITROGEN APPLICATION ON SUGARBEET - TIMING AND RATE

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OBJECTIVE: In recent years a growing concern among producers has been the premature yellowing or N deficiency, of sugarbeet fields. Many questions have arisen concerning the use of a foliar N application to correct this situation. Because of the possible detrimental effects on sugarbeet quality, a cooperative study was started with the objective of determining the effects of foliar N application on sugarbeet yield and quality after early yellowing under optimum fertilizer application and under inadequate N conditions.

PROCEDURE: The second year of this study was established at the Northwest Experiment Station, on a soil NO_3^--N test, 0-2 ft, of 40 lb A^{-1}. Table 1 lists the soil and foliar N treatments. The soil N treatments were applied fall, 1986 as Urea and incorporated. Six replications of ACH 164 were planted April 27 in randomized complete block design. The plots were overplanted and thinned to 125 plants per 100 foot of row. The foliar treatments were Urea-ammonium nitrate solution (UAN, 28% N) applied as 20 lb A^{-1} increments on June 30, July 16, and August 3.

Table 1. Treatments for foliar N trial, NWES 1987.

Treatment	Soil Preplant lb N A^{-1}	Foliar 6/30	7/15	7/30	Total
		------ lb N A^{-1} -----			
1	0	0	0	0	0
2	0	0	0	20	20
3	0	0	20	20	40
4	0	20	20	20	60
5	0	0	0	0	0
6	100	0	0	20	20
7	100	0	20	20	40
8	100	20	20	20	60

Petiole and blade samples were taken 10 days after the final treatment for N determination. Roots and tops were hand harvested September 25. The quality was determined by American Crystal Sugar research quality lab at Moorhead, MN. Brei samples were taken and N was determined on them at J.T. Moraghan's lab at NDSU.

RESULTS AND DISCUSSION: The root yield and recoverable sugar per acre were increased by the addition of soil N, but not by the use of foliar N. The response to soil N was 2.6 tons A^{-1} and 784 lb sugar A^{-1}. Even with the treatment receiving no preplant N, the addition of foliar did not significantly effect root yield, sugar content, recoverable sugar per acre or per ton. The recoverable sugar per ton was significantly decreased by the 100 lb N A^{-1} soil applied treatment. This decrease was caused by the increase in Na and Amino-N contents which measure reduced quality by the N fertilizer (Table 3). The foliar treatments caused a trend towards poorer quality, but this did not result in significantly lower recoverable sugar. In 1987, the use of foliar N did not increase the value of the crop at either soil N level, Table 4. It is not advisable to use a foliar N treatment on sugarbeets. The top growth Table 2 was significantly increased with increasing N application either soil, foliar, or both.

Table 2. Sugarbeet root and top yield, sugar content, recoverable sugar per ton, and recoverable sugar per acre, NWES 1987.

Soil N	Foliar	Yield	Sugar	Recoverable Sugar	Recoverable Sugar/Ton	Top Yield
lb N A^{-1}	lb N A^{-1}	T A^{-1}	%	lb A^{-1}	lb Ton^{-1}	lb A^{-1}
0	0	14.5	19.3	5207	360	1953
0	20	15.8	19.3	5663	358	2178
0	40	15.7	19.2	5563	355	2191
0	60	16.4	18.9	5748	349	2440
100	0	18.2	19.2	6452	355	2848
100	20	17.6	18.9	6133	348	3104
100	40	18.4	18.9	6340	347	3017
100	60	18.5	18.8	6373	344	3481
	0	16.4	19.3	5830	358	2401
	20	16.7	19.1	5898	353	2641
	40	17.1	19.1	5952	351	2604
	60	17.5	18.9	6061	347	2961
	0	15.6	19.1	5540	355	2190
	100	18.2	18.9	6324	349	3112
Soil N		**	NS	**	*	**
Foliar N		NS	NS	NS	NS	++
S x F		NS	NS	NS	NS	NS
C.V.%		12.8	2.7	12.9	3.3	18.8

**, *, and ++ are 0.01, 0.05, and 0.10 significance levels, respectively.

Table 3. Sugarbeet root impurities, NWES 1987.

Soil N	Foliar	Na	K	Amino-N	Index
lb N A^{-1}	lb N A^{-1}	---------ppm--------			
0	0	225	1933	347	462
0	20	208	1967	365	475
0	40	276	1919	370	485
0	60	282	1957	369	498
100	0	265	1822	415	492
100	20	321	1855	422	518
100	40	301	1878	479	547
100	60	366	1847	484	560
	0	245	1878	381	477
	20	265	1911	394	497
	40	289	1899	425	516
	60	324	1902	427	529
	0	249	1943	362	480
	100	313	1850	450	529
Soil N		**	**	**	**
Foliar N		NS	NS	NS	++
S x F		NS	NS	NS	NS
C.V.%		27.6	5.5	14.9	10.0
L.S.D. 0.05		46	62	36	30

**, *, and ++ are 0.01, 0.05, and 0.10 significance levels, respectively.

Table 4. Economic analyses of foliar N study, NWES 1987.

Soil N	Foliar	Net Beet Payment	
lb N A^{-1}	lb N A^{-1}	Net per ton	Net per acre
0	0	$44.82	$649
0	20	44.53	706
0	40	43.93	687
0	60	42.69	703
100	0	43.80	795
100	20	42.42	747
100	40	42.17	766
100	60	41.50	771
	0	44.31	722
	20	43.48	727
	40	43.05	727
	60	42.10	737
	0	43.99	686
	100	42.47	770

TIMING OF NITROGEN APPLICATION ON SUGARBEET

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OBJECTIVE: Nitrogen fertilizer management has received considerable attention from sugarbeet producers in the past because of the quality payment system. The producer in the Red River Valley area has gone from a situation of too much residual soil N to, in most cases, a manageable to deficit situation. Much concern has grown because of this shift in N situation about sugarbeet prematurely yellowing. The split application of nitrogen may provide an avenue of delaying the yellowing, allow more efficient use of the fertilizer, and not decrease quality. This study was designed with the objective to evaluate the effect of split application of soil N.

PROCEDURE: Plots were established at the Northwest Experiment Station, Crookston, MN, and the Mike Schjeken farm, Sacred Heart, MN. At both locations the Urea Ammonium Nitrate solution (UAN, 28%N) was used as an N source and knife in between the rows four inches deep at four dates. The NWES dates were April 27, June 5, June 25, and July 14. Because of rain, the Schjeken farm dates were delayed May 5, July 2, July 24, and August 3. The total amount of N applied was 80 lb A^{-1}. The soil tests were 41 and 43 NO_3^--N (0-2') A^{-1} at NWES and Schjeken location, respectively. KW 3265 was planted April 28 (NWES) and May 5 (So. MN). The treatments (Table 1) were arranged in a randomized complete block design with four replications. The sugarbeets were harvested September 24 (NWES) and 22 (So. MN) and the quality was determined at American Crystal Sugar's Tare Lab, East Grand Forks, MN.

RESULTS AND DISCUSSION: NWES: The results from Crookston are summarized in Table 1. In 1987 a yield andquality response occurred from N fertilization except for K concentration of the brei. There were no significant differences between the N application treatments for any of the measured variables.

Southern Minnesota: Table 2 lists the results for 1987. Except for a significant decrease in brei K concentration, there was no response to the use of nitrogen fertilizer. This was not expected with a soil test of 43 pounds NO_3^--N A^{-1} in the 0-2' depth. Significant differences between application times were with root yield and recoverable sugar per acre. The 20-20-20-20 treatment yield was less than the other treatments. Because of the late application dates, the plants were disrupted by the fertilizer applicator shanks and caused the lower tonage and sugar yield.

The soil N mineralization for 1987 was greater than in other years. This probably masked the effects of the fertilization particularly at the later dates.

Table 1. Sugarbeet yield and quality as effected by N applications, NWES, 1987, Crookston, MN.

Application Date				Yield	Sugar	Recoverable Sugar	Recoverable Sugar/Ton	Na	K	Amino-N	Index
4/2	6/5	6/25	7/14	T/A	%	lb/A	lb/Ton	-------ppm-----			
0	0	0	0	15.9	18.1	5358	338	223	1818	273	438
20	20	20	20	19.8	17.2	6257	316	438	1595	370	529
40	40	0	0	20.2	17.7	6607	328	290	1745	330	482
40	0	40	0	19.7	17.6	6374	324	328	1830	345	516
40	0	0	40	19.7	16.6	5981	303	393	1835	403	592
0	40	40	0	19.1	18.0	6380	333	303	1775	365	503
0	40	0	40	19.0	17.2	6004	317	353	1720	333	509
0	0	40	40	19.5	16.9	6041	310	395	1768	385	559
80	0	0	0	20.0	17.6	6454	324	365	1770	360	525
0	80	0	0	19.2	17.3	6156	320	328	1678	325	488
0	0	80	0	19.6	17.7	6370	326	335	1835	363	522
0	0	0	80	19.4	17.6	6293	325	348	1733	345	504
Treatment				++	NS	NS	NS	NS	NS	NS	NS
Check vs Rest				**	++	**	++	*	NS	*	*
C.V.%				8.5	4.1	8.7	5.1	33.0	7.7	19.9	19.6
LSD.05				2.36	1.0	775	24	162	194	100	108

**, *, and ++ are 0.01, 0.05, and 0.10 significance levels, respectively.

Table 2. Sugarbeet yield and quality as effected by N application, Mike Schjeken Farm, 1987, Sacred Heart, MN.

Application Date				Yield	Sugar	Recoverable Sugar	Recoverable Sugar/Ton	Na	K	Amino-N	Index
4/2	6/5	6/25	7/14	T/A	%	lb/A	lb/Ton	------ppm-----			
0	0	0	0	20.6	14.7	5336	258	243	2615	453	802
20	20	20	20	18.9	14.4	4830	253	243	2368	485	793
40	40	0	0	22.8	15.1	6033	265	253	2595	555	836
40	0	40	0	24.4	15.0	6549	268	203	2300	405	691
40	0	0	40	21.7	15.3	5975	275	190	2280	380	656
0	40	40	0	22.1	15.0	5875	270	278	2385	430	740
0	40	0	40	21.6	15.2	5830	266	243	2348	493	753
0	0	40	40	24.1	15.2	6554	272	215	2223	438	691
80	0	0	0	20.6	15.2	5573	270	218	2470	413	717
0	80	0	0	22.4	15.5	6163	275	238	2473	485	752
0	0	80	0	24.5	15.2	6720	274	193	2275	415	678
0	0	0	80	21.2	14.8	5571	263	190	2270	458	726
Treatment				++	NS	*	NS	NS	**	NS	NS
Check vs Rest				NS	NS	NS	NS	NS	**	NS	NS
C.V.%				11.2	4.4	12.8	5.5	22.3	5.7	16.4	11.2
LSD.05				3.6	0.9	1092	21	72	197	107	118

**, *, and ++ are 0.01, 0.05, and 0.10 significance levels, respectively.

THE EFFECTS OF SULFUR APPLICATION ON SUGARBEET

John A. Lamb, Soil Scientist
Northwest Experiment Station, University of Minnesota

OBJECTIVE: Determine if sugarbeets grown in Minnesota would respond to sulfur. Earlier data (15-20 years ago) indicated that no response in yield occurred when sulfur was applied. The sugarbeet industry has changed since then. Payment on quality, varietal changes, and environmental quality are examples of these changes. Many questions have arisen about sulfur in the past 2-3 years.

PROCEDURE: This study was conducted at two locations in 1987, the Northwest Experiment Station and Southern Minnesota on the Mike Schjeken farm. The soil characteristics are listed in Table 1.

Table 1. Soil characteristics for sulfur study.

	Depth	NWES	So. MN
NO_3^--N	0-24"	40	43
$NaHCO_3$ P	0-6"	9	18
K	0-6"	250	473
S	0-6"	NA	16 ppm
pH	0-6"	8.1	7.8

Elemental sulfur at rates 0, 25, and 50 pounds per acre was spread and incorporated prior to planting in the spring of 1987. Four replications in a randomized complete block design were used at both locations. Maribo 403 was planted April 23 at NWES and May 5 at Southern Minnesota. The plots were overplanted and thinned back to 125 plants per 100 feet of row. The experiment was harvested and quality run on September 16 and 22 for NWES and Southern Minnesota, respectively.

RESULTS AND DISCUSSION: The concern about the need of sulfur for sugarbeets has been, for the most part, unneeded. Tables 2 and 3 list the 1987 results. No response for any characteristic occurred. These results are similar to the 1986 results from NWES. The heavy textured soils of Minnesota normally have enough sulfur made available from the organic matter during the growing season to supply the crop. If a producer was growing sugarbeets on a lower organic matter and sandy textured soil, there may be a cause for concern. A soil test in this case would help indicate if sulfur should be used on a trial basis. The heavy textured soils, high clay contents, are normally underlayed with gypsum which is $CaSO_4$ and a good natural source of sulfur.

Table 2. Sugarbeet yield and quality parameter means and statistical analyses for sulfur study, NWES, 1987.

Sulfur Rate	Root Yield	Root Sugar	Recoverable Sugar	Recoverable Sugar/Ton	
lb/A	lb/A	%	lb/A	lb/Ton	Index
0	17.7	17.9	5774	328	542
25	17.0	17.7	5513	324	543
50	16.4	17.9	5408	329	515
Statistical Analyses					
Sulfur	NS	NS	NS	NS	NS
Linear	NS	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS
C.V. %	10.4	2.7	8.1	4.1	11.4

Table 3. Sugarbeet yield and quality parameter means and statistical analyses for sulfur study, southern Minnesota, 1987.

Sulfur Rate	Root Yield	Root Sugar	Recoverable Sugar	Recoverable Sugar/Ton	
lb/A	lb/A	%	lb/A	lb/Ton	Index
0	18.8	16.1	5384	286	757
25	19.1	15.8	5311	279	767
50	19.6	16.1	5627	287	729
Statistical Analyses					
Sulfur	NS	NS	NS	NS	NS
Linear	NS	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS
C.V. %	9.0	3.1	9.2	4.0	9.8

PHOSPHORUS FERTILIZATION ON SUGARBEET

John A. Lamb, Soil Scientist
Northwest Experiment Station, University of Minnesota

OBJECTIVE: The objective of this study is to gather more soil test information for phosphorus on sugarbeet. In the economic situation we are currently facing in agriculture, a producer must fine tune inputs into sugarbeet production. To do this the database on which soil test recommendations are made must be continually under revision. This means continual updating with new varieties and under different environmental conditions.

PROCEDURE: Five phorphorus rates (0, 20, 40, 60 and 80 lb P_2O_5 A^{-1}) were applied and incorporated, spring 1987. Sugarbeet variety KW 3265 was planted in four replications April 23, 1987 at the Northwest Experiment Station. The $NaHCO_3$ P soil test was 9 lb A^{-1}. Nitrogen was applied to all plots at 120 lb N A^{-1} (soil NO_3^--N 0-2' + fertilizer N) the previous fall. Plots were thinned to a uniform stand of 125 plants per 100 feet of row. Harvest occurred September 16 and quality determined at the American Crystal Sugar Quality Lab, East Grand Forks, MN.

RESULTS AND DISCUSSION: The results are listed in Table 1. Phosphorus even on a very low soil test did not effect sugarbeet yield or quality. This nonresponse is somewhat unsettling because under most conditions at a 9 lb A^{-1} soil test a response should have occurred. This suggests one of two things: 1) the soil test method is not calibrated well enough for this set of conditions, or 2) the early warm temperatures and above-normal summer temperatures caused the soil organic matter to mineralize P for plant use. More information is needed to understand the role of organic P in the P nutrition of crops grown in the Red River Valley.

Table 1. The effect of phosphorus on sugarbeet yield and quality parameters, NWES, 1987.

P Rate	Root Yield	Root Sugar	Recoverable Sugar	Recoverable Sugar/Ton	
lb P_2O_5/A	lb/A	%	lb/A	lb/Ton	Index
0	21.9	16.6	6561	300	623
20	22.7	16.7	6796	299	709
40	22.1	16.8	6750	305	593
60	23.3	16.0	6618	285	719
80	23.3	16.8	6996	300	699
Statistical Analyses					
Phoshorus	NS	NS	NS	NS	NS
Linear	NS	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS
C.V. %	6.9	3.4	7.1	4.5	12.2

HIGH PHOSPHORUS AND POTASSIUM RATES ON CONTINUOUS SPRING WHEAT

J.A. Lamb and T.E. Cymbaluk

OBJECTIVE: This study was designed to determine the effect of P and K rate combinations on spring wheat yield, nutrient uptake, and soil test P and K levels over an extended period of time. The P and K rate combinations used were selected to provide information on response curves and "maintenance" rates for both elements.

EXPERIMENTAL PROCEDURE: Ten treatments consisting of P and K combinations and applications made to date are shown in Table 1. Treatments applied in the fall of 1986 were broadcast and plowed down. Nitrogen, as urea, was fall applied at 100 lb N A^{-1} and incorporated with a field cultivator on October 14, 1986. Marshall wheat was planted on April 15, 1987 and harvested for grain yield on July 24, 1987. Whole plant samples were taken at soft dough July 6, 1987 for elemental analyses and used to determine forage yields, P, and K uptakes. Soil samples were taken after crop removal to measure the residual effects of the treatments. The plant samples are in the process of being analyzed at the time of this report so will not be reported.

Table 1. Phosphorus and potassium treatment combinations at Crookston in the high P and K study.

Treatment No.	Application Date: Spring 1980 / Fall 1985	Fall 1980 / Fall 1986	Fall 1981	Fall 1982	Fall 1983	Fall 1984
	P_2O_5 lb A^{-1} + K_2O lb A^{-1}					
1	0 + 0	0 + 0	0 + 0	0 + 0	0 + 0	0 + 0
2	0 + 100	0 + 100	0 + 100	0 + 100	0 + 100	0 + 100
3	50 + 100	50 + 100	50 + 100	50 + 100	50 + 100	50 + 100
4	100 + 100	100 + 100	100 + 100	100 + 100	100 + 100	100 + 100
5	150 + 100	0 + 100	0 + 100	150 + 100	0 + 100	0 + 100
6	100 + 0	100 + 0	100 + 0	100 + 0	100 + 0	100 + 0
7	100 + 50	100 + 50	100 + 50	100 + 50	100 + 50	100 + 50
8	100 + 150	100 + 0	100 + 0	100 + 150	100 + 0	100 + 0
9	150 + 100	0 + 0	0 + 0	0 + 0	0 + 0	0 + 0
10	100 + 150	0 + 0	0 + 0	0 + 0	0 + 0	0 + 0

RESULTS AND DISCUSSION: Table 2 lists the grain yield, grain protein, soil pH, $NaHCO_3$ P, and exchangeable K for 1987. The grain yields indicate a significant response to P fertilizer application which has increased the soil test P level in treatments 3 through 10 over check treatments 1 and 2. The soil test values (0-6") taken after the growing season reflect the elevated P levels. Potassium treatments did not effect the grain yield although the treatments have effected the soil test K values. Grain protein was not effected by the treatments.

Table 2. Treatment means and statistical analyses for grain yield, grain protein content, soil pH, $NaHCO_3$-P, and exchangeable K in 1987.

Treatment No.	Grain Yield	Grain Protein	pH 0-6"	$NaHCO_3$ P 0-6"	Exchangeable K
	bu A^{-1}	%		----------ppm----------	
1	35.4	12.9	8.1	4.7	147
2	37.7	12.8	8.1	4.0	202
3	52.4	12.5	8.1	19.7	189
4	45.7	12.7	8.1	33.0	184
5	49.1	12.4	8.0	16.5	195
6	46.0	12.8	8.1	25.9	130
7	47.6	12.5	8.0	27.4	155
8	48.6	12.0	8.0	39.2	165
9	43.0	13.2	8.1	12.7	135
10	47.8	12.6	8.1	9.9	152
Statistical Analyses					
TRT	*	NS	NS	**	**
C.V.	13.8	5.9	0.6	26.0	8.9
LSD .05	9.1	-	-	7.4	21

** and * are 0.01 and 0.05 significance levels, respectively.

RESIDUAL NITROGEN STUDY AT LAMBERTON[1]

J.A. STARICKA AND W.W NELSON

Objectives: 1) Determine the N-rate response for corn in a corn-soybean rotation under the climatic and soil conditions in southwestern Minnesota. 2) Determine if high rates of nitrogen on corn have an influence on soybean yields the following year.

Methods & Materials: The experiment was initiated in 1984 on a Normania loam. Each plot is 30 by 48' with 8 replications each arranged in a randomized block design. In 1984, all 8 blocks were planted in corn. Starting in 1985, half the blocks have been in corn, the other half in soybeans, alternating each year. The treatments consist of six N-rates ranging from 0 to 400 #/Ac applied side dress as urea during the corn year. Additional management data is given in Table 1.

Results: Yields are given in Table 2. Because of the amount of data, only treatment averages, versus individual plot data, will be given here.

In corn, there was a significant response to nitrogen each year. The yield of the check treatment increased each year which may be due in part to earlier planting dates each year. Also the N-rate at which maximum yield was reached decreased each year. The reason for this has not been determined. The highest corn yields were obtained in 1986, the year which had the greatest growing season precipitation (Table 3).

In soybeans, there has not been a response to nitrogen any of the 3 years. Similar to corn, highest yields of soybeans were obtained in 1986.

Soil nitrate samples have been taken each fall in 1-ft increments to 5 foot in the 0, 100, and 400 #N/ac treatment corn plots (Table 4). Between 1984 and 1985 the nitrate level increased in the 0 to 3-ft depth of the 0 and 100 #N/ac treatments but decreased in the 0 to 5-ft depth. The nitrate level increased in all 1-ft increments of the 400 #N/ac treatment. The nitrate levels in the 1-ft increments below 1 foot varied greatly between replications in the 400 #N/ac treatment both years.

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

Table 1a: Corn Management Information

Item		1984	1985	1986	1987
Fall Primary Tillage:		Moldboard	Soil Saver	Soil Saver	Soil Saver
Secondary Tillage	Type:	Disk Twice	Digger Twice	Digger Twice	Disk Twice
	Date:	15 & 18 May	10 May	6 & 7 May	23 & 27 April
Seed	Hybrid:	P 3732	P 3732	P 3732	P 3732
	Rate:	26,000 ppa	26,000 ppa	26,000 ppa	26,000 ppa
	Date:	18 May	13 May	8 May	29 April
Herbicide	Brand:	Sutan-Bladex	Lasso-Bladex	Eradicane-Bladex	Eradicane-Bladex
	Rate:	2.5 & 1.5 #/ac	2.5 & 1.5 #/ac	2.5 & 1.5 #/ac	2.5 & 1.5 #/ac
	Date:	15 May	10 May	6 May	23 April

Table 1b: Soybean Management Information

Item		1985	1986	1987
Fall Primary Tillage:		Soil Saver	Soil Saver	Soil Saver
Secondary Tillage	Type:	Digger Twice	Disk Twice, Digger	Disk Twice
	Date:	10 May	7 May	2 May
Seed	Variety:	Corsoy 79	Corsoy 79	Hardin
	Rate:	63 #/ac	56 #/ac	60 #/ac
	Date:	13 May	8 May	4 May
Herbicide	Brand:	Treflan-Amiben	Treflan-Amiben	Treflan-Amiben
	Rate:	0.75 & 2.5 #/ac	0.75 & 2.5 #/ac	0.75 & 2.5 #/ac
	Date:	10 May	7 May	2 May

Table 2: Corn and Soybean Yields

	Corn Yields				Soybean Yields		
N-Rate	1984	1985	1986	1987	1985	1986	1987
	Bu/Ac						
0	42	57	97	116	44.4	52.9	43.6
50	64	101	131	127	40.5	54.0	45.1
100	77	127	146	138	42.3	52.8	45.3
200	67	130	151	133	43.4	54.1	44.3
300	83	139	148	129	42.7	52.4	45.0
400	88	139	151	132	42.0	53.2	44.9
LSD(5%)	14	17	12	7	NS	NS	NS

Corn yields are average of 8 replications (1984), 4 replications (1985), or 2 samples from 4 replications (1986 & 1987). Soybean yields are average of 2 samples from 4 replications.

Table 3: Growing season precipitation.

	1984	1985	1986	1987	27-yr Avg.
	inches				
April	4.80	4.07	7.58	0.86	2.74
May	2.74	4.46	2.49	2.34	3.22
June	7.92	4.15	3.20	2.02	3.65
July	2.78	2.37	7.21	6.02	4.00
Aug.	2.51	6.15	3.71	1.54	2.66
Total	20.75	21.20	24.19	12.78	16.27

Table 4: Soil nitrate test results.

	0 #N/ac		100 #N/ac		400 #N/ac	
Depth	1984	1985	1984	1985	1984	1985
Feet	ppm					
0 to 1	1.7	2.6	3.2	2.6	10.1	27.2
1 to 2	0.8	2.1	1.4	2.8	17.6	23.3
2 to 3	1.4	1.5	2.3	2.8	8.1	13.7
3 to 4	3.5	1.7	3.8	2.2	4.2	12.1
4 to 5	4.8	2.0	4.2	2.3	4.6	7.7
Total	12.2	9.9	14.9	12.7	44.6	84.0

TWENTY-EIGHT YEARS OF FIELD EXPERIMENTATION WITH NITROGEN SOURCE, PLACEMENT, AND TIME OF APPLICATION TO A WEBSTER LOAM AT THE SOUTHWEST EXPERIMENT STATION LAMBERTON, MN[1]

J. A. Staricka and W. W. Nelson

(Annual reports of this experiment have been included in most of the University of Minnesota Soil Science Department 'Blue Books' and much of this information will not be included here).

The fertilizer treatments have now been applied annually to the same plot area for 28 years. Each plot is 20' by 77.5' with the four replications arranged in a randomized block. After ear corn removal and stalk cutting, the fall treatments are broadcast on their respective plots and the entire area is then moldboard plowed to approximately 12 inches deep. The fall surface treatments are then broadcast with no further working of the plow area. Spring treatments are broadcast before seedbed preparations in late April or early May. The corn is planted in 30-inch rows at a plant population of 26,000 plants/A, using a band starter fertilizer of 8-24-12 at a rate of 180#/A over the entire experimental area, thus supplying an additional 14 #N/A to all plots. Sidedress treatments are broadcast in June.

<u>1987 results:</u> The 1987 yields from this experiment are given in Table 1. The one-way analysis of variance (Table 2) indicates a significant treatment effect. The LSD for yield (95% conf. level) = 12.7 bu/ac.

Also included in Table 1 are the 27-yr averages. (In 1976, no yields were obtained due to drought, thus only 27 years of data exist). The overall average corn yield and the yield averages for all treatments were all above their corresponding 27-yr average. The trends in yield observed in 1987 follow the trends of the 27-yr averages closely. The greatest response is to increasing N-rates. There is a moderate response to delayed application time, with the exception of the fall surface treatments. There is little difference in yield between ammonium nitrate and urea treatments.

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

Table 1. Influence of nitrogen form, rate, and time of application on grain yield on a Webster loam, Southwest Experiment Station, Lamberton, MN 1987.

------ Nitrogen Treatment ------			------------------ 1987 ------------------					27-yr
Rate	Form	Time	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Avg.	Avg.
#N/Ac			----------- Bu/Ac @ 15.5 % moisture ----------					
--	Check	----	98.9	90.1	79.2	96.3	91.1	66.0
40	Ammonium Nitrate	Fall	132.4	124.9	109.0	113.4	119.9	84.4
40	Urea	Fall	121.8	111.1	112.1	118.6	115.9	88.1
40	Ammonium Nitrate	Fall Surface	149.3	115.7	121.9	101.6	122.1	81.6
40	Urea	Fall Surface	117.7	117.5	123.2	111.0	117.4	87.2
80	Ammonium Nitrate	Fall	135.0	131.8	127.4	131.2	131.4	105.0
80	Urea	Fall	131.1	123.5	141.7	146.7	135.8	104.2
160	Ammonium Nitrate	Fall	144.9	141.0	140.6	139.9	141.6	112.1
160	Urea	Fall	154.9	138.9	144.7	145.0	145.9	114.2
40	Ammonium Nitrate	Spring	111.7	109.4	102.5	120.7	111.1	95.6
40	Urea	Spring	132.4	141.4	111.6	125.5	127.7	94.1
80	Ammonium Nitrate	Spring	136.3	155.1	132.9	137.2	140.4	107.7
80	Urea	Spring	141.2	132.8	134.8	147.2	139.0	109.4
40	Ammonium Nitrate	Side Dress	116.8	121.3	135.7	116.9	122.7	97.9
40	Urea	Side Dress	124.0	121.3	129.0	129.0	125.8	98.3
80	Ammonium Nitrate	Side Dress	128.5	119.4	142.5	132.6	130.8	104.0
80	Urea	Side Dress	153.9	147.0	138.0	151.2	147.5	112.8
160	Ammonium Nitrate	Side Dress	151.7	166.7	161.1	158.7	159.6	117.1
	Average		132.4	128.3	127.1	129.0	129.2	98.9
	LSD (5%)						12.7	

Table 2. One-way analysis of variance.

Source	DF	Sum of Squares	Mean Square	F-Value	Probability
Treatment	17	16989	999.4	12.49	0.00
Error	54	4322	80.0		
Total	71	21311			

WEST CENTRAL EXPERIMENT STATION
WEATHER SUMMARY - 1987

Month	Period	Precipitation 1987	Precipitation 100-yr. av.	Precipitation Dev. from av.	Temperature 1987	Temperature 100-yr. av.	Temperature Dev. from av.	Soil Temperature (10 cm depth) 1987	Soil Temperature (10 cm depth) 10 yr. av.
January	1-31	0.63	0.68	-0.05	17.9	8.0	+ 9.9	24.5	20.7
February	1-28	0.32	0.67	-0.35	29.5	12.8	+16.7	26.7	23.9
March	1-31	1.57	1.13	+0.44	32.2	26.7	+ 5.5	30.0	29.2
April	1-10	T	0.57	-0.57	43.5	38.0	+ 5.5	37.2	
	11-20	0.33	0.64	-0.31	55.4	44.4	+11.0	46.0	
	21-30	0.06	1.05	-0.99	54.6	48.3	+ 6.3	51.2	
Total or av.		0.39	2.26	-1.87	51.2	43.6	+ 7.6	44.7	41.4
May	1-10	0.12	0.77	-0.65	60.1	52.0	+ 8.1	54.4	
	11-20	0.36	0.95	-0.59	62.7	55.8	+ 6.9	60.2	
	21-31	2.44	1.25	+1.19	60.3	60.0	+ 0.3	58.9	
Total or av.		2.92	2.97	- .05	61.0	56.1	+ 4.9	57.5	57.1
June	1-10	0.16	1.29	-1.13	65.4	63.0	+ 2.4	64.6	
	11-20	1.70	1.30	+0.40	71.8	66.3	+ 5.5	71.2	
	21-30	0.01	1.37	-1.36	66.8	68.1	- 1.3	73.3	
Total or av.		1.87	3.96	-2.09	68.0	65.8	+ 2.2	69.7	69.3
July	1-10	0.69	1.44	-0.75	68.7	70.1	- 1.4	72.7	
	11-20	0.30	1.06	-0.76	69.8	71.4	- 1.6	70.2	
	21-31	0.82	1.01	-0.19	76.9	71.4	+ 5.5	79.6	
Total or av.		1.81	3.51	-1.70	72.0	70.9	+ 1.1	74.3	76.7
August	1-10	0.28	1.04	-0.76	70.0	70.4	- 0.4	75.6	
	11-20	0.67	0.93	-0.26	67.4	69.0	- 1.6	72.5	
	21-31	0.51	1.04	-0.53	59.9	66.9	- 7.0	65.0	
Total or av.		1.46	3.01	-1.55	65.6	68.7	- 3.1	70.8	73.9
September	1-30	2.89	2.20	+0.69	59.0	59.0	0	60.8	61.5
October	1-31	0.42	1.74	-1.32	41.7	47.2	- 5.5	43.0	47.8
November	1-30	0.82	0.97	-0.15	35.0	29.7	+ 5.3	35.0	33.6
December	1-31	0.67	0.68	-0.01	20.9	15.2	+ 5.7	28.7	23.4
April-Aug. Growing Season		8.45	15.71	-7.26	63.6	61.0	+ 2.6	63.5	63.8
January-December Annual		15.77	23.78	-8.01	46.2	42.0	+ 4.2	47.3	46.7

ALFALFA FERTILITY-MANAGEMENT STUDY
MORRIS, MN 1987

S. D. Evans, C. C. Sheaffer, and G. A. Reginbal

OBJECTIVES: With the newer alfalfa management procedures, higher yields have resulted. In many cases this might put the plant under greater stress, so it is important to investigate the effect of P and K fertilization on alfalfa yield and stand longevity. Therefore, a study was set up at Morris in 1983 to investigate the effect of (1) P and K fertilization, (2) alfalfa cutting schedule, and (3) variety on alfalfa.

MATERIALS AND METHODS: The experiment was located on a Tara silt loam (Pachic Udic Haploboroll) site that tested medium in Bray P (19 lbs/acre) and high in exchangeable K (234 lbs/acre). The experiment was direct seeded on May 23-24, 1983. The design was a split-split plot with four replications. The main plots were cutting schedule. The first split was P and K fertilizer and the second split was variety. In 1983 the area was harvested but no yields were taken and no fertilizer applied. In 1984-86 the cuttings were taken as scheduled. Fertilizer was applied by hand after the first cutting except for the 300- and 400-lb K rates where 200 lbs/acre were applied after the first cutting and the remainder after the second cutting. In the spring of 1987 the plots were evaluated on May 7 and winter injury and percent stand notes were taken. In 1987 all plots were cut only three times on the 3-cut schedule to measure the residual effect of previous treatments. Yields were taken with a small flail chopper, weighed and a moisture sample collected from each plot. Samples of the Answer variety were saved for possible chemical analysis. The harvest dates in 1987 were June 3, June 30, and August 6. The plots were undercut on September 22 and a stand count taken.

RESULTS AND DISCUSSION: The yields for 1987 are given in Tables 1 and 2. The ANOVA results given in Table 3 show that the cutting schedule from 1984-86 had a highly significant effect on total 1987 yields. Those on the previous 4-cut schedule at 1/2 bud yielded only 1.69 tons/acre while those on the 3-cut schedule at 1/10 bloom yielded 2.98 tons/acre. The variety effect showed up as highly significant with Vernal outyielding Answer by .19 tons/acre. There was a highly significant effect of fertilizer with both P and K bringing about yield increases. The application of 100 lbs P_2O_5/acre doubled the yield over where no P was applied. The application of 400 lbs K_2O/acre increased the yield about 30% over the treatment with no K added. There was some indication of an interaction between cutting schedule and PK fertility. It appears that the treatments that had been on the 3-cut schedule were able to take better advantage of the extra P compared to those that had been on the 4-cut schedule. The fertilizer and variety effects on individual cuttings are shown in Tables 5 and 6.

The ANOVA's of the injury rating and stand evaluations are given in Table 6. All main effects were significant and the cutting schedule by variety interaction was significant for the first two variables. It can be seen in Table 7 that the 4-cut system resulted in a higher injury rating, a lower stand, and a lower plant count than the 3-cut system. The results of the fertilizer variable (Table 8) is not completely clear. The increased P appeared to reduce the injury, the stand, and the plant count. The addition of K also reduced the injury, but higher stand count. It appears that either the 50- or 100-lb K rate was sufficient. There was no effect of K on plant count. In Table 9 it can be seen that Vernal had a lower injury rating, a higher stand, and a slightly higher plant than Answer.

Table 1. Effect of cutting schedules, P and K fertilization and varieties on alfalfa yields at Morris in 1987.

Fertilizer Rate		3-cut+			4-cut+			Average over Fertilizer
		Variety			Variety			
P_2O_5	K_2O	Vernal	Answer	Average	Vernal	Answer	Average	
- - lb/acre - -		- - - - - - - - - - - - - - Dry Matter (T/acre) - - - - - - - - - - - - - -						
0	200	1.82	1.91	1.87	1.10	0.90	1.00	1.43
50	200	3.26	2.87	3.06	1.81	1.75	1.78	2.42
100	200	4.02	3.78	3.90	2.06	2.03	2.05	2.97
50	0	2.59	2.32	2.46	1.55	1.50	1.52	1.99
50	100	3.21	2.91	3.06	1.58	1.40	1.49	2.28
50	200	3.40	3.02	3.21	1.97	1.75	1.86	2.53
50	300	3.23	2.79	3.01	2.04	1.58	1.81	2.41
50	400	3.26	3.31	3.28	1.95	1.97	1.96	2.62
Average		3.10	2.86	2.98	1.76	1.61	1.69	2.33
CV = 10.6%								

+All plots were cut only 3 times in 1987. The 3-cut and 4-cut systems were used in 1984, 1985, and 1986.

Table 2. Effect of P and K fertilization and variety on alfalfa yields at Morris in 1987.

Fertilizer Rate		Varieties	
P_2O_5	K_2O	Vernal	Answer
- - - - lb/acre - - - - -		- - - Dry Matter (T/acre) -	
0	200	1.46	1.41
50	200	2.54	2.31
100	200	3.04	2.91
50	0	2.07	1.91
50	100	2.40	2.16
50	200	2.69	2.38
50	300	2.64	2.18
50	400	2.61	2.64
Average		2.43	2.24
CV = 10.6%			

Table 3. Effect of cutting schedule, P and K fertilization and variety on alfalfa yields.

Variable	Signif. level+
	- - % - -
Cutting Schedule (CS)	>99
PK Treatment (PK)	>99
CS x PK	>92
Variety (V)	>99
CS x V	69
PK x V	80
CS x PK x V	28

+Probability that differences are not due to chance.

Table 4. Effect of P and K fertilization and variety on alfalfa yields by individual cuttings in 1987.

	3-cut Schedule			4-cut Schedule		
Variable	1st	2nd	3rd	1st	2nd	3rd
	- - - - - - - - signif. level (%)+ - - - - - - - -					
PK Treatment (PK)	>99	>99	>99	98	>99	>99
Variety (V)	>99	>99	78	86	98	93
PK x V	49	83	69	54	18	84

+Probability that differences are not due to chance.

Table 5. Effect of P and K fertilization and variety on alfalfa dry matter percentage by individual cuttings in 1987.

	3-cut schedule			4-cut schedule		
Variable	1st	2nd	3rd	1st	2nd	3rd
	- - - - - - - - signif. level (%)+ - - - - - - - -					
PK Treatment (PK)	>99	>99	82	80	>99	>99
Variety (V)	61	77	2	86	85	23
PK x V	93	28	91	68	9	63

+Probability that differences are not due to chance.

Table 6. Effect of cutting schedule, P and k fertilization and varieties on alfalfa injury and stands at Morris in 1987.

Variable	5-7-87 Injury Rating[a]	5-7-87 Stand[b]	9-22-87 Plant Count[c]
	- - - - - signif.	level[+] - - - - -	
Cutting Schedule (CS)	>99	>99	>99
PK Treatment (PK)	98	97	>99
CS x PK	60	54	98
Variety (V)	>99	>99	>99
CS x V	>99	>99	18
PK x V	58	75	21
CS x PK x V	79	61	92

[+]Probability that differences are not due to chance.

Table 7. Effect of cutting schedule on alfalfa injury and stands at Morris in 1987.

Cutting Schedule	Injury Rating[a]	Stand[b]	Plant Count[c]
	---	-%-	- no.-
3-cut	5.0	49	18
4-cut	8.0	20	12

Table 8. Effect of P and K fertilization on alfalfa injury and stands at Morris in 1987.

Fertilizer Rate P_2O_5	Fertilizer Rate K_2O	Injury Rating[a]	Stand[b]	Plant Count[c]
- - lb/acre	- -	- -	- % -	- no. -
0	200	6.4	41	20
50	200	6.5	35	14
100	200	5.9	37	13
50	0	7.4	28	14
50	100	6.6	33	15
50	200	6.6	36	15
50	300	6.6	33	13
50	400	6.4	34	14

Table 9. Effect of Variety on alfalfa injury and stand at Morris in 1987.

Variety	Injury Rating[a]	Stand[b]	Plant Count[c]
	- -	- % -	- no. -
Vernal	6.2	39	16
Answer	6.9	30	14

[a] 1= no winter injury, 3= no stand loss but 10-20% of the plants showing injury, 5= 10-20% of the plants dead, 7= 30-50% of the plants dead, 8= 80-90% of the plants dead.

[b] Percent stand on 5-7-87

[c] number of plants in a 20- by 18-inch area on 9-22-87.

CONTINUOUS CORN SILAGE
MORRIS, MN 1987

S. D. Evans

OBJECTIVES: This study was initiated in 1965 on a McIntosh silt loam to determine the effect of removal of continuous corn silage and fertilizer on corn grain and corn silage yields and on soil properties. Silage yield samples were collected on all plots and then on half the plots the entire plant was removed with standard silage harvesting equipment. On the remaining plots shelled corn yield samples were collected and then these plots were harvested with a standard corn combine. Half the plots received a fertilizer rate of 74 + 48 + 48 ($N + P_2O_5 + K_2O$ in lbs/acre) and the other half a rate of 148 + 96 + 96.

MATERIALS AND METHODS: The experiment is set up as a latin square with 4 treatments: (1) silage, low fertility, (2) silage, high fertility, (3) grain, low fertility, and (4) grain, high fertility. The experimental area has been moldboard plowed each fall. In the spring the soil is tilled with a field cultivator prior to planting. In 1987 the variety used was Dekalb 461 and was planted on April 27 @ 24,300 seeds/acre. Thimet was applied in the row at planting at 10 lbs/acre (1.5 lb/acre a.i.). The fertilizer was all applied the previous fall prior to plowing. Lasso @ 3 lbs/acre a.i. + Bladex @ 2.2 lbs/acre a.i. were applied broadcast on April 28. Silage yields were taken on August 25 and grain yields on September 23. Yields were also taken as in past years on an adjacent unfertilized area where only the grain is removed. These check yields are an average from two measured areas.

RESULTS AND DISCUSSION:

Grain and Silage Yields: The silage yields are given in Table 1. The only significant difference in silage yields in 1987 was that grain, high fertility, was lower yielding than all other treatments. This was not consistent with other years and there is no logical explanation. The 22-year average shows no effect of the silage vs. grain. However, the higher fertility level shows an increased yield over the low fertility level. The grain yields for both 1987 and the 22-year average show an advantage for the higher fertility level.

Soil Test Values: The results of the 1987 soil test values are given in Table 4. There were large differences in soil P and K levels due to fertilizer treatments. The P levels on plots receiving only 48 lbs P_2O_5/acre annually are in the medium range while plots receiving 96 lbs P_2O_5/acre are in the very high range. Soil test K levels are higher under the high fertility treatment and are considerably higher where only the grain has been removed compared to removing corn silage.

Table 1. Effect of removal of continuous silage or grain on silage yields.

Treatment	1987 Yield	1966-87 Yield
	- - - dry matter,	tons/acre - - -
Silage, Low fertility	7.64	5.45
Silage, High fertility	7.65	5.97
Grain, Low fertility	7.86	5.50
Grain, High fertility	6.73	5.85
Signif. levels (%):		
Treatment	93.5	>99
Year	- -	>99
Treatment x Year	- -	>99
LSD, treatment (.05)	0.86	0.22

Table 2. Effect of fertilizer level on grain yields.

Treatment	1987 Yield	1966-87 Yield
	- - - bu/acre @ 15.5 % M. - - - -	
Grain, Low fertility	128.6	88.6
Grain, High fertility	119.3	94.2

Table 3. Yields on an average of two unfertilized checks adjacent to the experimental area.

Treatment	1987 Yield	1966-87 Yield
Grain	97.7 bu/acre	46.6 bu/acre
Silage	4.28 tons/acre	3.53 tons/acre

Table 4. Soil test results from the experimental area. Fall 1987.

Treatment	pH	Bray P	Olsen P	Exch. K	Zinc
		- - - - -	lbs/acre	- - - - -	ppm
Silage, High fertility	8.0	19	15	213	1.8
Silage, Low fertility	8.0	65	49	248	1.8
Grain, Low fertility	8.1	33	20	275	1.8
Grain, High fertility	8.0	69	57	341	2.0
Check	8.1	10	6	210	1.7

MANURE RATE STUDY
MORRIS, MN 1987

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

OBJECTIVES: This study was initiated in 1972 to investigate the effect of application of three rates of solid and liquid beef manure on corn growth and soil properties. The manure treatments were compared to commercial fertilizer and check treatments. Seven fall applications of manure were made from 1972 thru 1978 (application omitted in 1977). Fertilizer was applied to the commercial fertilizer treatment each year at the same rate. The treatments and abbreviations are as follows:

CHECK - CK - No fertilizer or manure
FERTILIZED - FE - 120 + 50 + 50 (N + P_2O_5 + K_2O) in lbs/acre/year
SOLID BEEF MANURE, RATE 1 - SB1 - 33 tons/acre annually (wet weight), total application of 233 tons/acre
SOLID BEEF MANURE, RATE 2 - SB2 - 67 tons/acre annually (wet weight), total application of 467 tons/acre
SOLID BEEF MANURE, RATE 3 - SB3 - 100 tons/acre annually (wet weight), total application of 700 tons/acre
LIQUID BEEF MANURE, RATE 1 - LB1 - 4530 gallons/acre annually, total application of 31700 gallons
LIQUID BEEF MANURE, RATE 2 - LB2 - 9060 gallons/acre annually, total application of 63400 gallons
LIQUID BEEF MANURE, RATE 3 - LB3 - 13580 gallons/acre annually, total application of 95100 gallons

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 100oF. 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 34 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. Except for one plot, 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-nitrogen analyses are given in Table 1. There was a significant treatment x depth interaction. Levels in the manure treatments generally increased with rate and there tended to be more nitrate-nitrogen at the 4-foot level then higher in the profile. The levels in all manure treatments except SB3 are not greatly different from the fertilized treatment. There was no treatment effect on ammonium-nitrogen levels, but the depth effect was highly significant. Levels in the first foot averaged 11 ppm while the other 3 one-foot increments averaged 2 to 3 ppm.

Table 1. Effect of two types of cattle manure and commercial fertilizer on the nitrate-nitrogen level of a Tara soil profile - Fall 1986.

DEPTH INCREMENT	CK	FE	SB1	SB2	SB3	LB1	LB2	LB3	MEAN
- ft -				ppm NO_3-N					
0-1	5	9	6	6	13	5	12	6	5
1-2	3	17	11	5	17	11	27	13	12
2-3	3	17	18	21	40	13	15	14	12
3-4	3	25	25	39	71	10	37	28	23
Mean	3	17	15	18	35	9	23	15	

Signif. Level (%):

Replication	- 80	
Treatment	- 99	BLSD (.05)-2
Depth	- >99	BLSD (.05)-4
Trt. x depth	- >99	

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 P, K, Mg, Fe, and Zn. Phosphorus levels generally increased with manure rate, but SB1 and all LB treatments are slightly below the sufficient level. Potassium increased with manure and all manure treatments have adequate levels. Magnesium levels decreased with increasing manure rate, but all levels are sufficient. Zinc levels increase with manure rate, but some treatments are slightly below the sufficiency level of 20 ppm.

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

Treatment	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
			%					ppm		
CK	2.03	0.18	1.75	0.50	0.38	107.9	16.7	7.4	59.6	5.6
FE	2.87	0.26	2.14	0.63	0.35	112.5	37.7	7.1	110.9	5.8
SB1	2.06	0.21	2.22	0.48	0.28	101.3	18.2	6.1	60.8	5.5
SB2	2.47	0.25	2.48	0.53	0.24	121.9	19.4	6.3	71.9	5.2
SB3	2.61	0.27	2.59	0.50	0.22	117.6	23.6	6.7	72.7	5.3
LB1	2.07	0.19	1.71	0.54	0.40	96.3	15.5	6.0	71.1	5.1
LB2	2.27	0.22	1.88	0.54	0.40	103.8	16.4	6.1	71.1	5.3
LB3	2.27	0.23	2.29	0.47	0.28	109.2	19.6	6.9	74.7	5.8
Signif. level (%)	86	98	>99	88	>99	98	>99	30	83	70
BLSD (.05)	NS	0.06	0.18	NS	0.07	14.3	4.3	NS	NS	NS
CV (%)	16.1	13.5	5.3	11.4	13.3	6.9	12.8	17.0	27.7	6.8

Plant and Yield Measurements: The early plant height, early dry weight, silage yields, and grain yields are given in Table 3. The early heights of the manure treatments were not significantly different from the fertilized treatment. All heights increased with manure rate, but the SB treatments are taller than FE and the LB treatments are shorter than FE. The only manure treatment with an early plant weight below FE was LB1. The SB2 and SB3 treatments are significantly heavier than FE. Grain yield generally increased with manure rate except for LB3. None of the manure treatments were significantly different in grain yield from FE. Silage yields increased with manure rate. There was a significant difference between the silage yield of LB1 and FE.

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.

Treatment	Early plant height	Early plant(10) dry wt.	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	-%-
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	Bray P	Olson P	Exch. K	Zn
	Elements			
	- - - - 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	CK	FE	SB1	SB2	SB3	LB1	LB2	LB3	Mean
	Treatment								
- 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 (%):

	NO_3-N		NH_4-N	
Replication	53		23	
Treatment	77		64	
Depth	>99	BLSD (.05)-3	>99	BLSD(.05) - 1
Trt x Depth	82		49	

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

[illegible]					[illegible]					
	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.

			Grain		Silage		
Treatment	Early plant height	Early plant(10) dry weight	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	- % -
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

	Elements			
Treatment	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	Treatment: Check	Fertilized	Solid Beef Manure	Liquid Beef Manure	Liquid Hog Manure	Mean
- 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	Treatment: Check	Fertilized	Solid Beef Manure	Liquid Beef Manure	Liquid Hog Manure	Mean
- 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^{o} F. The night of the high of 71^{o} F reached a low of 7^{o} 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^{o} 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

	Pounds Per Acre - 13 inches Water	
Location	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 1/
		---- 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 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	1986 Crop 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 Fall	N-Serve Preplant	N-Serve Split	No N-Serve Fall	No N-Serve Preplant	No N-Serve 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 pre-emergence 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.

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			Whole plant at silk		Stover		Final
Rate	Time[1/]	Source[2/]	N	DM	N	Yield	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			Stover N Yield[1/]		Grain N Yield at PM			
Rate	Time	Source	Silk	PM	Total	OLD[2/]	NEW[3/]	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.

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 Concentration1/	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)	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	Tillage System: 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 particuler 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.

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 lb/A[1/]	Grain Yield bu/A	Grain Moisture %
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/]	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.

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.

Tillage	Starter fertilizer[1/]	Poast herbicide[2/]	Population	Seed Moisture	Seed 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	Surface Residue: 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	6	7	8	9	10	11	12	13	14	18
	Days Post Planting — % 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	Herbicide1/ Grasses	Herbicide1/ Broadleaves	No Herbicide Grasses	No Herbicide 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	Poast1/ Preemerg	Poast1/ No Preemerg	No Poast Preemerg	No Poast 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 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

G.L. Malzer and T.J. Graff

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

Table 1. continued Split Plot Statistical Analysis

	Grain		Grain	N-Removal
<u>Tillage</u>	Bu/A	% N	mt/ha	kg/ha
Chisel	130.7	1.57	8.22	109.06
Ridge Till	134.4	1.54	8.45	110.28
P-Value	77	90	77	51
<u>N-Rate X Method X Inhibitor</u>				
<u>N-Rate kg/ha</u>				
60	129.1	1.50	8.12	102.72
120	133.3	1.56	8.38	110.50
180	133.0	1.58	8.36	111.98
240	134.8	1.58	8.47	113.47
P-Value	91	99	90	99
BLSD (.05)		0.02		4.32
<u>Method</u>				
1. 4 leaf	131.8	1.57	8.29	110.26
2. 8 leaf	133.6	1.52	8.40	108.25
3. Split 2/3 1/3	132.2	1.57	8.32	110.49
P-Value	33	99	35	54
BLSD (.05)		0.02		
<u>Inhibitor</u>				
None	131.6	1.55	8.27	108.18
N-Serve	133.5	1.57	8.40	111.17
P-Value	77	53	77	94
N-Rate X Method	66	83	67	83
N-Rate X Inhibitor	52	98	52	78
Method X Inhibitor	89	92	89	96
N-Rate X Method X Inhibitor	79	99	79	62
<u>N-Rate X Method X Inhibitor X Tillage</u>				
N-Rate X Tillage	8	27	8	2
Method X Tillage	66	96	66	52
Inhibitor X Tillage	55	81	54	84
N-Rate X Method X Tillage	59	54	59	68
N-Rate X Inhibitor X Tillage	91	98	91	97
Method X Inhibitor X Tillage	52	36	53	70
N-Rate X Method X Inhibitor X Tillage	86	92	86	71

Table 2. Influence of N-Rates, N-Forms, nitrification inhibitors, time of application on two tillage systems on grain yields at Westport, MN. 1987

N-Rate Kg/ha	N-Form	Inh.	Time	Tillage	Grain Bu/A	% N	Grain mt/ha	N-Removal kg/ha
120	AA	---	1	C	137.9	1.62	8.68	117.83
120	AA	NS	1	C	124.7	1.62	7.85	106.98
120	UREA	---	1	C	124.6	1.61	7.84	106.16
120	UREA	DCD	1	C	134.2	1.58	8.45	111.83
120	AA	---	2	C	135.6	1.56	8.53	112.50
120	AA	NS	2	C	138.5	1.51	8.71	110.03
120	UREA	---	2	C	129.6	1.61	8.15	110.22
120	UREA	DCD	2	C	143.4	1.43	9.02	108.43
180	AA	---	1	C	143.8	1.61	9.05	123.01
180	AA	NS	1	C	135.1	1.60	8.50	113.83
180	UREA	---	1	C	117.9	1.66	7.42	103.82
180	UERA	DCD	1	C	139.8	1.59	8.80	118.02
180	AA	---	2	C	136.3	1.56	8.58	112.53
180	AA	NS	2	C	138.4	1.60	8.70	117.10
180	UREA	---	2	C	140.0	1.55	8.81	114.44
180	UREA	DCD	2	C	135.0	1.48	8.49	104.90
120	AA	---	1	R	125.9	1.64	7.92	109.24
120	AA	NS	1	R	139.2	1.53	8.76	112.70
120	UREA	---	1	R	124.4	1.64	7.83	107.66
120	UREA	DCD	1	R	127.9	1.60	8.05	107.67
120	AA	---	2	R	138.4	1.59	8.71	116.51
120	AA	NS	2	R	135.4	1.63	8.52	117.20
120	UREA	---	2	R	126.4	1.53	7.95	102.77
120	UREA	DCD	2	R	133.1	1.48	8.37	104.24
180	AA	---	1	R	145.8	1.63	9.17	125.68
180	AA	NS	1	R	142.3	1.68	8.95	126.84
180	UREA	---	1	R	131.2	1.58	8.25	110.05
180	UREA	DCD	1	R	119.2	1.62	7.50	102.14
180	AA	---	2	R	120.3	1.61	7.57	101.79
180	AA	NS	2	R	138.5	1.58	8.71	115.50
180	UREA	---	2	R	131.8	1.49	8.29	103.68
180	UERA	DCD	2	R	130.5	1.57	8.21	108.93

Table 2. continued Split Plot Statistical Analysis

	Grain Bu/A	Grain % N	Grain mt/ha	N-Removal kg/ha
<u>Tillage</u>				
Chisel	134.7	1.57	8.47	111.97
Ridge Till	131.9	1.58	8.29	110.78
P-Value	66	34	66	61
<u>N-Form X Inh. X Time X N-Rate</u>				
<u>N-Form</u>				
Anhydrous Ammonia	136.0	1.59	8.55	114.95
Urea	130.6	1.56	8.21	107.80
P-Value	95	93	95	99
<u>Inhibitor</u>				
N-Serve	131.9	1.59	8.29	111.11
DCD	134.7	1.56	8.47	111.64
P-Value	70	82	69	23
<u>Time</u>				
1. 4 leaf 6/4/87	132.1	1.61	8.31	112.71
2. 8 leaf 6/18/87	134.4	1.54	8.45	110.04
P-Value	60	99	60	85
<u>N-Rate kg/ha</u>				
120	132.4	1.57	8.33	110.12
180	134.1	1.58	8.43	112.64
P-Value	46	58	45	83
N-Form X Inh.	50	61	50	17
N-Form X Time	85	87	85	57
N-Form X N-Rate	40	22	40	63
Inh. X Time	41	11	40	40
Inh. X N-Rate	38	86	39	42
Time X Rate	70	15	71	88
N-Form X Inh X Time	65	46	65	90
N-Form X Inh X Time X N-Rate	63	21	63	74
<u>N-Form X Inh. X Time X N-Rate X Tillage</u>				
N-Form X Tillage	64	60	64	82
Inh. X Tillage	3	88	4	62
Time X Tillage	70	54	70	48
N-Rate X Tillage	18	3	18	18
N-Form X Inh. X Tillage	97	89	97	86
N-Form X Time X Tillage	31	44	31	20
N-Form X N-Rate X Tillage	18	32	20	8
Inh. X Time X Tillage	31	73	32	71
Inh. X N-Rate X Tillage	32	44	32	8
Time X N-Rate X Tillage	41	36	41	66
N-Form X Inh. X Time X Tillage	86	42	86	93
N-Form X Inh. X Time X N-Rate X Tillage	70	92	70	68

LAND TREATMENT OF SEWAGE SLUDGE INCINERATOR ASH

C. Rosen, R. Polta, and T. King

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

Materials and Methods Ash samples were collected from the Metropolitan Waste Water Treatment Plant in St. Paul in April 1987. The following properties were determined on three subsamples: % moisture, calcium carbonate equivalent (CCE), citrate soluble phosphorus (total available phosphate), and elemental composition after digestion in concentrated nitric acid followed by perchloric acid (Table 1). Particle size analysis revealed that 99% passed through a 60 mesh screen and 88% passed through a 100 mesh screen.

A field experiment was initiated in May 1987 at the Rosholt Research Farm in Westport, MN. This site was selected because irrigation was available and soil test P was at a level where a response to applied phosphorus might be expected. The soil is characterized as a Estherville sandy loam. Selected soil chemical properties prior to planting are presented in Table 2.

Treatments consisted of a control, three rates of phosphate fertilizer (0-46-0: 70, 140 and 280 lb P_2O_5/A) and three equivalent rates of sewage sludge incinerator ash based on available phosphate (Table 3). Loading rates of selected metals based on the digest analysis and application rates were less than the annual maximum application rates set by the Minnesota Pollution Control Agency (Table 4). A gandy fertilizer spreader was used to broadcast applications of 0-0-60 (200 lbs/A) and 45-0-0 (195 lbs/A). Sludge ash and phosphate fertilizer were applied by hand. The entire plot area was disked to a depth of 6". A randomized complete block design with four replications was used. Field corn (Funks G-4100 hybrid) was planted on May 1, 1987 at a population of 32,000 in 30" rows. Each plot consisted of four 30' rows. Irrigation supplemented rainfall to provide approximately 1" of water per week. On June 12, 8 whole plants were sampled from each plot at the ends of the two middle rows. At this sampling, plant development corresponded to the 8-10 leaf stage. The entire plot was sidedressed with 46-0-0 (100 lbs/A) with a gandy on June 18. Suction cup lysimeters were installed in all treatments in reps 1 and 3 on July 8 at a depth of 18". Water samples were collected on July 15 and August 8, approximately 3 or 4 days after 1" of irrigation was supplied. Ear leaf samples were collected from each plot at the mid-silking stage (July 15). The plots (20' from the middle two rows) were harvested for grain plus cob and stover yields. Subsamples of stover and grain plus cob were collected for moisture determinations and elemental analyses. All plant samples were ground in a Wiley mill to pass through a 30 mesh screen. Multiple element analysis using ICP procedures were performed on ashed samples dissolved in 2 N HCl. Following Kjeldahl digestion, total nitrogen in plant tissues was determined using conductimetric procedures.

Soil samples were collected on October 10 at 3 depths: 0-6", 6-12", and 12-24". Samples were air dried, ground using a rolling pin and extracted with 1 N nitric acid. Multiple elements were determined using ICP procedures. Available phosphorus was determined after extracting with Bray P1 extractant and pH was determined on a 1:1 soil - water extract.

Results

Soil and Water Samples. Elemental analyses of the water collected in the suction cup lysimeters are presented in Table 5. Because of the coarse-textured nature of this soil, the lysimeters did not always perform properly. Therefore at each sampling date only one replication is reported. Concentrations of Pb, Ni, Cr and Cd were below detection limits of the ICP spectrophotometer. Other elements such as Cu, Zn and B were at background levels. None of the other elements determined exhibited trends with increasing ash or fertilizer treatments. These results indicate that in the short term, leaching of elements to the ground water from the ash does not appear to be a problem.

As expected, fertilizer and ash treatments increased Bray P1 soil test levels in the top 6" of soil (Table 6). The fertilizer appeared to be more effective in increasing P levels compared to the ash. Soil pH was not affected by any of the treatments. This is not surprising since the calcium carbonate equivalent of the ash material is low. Nitric acid extractable P increased with both fertilizer and ash rates. In contrast, acid extractable Zn, Cu, Cr and Cd increased with ash treatments, but not with P fertilizer treatments. Even though increases in these metals were recorded with the ash treatments, the levels were still very close to background. Fertilizer and ash treatments had no effect on soil pH, Bray P1 or nitric acid extractable elements at the 6-12" depth (Table 7). However, Bray P1 levels tended to increase with P fertilizer rate and ash rate at the 12-24" depth. Reasons for greater differences at the 12-24" depth compared to the 6-12" depth are not known at this point. Acid extractable elements did not significantly increase with P fertilizer or ash at the 12-24" depth.

Yield Data. None of the treatments significantly increased grain or stover yield over the check plot (Table 9). The reason for lack of yield response to applied phosphorus is that soil P in the plow layer was at a higher level than the initial soil tests indicated. Rather than being in a medium to high range, the check plots were actually in a high to very high range. Response to applied P therefore is not likely. Another factor that might be involved is that corn yields were low considering that irrigation was used. Consequently, the demand for P would not be as great had yields been higher. The cause for low yields may have been due to a two week period of water stress when plants were silking. In either case, the results do indicate that application of ash does not detrimentally affect yield. There was a trend for greater grain yields with the P fertilizer compared to ash. Stand counts also tended to be greater with the P fertilizer compared to the ash.

Tissue Analyses. Fertilizer and ash treatments increased tissue P concentrations in corn sampled at the 8 - 10 leaf stage (Table 10). Even though rates of ash were adjusted to equivalent rates of available P in fertilizer, corn grown in plots supplied with fertilizer had significantly higher P levels than corn supplied with ash. Nitrogen concentrations increased as P fertilizer rate increased. Tissue Ca was higher when supplied with fertilizer compared to ash. This reflects the high amount of Ca in 0-46-0. Ash treatments tended to lower tissue Mn compared to fertilizer treatments. In contrast, fertilizer treatments tended to lower tissue Zn and Cu compared to ash treatments. The other heavy metals, Pb, Ni, Cr, and Cd were all at background levels. Similar trends to those in the whole plant sample were observed for most elements in the ear leaf sampled at silking (Table 11). One exception was that N levels decreased in ear leaf tissue with P fertilizer rate. Ash and fertilizer increased P levels, but the increase was greater with the fertilizer compared to the ash. Calcium levels also increased with fertilizer and ash compared to the control. Fertilizer increased Mn, but decreased Cu and Zn concentrations compared to the ash treatments. Other heavy metals were not affected by treatments. Treatments did not affect concentrations of any of the elements in the grain (Table 12). The stover and cob tissue concentrated greater levels of Cu and Zn with the ash treatments compared to the fertilizer treatments (Tables 13 and 14). Stover and cob P levels increased with fertilizer but not ash treatments.

General Discussion. Even though no differences in corn yields due to treatments were detected, the results do show that ash treatments are not detrimental to yield or quality in the short term. From tissue analysis results, phosphate availability at equivalent rates does not appear to be as good from the ash source as from fertilizer source. This may be due to lower P solubility in the ash compared to the fertilizer which may not be readily detected by the available (citrate soluble) P test. Further experiments on this same site are required to evaluate longer term effects of incinerator ash on element movement in the soil profile as well as effects on element uptake and yield response by the crop.

Table 1. Selected Chemical Characteristics of incinerator sludge ash and phosphate fertilizer used in the study (means of 3 samples).

Chemical Characteristic		Sludge Ash		Phosphate Fertilizer	
Moisture	(%)	37.6		-	
Calcium Carbonate Equivalent	(%)	13.7		-	
Available P_2O_5*	(%)	8.8		46.0	
pH (1:1 water)		8.0		-	
Acid Digestible Elements: **		%	lb/dry ton	%	lb/dry ton
Phosphorus		7.40	148.0	21.36	427.2
Potassium		0.48	9.6	0.24	4.8
Calcium		9.14	182.8	14.57	291.4
Magnesium		4.26	85.2	0.48	9.6
Sodium		0.26	5.2	0.37	7.4
Aluminum		6.38	127.6	0.83	16.6
Iron		4.05	81.0	1.56	31.2
		ppm		ppm	
Cadmium		128	0.26	7	0.01
Chromium		1888	3.78	78	0.16
Copper		3846	7.69	7	0.01
Manganese		2353	4.71	294	0.59
Nickel		530	1.06	29	0.06
Lead		710	1.42	39	0.08
Zinc		7213	14.43	79	0.16
Boron		< 3.0	< 0.01	44	0.09

* Citrate Soluble P

** Acid digestible - boiling concentrated nitric acid and concentrated perchloric acid. After 6 hr. digestion 45% remained undigested. Results expressed on a dry weight basis.

Table 2. Selected Soil Chemical properties of the experimental site.

	---------Depth-----------	
Property	0-6"	6-12"
pH	5.7	6.1
Organic Matter %	5.1	2.7
Bray P (lb/A)	35	10
K (lb/A)	179	111

Table 3. Fertilizer and ash treatments applied prior to planting.

Material Applied	lb P_2O_5/A	lb d.w.material/A
Control	-	-
Phosphate Fertilizer	70	152
Phosphate Fertilizer	140	304
Phosphate Fertilizer	280	608
Sludge Ash	70	795
Sludge Ash	140	1590
Sludge Ash	280	3180

Table 4. Approximate loading rates for selected metals.

Treatment lb Ash/A	Cd	Pb	Zn	Cr	Cu	Ni
	lb/A					
795	0.1	0.6	5.7	1.5	3.1	0.4
1590	0.2	1.2	11.4	3.0	6.2	0.8
3180	0.4	2.4	22.8	6.0	12.4	1.6

Table 5. Elemental composition of lysimeter water as affected by fertilizer or ash treatments at two sampling dates.

Treatment lb P_2O_5/A	Source	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
July 15		ppm														
Control		<0.27	3.27	62.7	22.9	0.10	<0.01	6.45	0.19	0.13	<0.01	0.02	<0.11	<0.03	<0.01	<0.01
70	Fert.	0.32	3.27	63.8	23.7	0.20	0.04	7.15	0.20	0.05	0.04	0.03	<0.11	<0.03	<0.01	<0.01
140	Fert.	<0.27	3.09	62.6	23.6	0.15	<0.01	6.76	0.19	0.02	0.02	0.02	<0.11	<0.03	<0.01	<0.01
280	Fert.	<0.27	2.43	63.2	23.1	0.20	<0.01	7.35	0.19	0.02	0.04	0.03	<0.11	<0.03	<0.01	<0.01
70	Ash	<0.27	2.43	62.0	23.5	0.17	<0.01	5.65	0.20	0.03	0.02	0.02	<0.11	<0.03	<0.01	<0.01
140	Ash	<0.27	3.31	61.9	22.6	0.21	<0.01	7.78	0.19	0.05	0.08	0.03	<0.11	<0.03	<0.01	<0.01
280	Ash	<0.27	3.09	73.6	24.1	0.13	<0.01	13.70	0.17	0.04	0.01	0.03	<0.11	<0.03	<0.01	<0.01
August 6																
Control		<0.27	2.24	180.9	42.1	0.40	<0.01	7.55	0.11	0.05	<0.01	0.05	<0.11	0.04	<0.01	<0.01
70	Fert.	0.32	3.15	133.6	35.1	0.29	<0.01	14.46	0.24	0.06	0.02	0.05	<0.11	<0.03	<0.01	<0.01
140	Fert.	0.74	3.49	73.8	24.7	0.14	<0.01	8.88	0.16	0.03	0.02	0.04	<0.11	<0.03	<0.01	<0.01
280	Fert.	<0.27	2.42	100.5	19.4	0.22	<0.01	6.71	0.13	0.02	<0.01	0.07	<0.11	<0.03	<0.01	<0.01
70	Ash	<0.27	2.26	79.4	22.7	0.18	<0.01	7.89	0.17	0.04	0.02	0.04	<0.11	<0.03	<0.01	<0.01
140	Ash	<0.27	1.35	40.5	7.2	0.05	<0.01	3.76	0.05	0.02	<0.01	0.05	<0.11	0.04	<0.01	<0.01
280	Ash	<0.27	2.81	232.3	52.9	0.47	<0.01	8.78	0.14	0.02	0.01	0.05	<0.11	<0.03	<0.01	<0.01

Table 6. Effect of sludge ash and phosphate fertilizer on soil pH, Bray P1, and 1 N nitric acid extractable elements. (0-6 inch depth)

Treatment lb P_2O_5/A	Source	pH	Bray P1	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
				1 N nitric acid extractable														
			lb P/A	ppm														
Control	-	5.5	48	76	123	2895	463	1745	380	12	113	5.5	4.1	1.3	3.4	3.6	1.0	0.2
70	Fert.	5.5	50	76	133	2484	469	1825	394	11	116	6.0	3.6	1.3	3.5	3.8	1.0	0.2
140	Fert.	5.4	99	113	145	2824	434	1754	370	13	125	5.3	3.4	1.3	3.6	3.7	1.0	0.2
280	Fert.	5.5	97	111	139	2892	445	1774	371	12	109	5.3	3.3	1.3	3.4	3.6	1.0	0.2
70	Ash	5.4	50	82	133	2941	455	1775	372	11	112	5.4	3.9	1.3	2.7	3.7	1.0	0.2
140	Ash	5.6	66	114	136	3054	483	1826	391	13	114	6.4	5.2	1.4	3.8	3.7	1.2	0.3
280	Ash	5.5	81	135	131	3108	511	1934	445	14	120	7.4	6.1	1.4	3.3	4.1	1.4	0.3
Significance		NS	*	**	NS	NS	NS	NS	NS	NS	NS	*	*	NS	*	NS	*	**
BLSD		-	41	33	-	-	-	-	-	-	-	1.4	1.2	-	0.7	-	0.3	0.1
Contrasts																		
Ctrl. vs Rest		NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fert. vs Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	**	*	NS	NS	*	**
Linear Fert.		NS	**	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Linear Fert.		NS	*	**	NS	NS	NS	*	*	NS	NS	**	**	*	NS	*	**	**
Quad. Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 7. Effect of sludge ash and phosphate fertilizer on Soil pH, Bray P1 and selected elements extracted with 1 N nitric acid. (6-12 inch depth)

Treatment lb P_2O_5/A	Source	pH	Bray P1	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
				1 N nitric acid extractable														
			lb P/A	ppm														
Control	-	5.9	11	40	66	2558	580	1730	533	15	54	4.5	3.2	1.1	2.4	2.7	1.3	0.1
70	Fert.	5.8	20	34	69	2637	583	1756	546	13	59	4.6	3.1	1.1	2.3	3.0	1.3	0.1
140	Fert.	5.8	15	41	70	2519	564	1696	525	14	58	4.5	2.8	1.1	2.4	2.9	1.3	0.1
280	Fert.	5.8	16	36	66	2487	567	1707	540	13	56	4.8	2.8	1.1	2.4	2.9	1.3	0.1
70	Ash	5.8	14	37	71	2670	587	1780	550	13	61	4.5	3.3	1.2	1.8	3.2	1.3	0.1
140	Ash	5.9	14	43	66	2519	580	1754	553	12	55	5.3	4.9	1.1	2.4	2.7	1.3	0.1
280	Ash	5.9	14	30	67	2521	625	1782	638	13	56	5.3	3.4	1.1	1.9	2.9	1.4	0.1
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (0.05)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Contrasts																		
Ctrl. vs Rest		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fert. vs Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Linear Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad. Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Linear Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad. Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 8. Effect of sludge ash and phosphate fertilizer on soil pH, Bray P1 and selected elements extracted with 1 N nitric acid. (12-24 inch depth).

Treatment lb P_2O_5/A	Source	pH	Bray P1	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
				1 N nitric acid extractable														
			lb P/A	ppm														
Control	-	6.4	6	85	55	1663	476	1105	569	10	43	3.0	1.6	0.9	1.6	1.6	1.0	0.1
70	Fert.	6.1	9	60	57	1583	454	1154	543	11	39	3.0	1.6	0.9	1.5	1.6	1.1	0.1
140	Fert.	6.3	8	60	57	1568	460	1141	549	10	37	3.2	2.0	0.8	1.3	1.6	1.0	0.1
280	Fert.	6.3	11	63	58	1554	450	1150	539	11	40	3.4	1.7	0.8	1.3	1.6	1.1	0.1
70	Ash	6.2	7	68	55	1593	468	1180	579	8	42	2.9	1.8	0.8	1.2	1.6	1.0	0.1
140	Ash	6.3	12	89	53	1708	513	1062	538	10	50	2.7	1.8	0.9	1.1	1.9	1.0	0.1
280	Ash	6.2	16	79	64	1628	488	1232	638	11	54	3.8	2.2	0.9	2.0	1.9	1.2	0.1
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (0.05)		-	4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Contrasts</u>																		
Ctrl. vs Rest		NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fert. vs Ash		NS	*	*	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS
Linear Fert.		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad. Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Linear Ash		NS	**	NS	NS	NS	NS	NS	NS	NS	*	*	NS	NS	NS	NS	NS	NS
Quad. Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS

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

Table 9. Effect of sludge ash and phosphate fertilizer on grain yield (dry weight basis), stover yield (dry weight basis) and stand count.

Treatment lb P_2O_5/A	Source	Grain Yield bu/A	Stover Yield T/A	Stand Count plants/A x 1000
Control	-	120.9	2.05	28.7
70	Fert	129.4	2.22	30.2
140	Fert	124.5	2.19	30.1
280	Fert	128.8	2.21	30.5
70	Ash	122.9	2.06	29.5
140	Ash	120.8	2.14	29.3
280	Ash	124.1	2.30	28.1
Significance		NS	NS	NS
BLSD (0.05)		-	-	-
<u>Contrasts</u>				
Ctrl. vs Rest		NS	NS	NS
Fert. vs Ash		*	NS	*
Linear Fert.		NS	NS	NS
Quad. Fert.		NS	NS	NS
Linear Ash		NS	NS	NS
Quad. Ash		NS	NS	NS

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

Table 10. Effect of sludge ash and phosphate fertilizer on the elemental composition of whole plants sampled at the 8-12 leaf stage.

Treatment lb P_2O_5/A	Source	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
		%					ppm										
Control	-	4.25	0.35	3.84	0.52	0.37	274	286	11	105	36	8.0	7.9	<0.89	1.1	1.1	0.1
70	Fert.	4.39	0.40	3.85	0.54	0.36	265	288	11	120	35	8.1	8.4	<0.89	1.1	1.2	0.1
140	Fert.	4.52	0.43	3.93	0.57	0.35	255	287	13	135	32	7.4	8.5	<0.89	1.9	2.1	0.1
280	Fert.	4.52	0.47	3.92	0.58	0.36	298	316	13	128	31	6.9	9.1	<0.89	1.4	1.5	0.1
70	Ash	4.34	0.39	4.01	0.51	0.35	268	287	13	114	37	8.1	8.5	<0.89	1.1	1.1	0.1
140	Ash	4.25	0.36	3.83	0.53	0.36	266	280	11	114	38	8.6	6.9	<0.89	1.0	1.2	0.1
280	Ash	4.34	0.37	3.89	0.54	0.36	301	316	12	110	37	9.1	8.0	<0.89	1.3	1.4	0.1
Significance		NS	**	NS	NS	NS	NS	NS	NS	NS	*	*	NS	NS	NS	NS	NS
BLSD (0.05)		-	0.04	-	-	-	-	-	-	-	4	1.3	-	-	-	-	-
Contrasts																	
Ctrl. vs Rest		NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fert. vs Ash		*	**	NS	*	NS	NS	NS	NS	*	**	**	NS	NS	NS	NS	NS
Linear Fert.		*	**	NS	**	NS	NS	NS	NS	NS	**	*	NS	NS	NS	NS	NS
Quad. Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Linear Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Quad. Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 11. Effect of sludge ash and phosphate fertilizer on elemental composition of the ear leaf sampled during initial silking.

Treatment lb P_2O_5/A	Source	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
		%					ppm										
Control	-	3.16	0.24	2.01	0.61	0.47	61	211	14	111	33	8.7	8.0	<0.9	0.3	0.3	0.1
70	Fert.	3.01	0.24	2.05	0.66	0.49	64	196	16	115	30	7.9	7.6	<0.9	0.3	0.4	0.1
140	Fert.	2.96	0.26	2.06	0.70	0.50	58	188	18	131	27	7.4	7.7	<0.9	0.3	0.3	0.1
280	Fert.	2.93	0.28	1.95	0.72	0.52	57	190	18	119	24	6.8	7.3	<0.9	0.3	0.3	0.1
70	Ash	3.07	0.24	2.08	0.65	0.46	56	201	16	112	34	8.9	7.8	<0.9	0.3	0.4	0.1
140	Ash	2.98	0.25	1.99	0.63	0.47	60	212	17	106	33	9.2	7.2	1.2	0.4	0.4	0.1
280	Ash	3.06	0.25	1.98	0.65	0.49	54	199	15	105	36	9.2	7.4	<0.9	0.3	0.3	0.1
Significance		NS	**	NS	**	*	NS	NS	*	NS	**	**	NS	NS	NS	NS	NS
BLSD (0.05)		-	0.01	-	0.04	0.04	-	-	3	-	3	0.6	-	-	-	-	-
Contrasts																	
Ctrl. vs Rest		**	**	NS	**	NS	NS	NS	**	NS	*	NS	NS	NS	NS	NS	NS
Fert. vs Ash		NS	**	NS	**	**	NS	NS	*	**	**	**	NS	NS	NS	NS	NS
Linear Fert.		**	**	NS	**	*	NS	NS	**	NS	**	**	NS	NS	NS	NS	NS
Quad. Fert.		NS	NS	NS	*	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Linear Ash		NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad. Ash		NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 12. Effect of sludge ash and phosphate fertilizer on elemental composition of grain sample at harvest.

Treatment lb P_2O_5/A	Source	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
		--------%-------			ppm												
Control	-	1.64	0.28	0.34	38	1296	1.0	23	1.5	9.1	25	1.0	2.2	1.0	0.3	0.1	0.1
70	Fert.	1.64	0.29	0.35	38	1327	0.6	23	0.9	10.0	24	1.0	2.0	<0.9	0.3	0.1	0.1
140	Fert.	1.63	0.29	0.35	38	1333	0.9	23	1.4	10.0	25	0.9	2.1	0.9	0.4	0.1	0.1
280	Fert.	1.56	0.29	0.35	38	1353	0.7	23	0.9	10.0	25	0.9	2.1	0.9	0.3	0.1	0.1
70	Ash	1.93	0.28	0.34	37	1307	0.9	23	1.6	9.3	24	1.2	2.1	1.0	0.4	0.2	0.1
140	Ash	1.62	0.29	0.34	39	1306	3.6	23	1.2	9.5	24	1.1	2.2	1.2	0.3	0.1	0.1
280	Ash	1.64	0.30	0.35	39	1369	0.8	23	1.0	9.7	24	0.8	2.1	<0.9	0.3	0.1	0.1
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (0.05)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Contrasts</u>																	
Ctrl. vs Rest		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fert. vs Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Linear Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad. Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Linear Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad. Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 13. Effect of sludge ash and phosphate fertilizer on elemental composition of the cob at harvest.

Treatment lb P_2O_5/A	Source	N	K	P	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
		----%-----		ppm													
Control	-	0.30	0.46	192	145	516	0.4	8.9	<0.9	12	36	4.6	2.0	<0.9	0.5	0.5	<0.06
70	Fert.	0.29	0.46	175	163	524	0.4	6.6	<0.9	13	32	3.9	1.8	<0.9	0.3	0.4	<0.06
140	Fert.	0.28	0.45	212	174	528	1.5	7.1	<0.9	13	27	3.6	1.8	<0.9	0.4	0.4	<0.06
280	Fert.	0.28	0.46	193	153	356	0.4	7.3	<0.9	13	20	3.3	1.8	<0.9	0.3	0.4	<0.06
70	Ash	0.26	0.40	171	153	561	0.5	14.2	<0.9	13	38	4.4	1.8	<0.9	0.4	0.5	<0.06
140	Ash	0.26	0.44	171	133	470	0.4	6.2	<0.9	10	28	4.1	1.7	<0.9	0.4	0.4	<0.06
280	Ash	0.30	0.43	188	128	498	0.6	8.0	<0.9	11	34	4.6	2.0	<0.9	0.5	0.4	<0.06
Significance		*	NS	NS	NS	**	NS	NS	NS	NS	**	**	NS	NS	NS	NS	NS
BLSD (0.05)		0.03	-	-	-		-	-	-	-			-	-	-	-	-
<u>Contrasts</u>																	
Ctrl vs Rest		*	NS	NS	NS	NS	NS	NS	NS	NS	*	*	NS	NS	NS	NS	NS
Fert. vs Ash		NS	NS	*	*	NS	NS	NS	NS	NS	**	**	NS	NS	NS	NS	NS
Linear Fert.		NS	NS	NS	NS	**	NS	NS	NS	NS	**	**	NS	NS	NS	NS	NS
Quad. Fert.		NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Linear Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad Ash		**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 14. Effect of sludge ash and phosphate fertilizer on elemental composition of stover sampled at harvest.

Treatment lb P_2O_5/A	Source	N	K	Ca	Mg	P	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
		%				ppm											
Control	-	0.65	1.23	0.33	0.27	375	59	70	4.4	80	17	4.2	5.0	<0.9	0.4	0.4	0.1
70	Fert.	0.70	1.25	0.38	0.29	423	50	65	5.4	79	12	3.4	4.8	<0.9	0.4	0.4	0.1
140	Fert.	0.66	1.26	0.40	0.26	465	53	69	5.2	87	11	3.0	5.1	<0.9	0.5	0.4	0.1
280	Fert.	0.67	1.22	0.38	0.26	553	39	54	4.0	78	9	2.6	4.8	1.2	0.3	0.3	0.1
70	Ash	0.67	1.25	0.34	0.28	384	40	54	4.0	73	15	3.9	4.8	<0.9	0.3	0.3	0.1
140	Ash	0.65	1.14	0.33	0.28	396	53	64	4.3	69	13	4.0	4.7	0.9	0.5	0.4	0.1
280	Ash	0.62	1.07	0.35	0.27	371	45	62	3.9	71	13	4.0	5.1	<0.9	0.4	0.3	0.1
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	**	**	NS	NS	NS	*	NS
BLSD (0.05)		-	-	-	-	-	-	-	-	-	3	0.3	-	-	-	0.1	-
Contrasts																	
Ctrl. vs Rest		NS	NS	NS	NS	NS	*	NS	NS	NS	**	**	NS	NS	NS	NS	NS
Fert. vs Ash		NS	NS	**	NS	*	NS	NS	*	**	**	**	NS	NS	NS	NS	NS
Linear Fert.		NS	NS	NS	NS	**	*	*	NS	NS	**	**	NS	NS	NS	NS	NS
Quad. Fert		NS	NS	*	NS	NS	NS	NS	*	NS	*	**	NS	NS	NS	NS	NS
Linear Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS
Quad. Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS

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

LIQUID STARTER FERTILIZER COMPARISON

Olmsted Co., 1987

T. L. Wagar and M. O'Leary

In southeastern Minnesota starter fertilizer is used extensively by corn producers to improve fertilizer efficiency. This study was conducted to compare the effect of two popular liquid starter fertilizer products on corn grain yield, early plant growth and grain moisture at harvest.

Experimental Procedures

Corn (Pioneer 3737) was planted on May 2 with a Kinze planter in 30" rows (30,200 pop.) on a Radford silt loam soil. The site was chisel plowed in the fall of 1986 and field cultivated in the spring before planting. Weeds were controlled with 2 1/2 pts/A Prowl and 1.6 lbs/A Bladex DF. No soil insecticide was used since this was corn following soybean. Soil tests were: OM 3.6%, P 70 lbs/A, K 286 lbs/A, and pH 7.3. Liquid 28% N solution was injected at planting to provide 120 lb. N /acre. Treatments were randomizded in strips (six rows 300 feet long) and were replicated four times. Two liquid starter fertilizers (7-21-7 and 9-18-9) were applied at 5 gals/A with the seed and compared with a no starter treatment.

Whole (above the soil surface) corn plants were randomly harvested at the eight leaf stage of growth for early plant growth determination. The corn grain yield was determined by mechanical harvesting and weighed by a weigh wagon. Grain moisture was determined by the oven dry method.

Results and Discussion

The following table shows that there was no difference in early plant growth, grain yield,and grain moisture from any of the treatments. With the above normal temperatures in the spring to rapidly warm the soil and with the high soil fertility levels no crop response was observed. The results of this study are consistent with similar research conducted in prior years in southern Minnesota.

Table 1. The Effect of Liquid Starter Placed with the Seed on Corn Growth, Yield, and Moisture

	Whole Plant- 8 leaf	Grain	
Treatment	Dry Weight/6 plants	Yield	Moisture
	grams	bu/A	%
No Starter	31.2	188	16.2
7-21-7 (5 gal/A)	26.7	182	15.9
9-18-9 (5 gal/A)	27.8	190	15.9
Significance	NS	NS	NS
Probability level	(.31)	(.65)	(.24)
CV (%)	13.9	6.9	2.0

INFLUENCE OF NITROGEN AND POTASSIUM FERTILIZATION ON THE YIELD AND NUTRIENT ACCUMULATION OF FOUR DIFFERENT CORN HYBRIDS--1987

G.L. Malzer, G.W. Randall and T.J. Graff

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

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

Experimental Procedures

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

Potassium treatments were broadcast before planting and incorporated by plowing. The four corn hybrids were planted on April 28th, at a population of 30,700 seeds/A in 30 inch rows. Starter fertilizer was applied as a side banded application of 160 lbs/A of 10-10-10. Weed control was accomplished by using Roundup (1 lb/A a.i.) and Dual (1.5 lbs/A a.i.) on April 30th and Buctril (3/8 lb/A a.i.) on May 27. Nitrogen treatments were applied as anhydrous ammonia on June 2nd (4-5 leaf growth stage). Nitrification inhibitors were applied by injection into the anhydrous ammonia flow stream. Injection took place before the manifold and passed through a bidirectional flow integrator prior to the manifold.

Plant and soil samples were taken four times during the growing season. Plant samples were taken on June 12th, July 16th, August 10th, and September 16. These dates corresponded to the 12-leaf, silking, predent, and physiological maturity, growth stages, respectively. Total plant material was removed from 20 ft^2 of plot area for each of the first three harvests and 100 ft^2 was sampled for the final sampling. For the first two harvests total dry matter production was determined and subsamples collected for nitrogen concentration and determination of total nitrogen uptake. Plant samples obtained during the third and fourth harvest were separated into grain and stover samples. Separate determinations were made for dry matter production and nitrogen concentrations. Grain yields were adjusted to 15.5% moisture. Soil samples were collected from all nitrogen combinations at the high K rate for two hybrids (Pioneer 3732 and A632 x LH39). Six to eight cores were taken from a depth of 0-1 ft through the anhydrous ammonia injection zone. All soil samples were analyzed for nitrate and ammonium nitrogen.

The irrigation program began on May 4th and continued through September 8th with a total of 12.8 inches being applied through an overhead solid set irrigation system. An additional 14.3 inches of water was obtained during the growing season as rainfall.

Waseca: The corn experiment at Waseca was similar to that established at Becker except only 40 treatments were evaluated. The experimental design was a split plot with four replications. Treatments included a factorial combination of four hybrids (Pioneer 3732, Pioneer 3475, LH74 x LH51, and A632 x LH38), with two nitrogen rates (80 and 160 lbs N/A), two potassium rates (0 and 100 lbs K/A), and two nitrification

inhibitor treatments (w/wo N-Serve 0.5 lbs/A). Two controls both with no fertilizer nitrogen but one with potassium and one without was also included into the experiment.
Potassium treatments were applied in the fall of 1986. The four corn hybrids were planted on April 27 at a population of 32,000 seeds/A in 30 inch rows. Weed control was accomplished with a tank mix of Lasso (3.5 lbs/A a.i.) and Bladex (3 lbs/A a.i.) on May 5th. Nitrogen treatments were applied as anhydrous ammonia on June 5th using procedures similar to that used at Becker.

Plant and soil samples were taken four times (June 26th, July 17th, August 14th, and September 14th), during the growing season. This coincides with the comparable growth stages at the Becker location. The same plant sampling procedures were used at the Waseca location as was described with the other experiment. Soil samples were collected from the zero k rate (all N combinations) for two of the hybrids (Pioneer 3732 and A632 x LH38) at each plant sampling.

General Results

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

Becker: Grain yields at this location in 1987 were excellent. The hybrid yields were significantly different. Pioneer 3732 had lower yields than the other hybrids tested. A significant yield response to nitrogen rate was obtained up to 160 lbs N/A, but the yield increase over the 80 lb/A treatment was only 12 bu/A (204 to 216 bu/A). The nitrification inhibitor treatments did not significantly (.05) increase final yields, but did increase nitrogen concentrations in the grain and stover which resulted in more total nitrogen removed by the crop. Samples at the predent growth stage indicated a yield increase from the nitrification inhibitor treatment, but this did not carry over to the final yield. A significant nitrogen-hybrid-inhibitor interaction would suggest that all hybrids did not respond in the same manner to the nitrogen treatments applied. Potassium had no significant impact on final grain yield. A trend for reduced yields and reduced nitrogen uptake with increasing rates of potassium were observed with the final harvest. Earlier samples indicated significant reductions in production and N uptake with K fertilization.

Waseca: Grain yields at this location were excellent in 1987. Potassium application had no significant influence on grain yield, but a significant hybrid-inhibitor-K rate interaction would suggest that not all hybrids responded in the same manner to the potassium treatment. Hybrids were again significant with Pioneer 3732 having lower final yields than the other hybrids tested. Grain yields were significantly increased up the 160 lbs N/A rate but this increase was only 4.6 bu/A (184 to 188.6 bu/A). The nitrification inhibitor treatment had no overall influence on grain yield or nitrogen uptake except for the three way interaction previously mentioned. Samples taken at predent indicated that potassium fertilization was reducing yields. At the predent stage Pioneer 3732 which had the lowest final yield was the highest yielding hybrid at that stage. This would suggest that the hybrids were indeed accumulating nitrogen and yield components at varying rates through the season.

These experiments will be continued next year to determine how environmental differences influence the ability of a hybrid to respond and utilize fertilizer nitrogen and potassium.

Table 1. Influence of N-Rates, K-Rates, nitrification inhibitors on four corn hybrids, stover N content, total N removal and drymatter production by irrigated corn Becker, MN 1987.

N-Rate	Hybrid	Inh.	K-Rate	Whole Plant 12 Leaf Stover			Whole Plant Tassling Stover		
#/A			#/A	T/A	% N	#/A	T/A	% N	#/A
80	Pioneer 3732	---	---	1.44	2.85	83.2	4.43	1.95	174.1
80		NS	---	1.68	2.92	98.5	4.70	1.82	170.6
80		---	100	1.41	2.68	75.3	4.39	1.82	160.5
80		NS	100	1.36	2.85	78.1	4.42	1.79	158.2
80		---	200	1.24	2.97	73.6	4.52	1.87	170.4
80		NS	200	1.34	2.92	78.0	3.97	1.74	137.9
160		---	200	1.33	2.91	76.9	4.17	2.07	171.8
160		NS	200	1.35	2.91	78.6	3.90	1.80	142.2
240		---	---	1.48	2.89	85.2	4.31	1.98	172.3
240		NS	---	1.37	3.02	81.9	4.28	2.04	172.0
240		---	100	1.21	2.87	69.5	3.81	2.07	158.1
240		NS	100	1.37	2.75	75.2	4.43	2.08	185.0
240		---	200	1.21	2.95	70.7	4.09	1.92	156.5
240		NS	200	1.24	2.88	71.5	4.47	2.02	180.2
80	Pioneer 3737	---	---	1.52	3.02	91.0	4.72	1.94	184.0
80		NS	---	1.46	3.25	94.4	4.19	2.08	173.2
80		---	100	1.28	3.00	76.8	4.16	2.06	171.7
80		NS	100	1.31	3.00	78.8	4.27	2.06	176.1
80		---	200	1.22	2.95	71.3	3.96	1.92	151.9
80		NS	200	1.24	3.05	73.2	4.07	1.94	159.5
160		---	200	1.12	3.04	68.2	3.88	1.98	153.9
160		NS	200	1.19	3.18	75.6	4.33	2.03	175.0
240		---	---	1.35	3.16	84.9	4.32	2.16	186.4
240		NS	---	1.40	3.15	88.2	4.29	2.14	183.1
240		---	100	1.16	3.04	70.5	3.97	2.22	175.8
240		NS	100	1.26	3.11	78.4	3.82	2.10	159.9
240		---	200	1.04	3.01	62.5	3.85	2.13	164.6
240		NS	200	1.24	3.07	76.1	4.12	2.23	183.4
80	A632 X LH39	---	---	1.39	2.99	82.1	4.63	1.87	173.0
80		NS	---	1.45	2.93	84.5	4.53	2.04	184.6
80		---	100	1.19	2.82	66.5	3.78	1.82	136.1
80		NS	100	1.29	2.98	77.1	4.08	2.04	164.9
80		---	200	1.20	2.78	66.5	3.84	1.91	146.7
80		NS	200	1.05	2.89	66.4	4.02	1.97	159.0
160		---	200	1.37	2.92	80.0	3.98	2.19	175.2
160		NS	200	1.06	3.10	71.4	4.16	1.88	155.6
240		---	---	1.50	3.02	90.8	4.46	2.05	182.0
240		NS	---	1.38	2.99	81.3	3.90	2.03	157.1
240		---	100	1.23	3.11	76.3	3.92	2.14	167.1
240		NS	100	1.25	2.98	74.7	4.00	2.27	182.3
240		---	200	1.34	2.85	76.2	4.09	2.15	175.7
240		NS	200	1.29	2.98	76.5	4.41	2.05	179.8
80	DeKalb 484	---	---	1.46	2.86	83.2	3.90	2.03	158.1
80		NS	---	1.29	2.76	70.8	4.22	1.98	170.9
80		---	100	1.21	2.95	71.1	4.03	1.83	146.8
80		NS	100	1.28	2.88	73.3	4.07	2.06	168.0
80		---	200	1.04	3.01	62.4	3.71	1.69	125.7
80		NS	200	1.33	3.01	79.8	3.89	1.83	142.0
160		---	200	1.23	3.11	76.1	4.11	1.99	162.8
160		NS	200	1.13	2.97	66.9	3.81	1.95	147.7
240		---	---	1.37	2.98	81.3	4.13	2.32	192.1
240		NS	---	1.43	2.90	83.1	4.35	2.09	181.8
240		---	100	1.20	2.71	65.0	3.60	1.91	137.3
240		NS	100	1.13	3.05	68.4	4.08	2.15	175.0
240		---	200	1.14	2.82	64.0	4.10	2.19	180.6
240		NS	200	1.03	2.92	65.7	3.92	2.10	167.1

Table 2. Influence of N-Rates, K-Rates, nitrification inhibitors on four corn hybrids on grain yields, and drymatter production at the predent stage of plant growth on irrigated corn Becker, MN 1987.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
#/A			#/A	Bu/A	---------------	T/A	-------------	
80	Pioneer 3732	---	---	133.5	3.92	4.67	0.76	8.59
80		NS	---	129.2	3.76	4.91	0.70	8.66
80		---	100	119.3	3.46	4.58	0.64	8.04
80		NS	100	108.7	3.17	4.47	0.59	7.64
80		---	200	125.5	3.62	4.70	0.65	8.32
80		NS	200	134.2	3.90	5.02	0.72	8.92
160		---	200	124.3	3.64	4.63	0.70	8.27
160		NS	200	131.8	3.85	4.65	0.73	8.50
240		---	---	130.7	3.81	4.34	0.71	8.15
240		NS	---	131.7	3.82	4.15	0.70	7.97
240		---	100	122.9	3.56	4.38	0.65	7.95
240		NS	100	127.9	3.72	4.41	0.70	8.13
240		---	200	117.0	3.44	4.32	0.68	7.76
240		NS	200	132.6	3.84	4.50	0.70	8.34
80	Pioneer 3737	---	---	143.8	4.03	4.23	0.62	8.25
80		NS	---	139.2	3.85	4.01	0.56	7.86
80		---	100	139.0	3.90	4.11	0.62	8.02
80		NS	100	132.8	3.74	4.18	0.60	7.92
80		---	200	132.3	3.73	4.03	0.60	7.76
80		NS	200	134.1	3.70	3.90	0.53	7.61
160		---	200	127.6	3.64	3.89	0.62	7.53
160		NS	200	141.7	4.03	4.16	0.68	8.20
240		---	---	152.8	4.29	4.62	0.67	8.91
240		NS	---	137.9	3.92	4.22	0.66	8.15
240		---	100	129.1	3.66	3.93	0.61	7.59
240		NS	100	130.1	3.65	4.09	0.57	7.74
240		---	200	139.3	3.92	3.94	0.62	7.86
240		NS	200	131.8	3.81	4.07	0.69	7.87
80	A632 X LH39	---	---	128.2	3.89	4.25	0.86	8.15
80		NS	---	135.8	4.05	4.24	0.83	8.28
80		---	100	125.4	3.79	4.13	0.82	7.92
80		NS	100	122.8	3.80	4.23	0.89	8.02
80		---	200	115.0	3.46	3.99	0.74	7.44
80		NS	200	120.3	3.64	4.16	0.79	7.80
160		---	200	123.9	3.76	4.22	0.83	7.97
160		NS	200	122.4	3.69	4.15	0.80	7.84
240		---	---	134.4	4.04	4.32	0.86	8.36
240		NS	---	133.0	4.01	4.38	0.86	8.39
240		---	100	123.2	3.70	4.03	0.78	7.73
240		NS	100	125.4	3.77	4.14	0.80	7.91
240		---	200	121.6	3.76	4.25	0.88	8.01
240		NS	200	139.0	4.23	4.59	0.94	8.82
80	DeKalb 484	---	---	126.4	3.70	4.58	0.71	8.82
80		NS	---	122.5	3.60	4.47	0.70	8.06
80		---	100	113.6	3.34	4.37	0.65	7.71
80		NS	100	117.0	3.43	3.91	0.66	7.34
80		---	200	115.5	3.36	4.24	0.63	7.60
80		NS	200	117.3	3.46	4.52	0.69	7.98
160		---	200	113.4	3.34	4.32	0.66	7.67
160		NS	200	107.2	3.23	4.10	0.70	7.33
240		---	---	125.9	3.69	4.36	0.71	8.05
240		NS	---	140.8	4.12	4.82	0.79	8.94
240		---	100	122.6	3.61	4.07	0.71	7.68
240		NS	100	123.3	3.67	4.45	0.75	8.11
240		---	200	112.9	3.33	4.06	0.65	7.39
240		NS	200	119.7	3.51	4.07	0.68	7.58

Table 3. Influence of N-Rates, K-Rates, nitrification inhibitors on four corn hybrids on grain, stover, and cob N content and total N removal at the predent stage of plant growth on irrigated corn Becker, MN 1987.

N-Rate	Hybrid	Inh.	K-Rate	N-Concentration Stover	Grain	Cob	N-Removal Stover	Grain	Cob	Total
#/A			#/A	-----------	%	----------	-----------	#/A	-----------	
80	Pioneer 3732	---	---	1.39	1.36	0.63	149.9	86.3	9.5	245.8
80		NS	---	1.34	1.39	0.62	150.5	84.7	8.6	243.8
80		---	100	1.37	1.39	0.58	144.1	79.1	7.4	230.6
80		NS	100	1.32	1.40	0.71	133.1	71.6	8.3	213.1
80		---	200	1.15	1.34	0.70	121.9	79.7	9.2	210.8
80		NS	200	1.30	1.39	0.72	149.9	88.5	10.4	248.9
160		---	200	1.38	1.38	0.74	147.4	80.9	10.2	238.6
160		NS	200	1.24	1.38	0.78	133.1	86.0	11.4	230.6
240		---	---	1.51	1.43	0.69	151.8	87.7	9.6	249.1
240		NS	---	1.27	1.45	0.57	124.5	90.3	8.2	223.1
240		---	100	1.23	1.39	0.73	123.6	81.0	9.6	214.3
240		NS	100	1.39	1.36	0.69	141.0	82.5	9.5	233.1
240		---	200	1.32	1.36	0.77	131.3	75.1	10.3	216.8
240		NS	200	1.41	1.42	0.67	145.8	89.2	9.4	244.5
80	Pioneer 3737	---	---	1.32	1.45	0.51	128.6	99.0	6.3	233.9
80		NS	---	1.22	1.55	0.60	111.5	102.3	6.6	220.4
80		---	100	1.20	1.44	0.54	112.8	94.9	6.4	214.2
80		NS	100	1.32	1.46	0.62	125.9	91.9	7.2	225.1
80		---	200	1.11	1,42	0.55	102.8	88.7	6.5	198.2
80		NS	200	1.23	1.45	0.39	108.5	91.6	4.0	204.2
160		---	200	1.31	1.48	0.60	118.7	89.1	7.3	215.2
160		NS	200	1.34	1.49	0.56	130.2	100.1	7.7	238.1
240		---	---	1.18	1.52	0.45	124.7	109.9	6.1	240.7
240		NS	---	1.55	1.56	0.46	150.4	101.6	5.9	257.9
240		---	100	1.24	1.49	0.61	112.3	90.8	7.4	210.6
240		NS	100	1.33	1.51	0.54	122.2	93.0	6.1	221.4
240		---	200	1.47	1.42	0.57	133.2	93.4	7.1	233.8
240		NS	200	1.19	1.52	0.53	113.5	94.9	7.3	215.7
80	A632 X LH39	---	---	1.26	1.56	0.51	129.6	94.8	8.7	233.2
80		NS	---	1.41	1.66	0.53	143.3	106.8	8.8	259.0
80		---	100	1.03	1.42	0.50	101.5	84.5	8.4	194.5
80		NS	100	1.23	1.58	0.49	126.5	92.4	8.6	227.6
80		---	200	1.27	1.57	0.70	119.9	85.5	10.2	215.7
80		NS	200	1.22	1.61	0.52	121.6	91.5	8.0	221.2
160		---	200	1.17	1.69	0.57	118.7	98.7	9.3	226.8
160		NS	200	1.33	1.61	0.59	129.6	93.4	9.4	232.5
240		---	---	1.23	1.69	0.47	126.8	107.5	8.0	242.4
240		NS	---	1.36	1.78	0.46	141.9	111.9	7.9	261.8
240		---	100	1.41	1.60	0.43	136.4	93.5	6.6	236.6
240		NS	100	1.38	1.66	0.59	134.7	98.5	9.4	242.7
240		---	200	1.31	1.69	0.51	135.4	97.3	8.9	241.7
240		NS	200	1.34	1.75	0.52	148.8	115.1	9.8	273.7
80	DeKalb 484	---	---	1.13	1.61	0.53	119.7	96.6	7.4	223.8
80		NS	---	1.18	1.62	0.47	122.5	93.8	6.6	223.0
80		---	100	1.17	1.54	0.57	118.4	82.8	7.4	208.7
80		NS	100	1.27	1.58	0.51	116.6	87.7	6.8	211.1
80		---	200	1.16	1.45	0.49	115.1	78.9	6.2	200.3
80		NS	200	1.30	1.55	0.50	136.4	86.2	6.8	229.5
160		---	200	1.25	1.65	0.55	125.0	88.6	7.4	221.2
160		NS	200	1.25	1.63	0.72	119.3	82.5	10.0	211.9
240		---	---	1.55	1.66	0.53	155.8	98.7	7.3	261.9
240		NS	---	1.43	1.69	0.68	160.7	112.5	10.9	284.2
240		---	100	1.36	1.53	0.64	130.0	89.0	9.3	228.3
240		NS	100	1.46	1.67	0.59	151.0	97.9	8.8	257.7
240		---	200	1.27	1.59	0.73	119.9	85.0	9.5	214.4
240		NS	200	1.42	1.61	0.53	136.5	91.0	7.2	234.9

Table 4. Influence of N-Rates, K-Rates, nitrification inhibitors on four corn hybrids on grain yields, and drymatter production at physiological maturity on irrigated corn Becker, MN 1987.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
#/A			#/A	Bu/A	--------------T/A-------------			
80	Pioneer 3732	---	---	202.8	4.80	3.77	0.70	9.28
80		NS	---	213.4	5.05	4.22	0.74	10.01
80		---	100	197.5	4.69	3.94	0.66	9.28
80		NS	100	192.6	4.56	3.82	0.65	9.03
80		---	200	196.9	4.66	3.80	0.65	9.11
80		NS	200	196.3	4.65	3.79	0.64	9.08
160		---	200	202.1	4.78	3.76	0.67	9.22
160		NS	200	201.2	4.76	3.91	0.69	9.37
240		---	---	214.6	5.08	4.04	0.71	9.83
240		NS	---	201.6	4.77	3.68	0.64	9.09
240		---	100	204.8	4.85	3.65	0.68	9.18
240		NS	100	207.2	4.90	3.79	0.69	9.38
240		---	200	210.3	4.98	3.77	0.68	9.43
240		NS	200	193.4	4.58	3.49	0.67	8.74
80	Pioneer 3737	---	---	221.1	5.23	3.30	0.56	9.09
80		NS	---	212.3	5.02	3.43	0.56	9.01
80		---	100	202.1	4.78	3.29	0.52	8.59
80		NS	100	215.5	5.10	3.45	0.55	9.11
80		---	200	205.8	4.87	3.08	0.50	8.45
80		NS	200	224.7	5.32	3.41	0.60	9.33
160		---	200	220.5	5.22	3.08	0.60	8.90
160		NS	200	223.9	5.30	3.13	0.56	9.00
240		---	---	210.4	4.98	3.37	0.54	8.89
240		NS	---	220.4	5.21	3.31	0.60	9.13
240		---	100	212.3	5.02	3.16	0.54	8.73
240		NS	100	222.3	5.26	3.03	0.60	8.89
240		---	200	218.9	5.18	3.47	0.60	9.25
240		NS	200	222.8	5.27	3.35	0.55	9.18
80	A632 X LH39	---	---	220.9	5.23	3.48	0.82	9.52
80		NS	---	212.9	5.04	3.23	0.80	9.07
80		---	100	200.6	4.75	2.99	0.73	8.47
80		NS	100	223.6	5.29	3.45	0.80	9.54
80		---	200	208.6	4.94	3.42	0.75	9.10
80		NS	200	201.7	4.77	3.10	0.75	8.62
160		---	200	226.7	5.36	3.52	0.87	9.75
160		NS	200	223.0	5.28	3.23	0.84	9.35
240		---	---	213.9	5.06	3.33	0.78	9.17
240		NS	---	213.4	5.05	3.39	0.79	9.24
240		---	100	217.9	5.16	3.10	0.85	9.10
240		NS	100	215.5	5.10	3.05	0.77	8.91
240		---	200	215.4	5.10	3.20	0.75	9.05
240		NS	200	226.3	5.36	3.53	0.85	9.73
80	DeKalb 484	---	---	217.4	5.15	3.43	0.66	9.23
80		NS	---	213.5	5.05	3.46	0.62	9.14
80		---	100	213.2	5.05	3.47	0.61	9.13
80		NS	100	204.7	4.84	3.38	0.59	8.81
80		---	200	187.3	4.43	3.01	0.54	7.98
80		NS	200	212.2	5.02	3.45	0.65	9.12
160		---	200	212.9	5.04	3.45	0.66	9.14
160		NS	200	217.2	5.14	3.58	0.68	9.40
240		---	---	223.4	5.29	3.41	0.69	9.39
240		NS	---	224.5	5.31	3.81	0.66	9.79
240		---	100	204.4	4.84	3.19	0.61	8.65
240		NS	100	223.3	5.28	3.41	0.67	9.36
240		---	200	222.5	5.27	3.18	0.69	9.45
240		NS	200	224.0	5.30	3.46	0.68	9.45

Table 5. Influence of N-Rates, K-Rates, nitrification inhibitors on four corn hybrids on grain,stover,and cob N content and total N removal at physiological maturity on irrigated corn Becker, MN 1987.

N-Rate	Hybrid	Inh.	K-Rate	N-Concentration Stover	Grain	Cob	N-Removal Stover	Grain	Cob	Total
#/A			#/A	------------%	----------		------------#/A	------------		
80	Pioneer 3732	---	---	0.74	1.35	0.61	71.4	129.7	8.5	209.7
80		NS	---	0.78	1.51	0.62	79.2	151.9	9.0	240.2
80		---	100	0.66	1.30	0.59	62.0	122.0	7.8	191.8
80		NS	100	0.70	1.34	0.66	64.2	121.7	8.6	194.5
80		---	200	0.67	1.27	0.59	63.2	119.3	7.6	190.2
80		NS	200	0.83	1.42	0.60	76.8	132.6	7.7	217.1
160		---	200	0.81	1.35	0.60	77.0	129.1	8.0	214.2
160		NS	200	0.78	1.40	0.65	73.4	133.1	8.9	215.4
240		---	---	0.82	1.45	0.63	83.3	147.3	8.8	239.5
240		NS	---	0.91	1.41	0.66	87.3	134.9	8.4	230.6
240		---	100	0.78	1.40	0.64	74.9	136.1	8.7	219.8
240		NS	100	0.93	1.48	0.63	91.2	145.4	8.7	245.4
240		---	200	0.84	1.39	0.62	83.2	138.9	8.3	230.5
240		NS	200	0.86	1.39	0.64	78.3	127.5	8.6	214.6
80	Pioneer 3737	---	---	0.67	1.40	0.53	69.7	146.8	5.9	222.5
80		NS	---	0.77	1.47	0.54	77.6	147.1	6.0	230.8
80		---	100	0.71	1.38	0.46	67.7	131.3	4.8	204.0
80		NS	100	0.71	1.39	0.49	72.7	141.5	5.4	219.7
80		---	200	0.62	1.37	0.51	60.5	113.1	5.1	198.3
80		NS	200	0.71	1.45	0.53	75.1	154.4	6.4	236.0
160		---	200	0.72	1.40	0.45	75.4	146.1	5.3	226.8
160		NS	200	0.74	1.45	0.51	78.5	154.3	5.8	238.6
240		---	---	0.76	1.48	0.57	76.2	147.0	6.2	229.4
240		NS	---	0.88	1.51	0.61	91.5	156.8	7.3	255.7
240		---	100	0.74	1.42	0.46	74.2	142.5	4.9	221.7
240		NS	100	0.79	1.46	0.54	82.5	153.3	6.4	242.3
240		---	200	0.70	1.46	0.54	72.0	150.9	6.5	229.5
240		NS	200	0.74	1.46	0.53	77.4	153.8	5.8	237.1
80	A632 X LH39	---	---	0.64	1.49	0.49	66.7	156.1	7.9	230.8
80		NS	---	0.73	1.56	0.52	73.1	157.6	8.3	239.1
80		---	100	0.68	1.38	0.46	65.1	131.1	6.7	202.9
80		NS	100	0.65	1.49	0.44	68.4	158.4	6.9	233.9
80		---	200	0.66	1.46	0.50	65.0	143.8	7.5	216.4
80		NS	200	0.57	1.47	0.47	54.5	141.1	7.0	202.7
160		---	200	0.73	1.47	0.57	78.7	157.4	9.8	246.0
160		NS	200	0.77	1.60	0.48	81.5	168.2	8.0	257.7
240		---	---	0.79	1.50	0.52	80.5	151.1	8.0	239.8
240		NS	---	0.92	1.62	0.60	92.8	163.4	9.6	265.8
240		---	100	0.71	1.61	0.52	73.1	165.9	8.8	247.9
240		NS	100	0.74	1.55	0.53	75.4	158.3	8.1	241.9
240		---	200	0.70	1.54	0.57	71.0	156.5	8.6	236.2
240		NS	200	0.83	1.61	0.56	88.3	171.7	9.6	269.6
80	DeKalb 484	---	---	0.66	1.42	0.55	67.8	146.4	7.3	221.7
80		NS	---	0.71	1.52	0.52	71.5	153.7	6.4	231.7
80		---	100	0.65	1.47	0.50	65.4	148.0	6.1	219.6
80		NS	100	0.72	1.49	0.51	69.9	144.1	5.9	219.9
80		---	200	0.51	1.33	0.52	45.3	117.7	5.5	168.4
80		NS	200	0.63	1.46	0.45	63.4	146.5	5.8	215.8
160		---	200	0.73	1.52	0.56	72.4	153.9	7.4	233.7
160		NS	200	0.72	1.55	0.57	73.9	159.8	7.6	241.4
240		---	---	0.83	1.62	0.58	87.4	171.3	7.9	266.8
240		NS	---	0.87	1.62	0.51	91.6	171.9	6.6	270.3
240		---	100	0.66	1.49	0.55	63.4	144.4	6.6	214.6
240		NS	100	0.76	1.55	0.57	80.2	164.2	7.5	252.0
240		---	200	0.83	1.55	0.56	87.2	163.0	7.6	257.9
240		NS	200	0.76	1.57	0.56	80.1	166.2	7.6	254.0

Table 6. Continued from table 1. 200 # K-Rate only RCB (Hybrid X N-Rate)	Whole Plant 12 Leaf Stover			Whole Plant Tassling Stover		
Hybrids	T/A	% N	#/A	T/A	% N	#/A
Pioneer 3732	1.29	2.93	75.8	4.23	1.91	162.4
Pioneer 3737	1.17	3.05	71.2	4.03	2.03	164.7
A632 X LH39	1.25	2.91	72.8	4.08	2.02	165.3
DeKalb 484	1.16	2.97	69.2	3.92	1.95	154.3
P-Value	28	94	98	89	81	48
BLSD (.05)			4.7			
N-Rate						
80	1.22	2.94	71.4	3.99	1.85	149.1
160	1.24	3.02	74.9	4.07	1.99	162.4
240	1.20	2.93	70.4	4.13	2.09	173.5
P-Value	46	89	95	52	99	99
BLSD (.05)			4.0		0.10	14.0
Inhibitor						
None	1.20	2.94	70.7	4.02	2.00	161.3
N-Serve	1.23	2.99	73.7	4.11	1.96	162.0
P-Value	71	82	95	77	57	10
Hybrid X N-Rate	81	34	95	11	28	8
Hybrid X Inhibitor	92	70	87	66	45	51
N-Rate X Inhibitor	78	2	81	40	65	44
Hybrid X N-Rate X Inh.	74	16	96	52	31	57
Split Plot without the 160# N-Rate						
K-Rate						
0	1.43	2.97	85.3	4.33	2.03	175.9
100	1.25	2.92	73.4	4.05	2.02	163.9
200	1.21	2.94	70.9	4.06	1.97	161.3
P-Value	98	72	99	50	50	94
BLSD(.05)	0.09		4.8			
Hybrid X N-Rate X Inhibitor						
Hybrid						
Pioneer 3732	1.36	2.87	78.4	4.31	1.92	166.3
Pioneer 3737	1.29	3.06	78.8	4.14	2.08	172.5
A632 X LH39	1.30	2.94	76.6	4.13	2.02	167.4
DeKalb 484	1.24	2.90	72.3	4.00	2.01	162.1
P-Value	94	99	98	99	99	70
BLSD(.05)		0.06	4.8	0.19	0.09	
N-Rate						
80	1.32	2.92	77.4	4.18	1.91	161.0
240	1.27	2.96	75.7	4.11	2.10	173.1
P-Value	87	85	69	74	99	99
Inhibitor						
None	1.28	2.92	75.0	4.11	1.99	164.5
N-Serve	1.31	2.96	78.0	4.18	2.02	169.6
P-Value	78	86	94	73	63	82
Hybrid X N-Rate	77	48	91	50	9	43
Hybrid X Inhibitor	17	13	33	32	27	27
N-Rate X Inhibitor	36	24	50	51	58	7
Hybrid X N-Rate X Inhibitor	47	79	58	55	71	88
Hybrid X N-Rate X Inhibitor X K-Rate						
Hybrid X K-Rate	5	90	12	24	23	94
N-Rate X K-Rate	34	55	8	97	57	91
Hybird X N-Rate X K-Rate	15	33	43	54	53	59
Inhibitor X K-Rate	60	11	66	80	56	83
Hybrid X Inhibitor X K-Rate	32	59	35	79	63	31
N-Rate X Inhibitor X K-Rate	18	8	11	49	8	44
Hybrid X N-Rate X Inhibitor X K-Rate	95	72	76	83	6	31

Table 7. Continued from table 2.Predent 200 # K-Rate only RCB (Hybrid X N-Rate)	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
Hybrids	Bu/A	-------------T/A--------------			
Pioneer 3732	126.9	2.99	4.61	0.68	8.31
Pioneer 3737	134.4	3.17	3.99	0.61	7.79
A632 X LH39	123.7	2.92	4.22	0.82	7.97
DeKalb 484	114.3	2.70	4.21	0.66	7.58
P-Value	99	99	99	99	99
BLSD (.05)	6.0	0.14	0.22	0.03	0.38
N-Rate					
80	124.3	2.93	4.31	0.66	7.92
160	123.5	2.91	4.24	0.70	7.88
240	126.7	2.99	4.22	0.72	7.95
P-Value	50	50	35	99	8
BLSD (.05)				0.03	
Inhibitor					
None	122.3	2.89	4.21	0.68	7.79
N-Serve	127.3	3.00	4.31	0.71	8.04
P-Value	97	97	76	96	93
Hybrid X N-Rate	58	58	21	94	86
Hybrid X Inhibitor	45	45	6	4	18
N-Rate X Inhibitor	39	40	41	81	43
Hybrid X N-Rate X Inh.	74	74	81	61	42
Split Plot without the 160# N-Rate					
K-Rate					
0	134.1	3.16	4.40	0.72	8.31
100	123.9	2.92	4.21	0.68	7.83
200	125.5	2.96	4.26	0.69	7.93
P-Value	92	92	91	99	89
BLSD(.05)				0.02	
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3732	126.1	2.97	4.53	0.67	8.20
Pioneer 3737	136.8	3.23	4.10	0.60	7.95
A632 X LH39	127.0	3.00	4.22	0.83	8.06
DeKalb 484	121.4	2.86	4.32	0.68	7.88
P-Value	99	99	99	99	77
BLSD(.05)	5.3	0.12	0.18	0.02	
N-Rate					
80	126.3	2.98	4.32	0.68	8.00
240	129.4	3.05	4.26	0.71	8.05
P-Value	87	87	60	99	35
Inhibitor					
None	127.1	3.00	4.26	0.69	7.97
N-Serve	128.6	3.03	4.32	0.70	8.08
P-Value	56	56	61	65	65
Hybrid X N-Rate	25	25	94	34	69
Hybrid X Inhibitor	70	70	24	76	56
N-Rate X Inhibitor	64	64	51	77	64
Hybrid X N-Rate X Inhibitor	35	35	41	19	18
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	37	37	62	58	52
N-Rate X K-Rate	5	5	13	85	6
Hybird X N-Rate X K-Rate	90	90	79	99	96
Inhibitor X K-Rate	88	88	54	88	82
Hybrid X Inhibitor X K-Rate	30	30	16	6	33
N-Rate X Inhibitor X K-Rate	19	19	38	38	38
Hybrid X N-Rate X Inhibitor X K-Rate	51	51	34	55	34

Table 8. Continued from table 3. Predent 200 # K-Rate only RCB (Hybrid X N-Rate)	N-Concentration Stover	Grain	Cob	N-Removal Stover	Grain	Cob	Total
Hybrids	---------%---------			------------#/A-----------			
Pioneer 3732	1.30	1.38	0.71	138.0	82.9	9.9	230.9
Pioneer 3737	1.27	1.46	0.53	117.8	92.9	6.6	217.5
A632 X LH39	1.27	1.65	0.56	129.0	96.9	9.3	235.3
DeKalb 484	1.27	1.57	0.58	125.4	85.4	7.9	218.7
P-Value	6	99	99	99	99	99	95
BLSD (.05)		0.03	0.06	13.0	4.8	1.0	17.1
N-Rate							
80	1.21	1.47	0.57	122.0	86.3	7.7	216.1
160	1.28	1.53	0.62	127.6	89.7	8.9	226.2
240	1.34	1.54	0.60	133.1	92.6	8.7	234.4
P-Value	98	99	86	88	98	97	98
BLSD (.05)	0.09	0.03			4.6	0.9	13.6
Inhibitor							
None	1.26	1.50	0.62	124.1	86.7	8.5	219.5
N-Serve	1.29	1.53	0.57	131.0	92.3	8.3	231.7
P-Value	64	97	94	88	99	38	98
Hybrid X N-Rate	8	88	89	41	88	47	66
Hybrid X Inhibitor	41	25	26	22	32	17	19
N-Rate X Inhibitor	46	93	88	57	87	71	64
Hybrid X N-Rate X Inh.	83	27	94	68	73	90	76
Split Plot without the 160# N-Rate							
K-Rate							
0	1.33	1.56	0.54	137.0	99.0	7.9	244.0
100	1.29	1.50	0.58	126.9	88.2	7.9	223.1
200	1.28	1.50	0.58	127.5	89.5	8.2	225.3
P-Value	49	84	50	73	93	8	85
BLSD(.05)							
Hybrid X N-Rate X Inhibitor							
Hybrid							
Pioneer 3732	1.33	1.39	0.67	138.9	83.0	9.1	231.2
Pioneer 3737	1.27	1.48	0.52	120.5	96.0	6.4	223.0
A632 X LH39	1.28	1.63	0.51	130.5	98.3	8.6	237.5
DeKalb 484	1.31	1.59	0.56	131.9	91.7	7.8	231.5
P-Value	48	99	99	99	99	99	87
BLSD(.05)		0.03	0.04	10.1	4.0	0.7	
N-Rate							
80	1.24	1.49	0.56	125.4	89.1	7.7	222.4
240	1.35	1.55	0.58	135.5	95.3	8.3	239.2
P-Value	99	99	72	99	99	97	99
Inhibitor							
None	1.27	1.49	0.57	126.9	90.0	8.0	225.0
N-Serve	1.32	1.55	0.56	134.0	94.5	7.9	236.6
P-Value	92	99	64	96	99	25	99
Hybrid X N-Rate	80	99	98	93	87	95	96
Hybrid X Inhibitor	14	61	7	25	81	16	60
N-Rate X Inhibitor	40	22	20	8	60	42	33
Hybrid X N-Rate X Inhibitor	3	10	88	9	33	68	9
Hybrid X N-Rate X Inhibitor X K-Rate							
Hybrid X K-Rate	1	99	57	6	83	59	44
N-Rate X K-Rate	6	45	52	4	16	52	8
Hybird X N-Rate X K-Rate	94	28	50	95	63	36	94
Inhibitor X K-Rate	35	4	95	50	86	59	63
Hybrid X Inhibitor X K-Rate	90	70	43	70	25	54	69
N-Rate X Inhibitor X K-Rate	35	10	9	42	18	20	27
Hybrid X N-Rate X Inhibitor X K-Rate	98	73	87	92	63	89	80

Table 9. Continued from table 4.	Grain	Dry Matter Production			
200 # K-Rate only RCB (Hybrid X N-Rate)	Yields	Grain	Stover	Cob	Total
Hybrids Physiological Mature	Bu/A	-------------T/A-------------			
Pioneer 3732	200.6	4.74	3.77	0.66	9.19
Pioneer 3737	219.4	5.18	3.25	0.56	9.01
A632 X LH39	216.9	5.12	3.33	0.79	9.26
DeKalb 484	212.7	5.02	3.35	0.64	9.03
P-Value	99	99	99	99	76
BLSD (.05)	5.9	0.14	0.14	0.02	
N-Rate					
80	204.2	4.82	3.37	0.62	8.84
160	216.3	5.11	3.47	0.69	9.29
240	216.7	5.12	3.42	0.68	9.24
P-Value	99	99	59	99	99
BLSD (.05)	5.2	0.12		0.02	0.23
Inhibitor					
None	210.6	4.98	3.39	0.65	9.03
N-Serve	214.2	5.06	3.46	0.67	9.21
P-Value	87	87	78	92	91
Hybrid X N-Rate	82	83	93	73	79
Hybrid X Inhibitor	93	93	88	42	93
N-Rate X Inhibitor	78	78	13	87	63
Hybrid X N-Rate X Inh.	89	89	97	99	99
Split Plot without the 160# N-Rate					
K-Rate					
0	214.8	5.07	3.53	0.67	9.29
100	209.8	4.96	3.38	0.65	9.00
200	210.4	4.97	3.40	0.65	9.04
P-Value	62	62	63	81	76
BLSD(.05)					
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3732	202.6	4.79	3.80	0.67	9.28
Pioneer 3737	215.7	5.09	3.30	0.55	8.96
A632 X LH39	214.2	5.06	3.26	0.77	9.12
DeKalb 484	214.2	5.06	3.38	0.63	9.09
P-Value	99	99	99	99	97
BLSD(.05)	4.3	0.01	0.09	0.02	0.22
N-Rate					
80	208.2	4.92	3.46	0.64	9.03
240	215.8	5.08	3.41	0.67	9.19
P-Value	99	99	74	99	96
Inhibitor					
None	210.1	4.96	3.40	0.65	9.03
N-Serve	213.2	5.04	3.47	0.66	9.19
P-Value	94	93	94	88	97
Hybrid X N-Rate	67	68	74	81	78
Hybrid X Inhibitor	91	91	88	71	91
N-Rate X Inhibitor	44	44	64	67	63
Hybrid X N-Rate X Inhibitor	52	52	97	5	83
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	58	58	71	35	59
N-Rate X K-Rate	99	99	96	99	95
Hybird X N-Rate X K-Rate	66	66	29	29	32
Inhibitor X K-Rate	89	89	6	80	65
Hybrid X Inhibitor X K-Rate	57	57	61	44	63
N-Rate X Inhibitor X K-Rate	71	71	1	57	36
Hybrid X N-Rate X Inhibitor X K-Rate	99	99	99	99	99

Table 10. Continued from table 5.	N-Concentration			N-Removal			
200 # K-Rate only RCB (Hybrid X N-Rate)	Stover	Grain	Cob	Stover	Grain	Cob	Total
Hybrids **Physiological Mature**	---------%---------			------------#/A-----------			
Pioneer 3732	0.80	1.37	0.61	76.5	130.5	8.3	215.4
Pioneer 3737	0.70	1.43	0.51	73.1	148.7	5.8	227.7
A632 X LH39	0.71	1.52	0.52	73.2	156.4	8.4	238.1
DeKalb 484	0.69	1.49	0.53	70.3	151.2	6.9	228.6
P-Value	99	99	99	88	99	99	99
BLSD (.05)	0.05	0.03	0.03		5.8	0.59	8.6
N-Rate							
80	0.60	1.40	0.52	62.9	136.1	6.6	205.6
160	0.75	1.46	0.54	77.2	150.6	7.6	235.5
240	0.78	1.49	0.57	79.7	153.5	7.8	241.2
P-Value	99	99	99	99	99	99	99
BLSD (.05)	0.04	0.03	0.03	3.90	5.0	0.53	7.0
Inhibitor							
None	0.70	1.42	0.54	70.8	142.5	7.3	220.7
N-Serve	0.75	1.48	0.54	75.7	151.0	7.4	234.2
P-Value	96	99	3	99	99	52	99
Hybrid X N-Rate	73	88	81	99	98	81	99
Hybrid X Inhibitor	25	6	85	21	55	53	45
N-Rate X Inhibitor	48	88	35	76	92	8	96
Hybrid X N-Rate X Inh.	93	71	41	99	93	88	99
Split Plot without the 160# N-Rate							
K-Rate							
0	0.77	1.49	0.56	79.2	152.1	7.6	239.0
100	0.72	1.44	0.53	71.9	144.2	7.0	223.2
200	0.71	1.44	0.54	71.3	144.8	7.2	223.4
P-Value	90	79	82	93	73	98	89
BLSD(.05)						0.4	
Hybrid X N-Rate X Inhibitor							
Hybrid							
Pioneer 3732	0.79	1.39	0.62	76.2	133.9	8.4	218.6
Pioneer 3737	0.73	1.43	0.52	74.6	146.5	5.9	227.2
A632 X LH39	0.71	1.52	0.51	72.8	154.6	8.1	235.6
DeKalb 484	0.71	1.50	0.53	72.8	153.1	6.7	232.7
P-Value	99	99	99	74	99	99	99
BLSD(.05)	0.03	0.03	0.02		4.8	0.4	7.6
N-Rate							
80	0.68	1.42	0.52	67.3	140.7	6.8	214.9
240	0.79	1.50	0.57	81.0	153.4	7.7	242.2
P-Value	99	99	99	99	99	99	99
Inhibitor							
None	0.70	1.43	0.54	70.6	143.3	7.1	221.2
N-Serve	0.77	1.49	0.55	77.6	150.7	7.4	235.9
P-Value	99	99	67	99	99	87	99
Hybrid X N-Rate	72	73	65	86	92	88	96
Hybrid X Inhibitor	30	8	75	26	34	67	34
N-Rate X Inhibitor	40	95	44	30	89	11	62
Hybrid X N-Rate X Inhibitor	84	27	14	76	54	30	67
Hybrid X N-Rate X Inhibitor X K-Rate							
Hybrid X K-Rate	39	17	82	12	72	34	20
N-Rate X K-Rate	85	62	14	83	99	89	94
Hybird X N-Rate X K-Rate	90	97	21	97	99	25	99
Inhibitor X K-Rate	47	43	63	13	99	22	11
Hybrid X Inhibitor X K-Rate	45	5	48	15	42	66	13
N-Rate X Inhibitor X K-Rate	71	54	3	83	22	10	89
Hybrid X N-Rate X Inhibitor X K-Rate	70	96	29	97	75	83	99

Table 11. Influence of N-Rates, K-Rates, nitrification inhibitors on four corn hybrids, stover N content, total N removal and drymatter production Waseca, MN 1987.

N-Rate	Hybrid	Inh.	K-Rate	Whole Plant 12 Leaf Stover			Whole Plant Tassling Stover		
#/A			#/A	T/A	% N	#/A	T/A	% N	#/A
0	Pioneer 3732	---	---	1.63	2.37	77.1	4.38	1.47	127.8
0		---	100	1.69	2.02	68.2	4.14	1.11	92.2
80		---	---	1.82	2.53	91.5	4.71	1.56	147.7
80		NS	---	1.62	2.47	79.8	4.55	1.52	138.5
80		---	100	1.79	2.32	83.0	4.40	1.49	131.8
80		NS	100	1.66	2.42	80.3	4.92	1.42	140.5
160		---	---	1.77	2.40	84.6	4.68	1.60	149.6
160		NS	---	1.75	2.64	92.3	4.78	1.69	160.0
160		---	100	1.57	2.42	76.0	4.34	1.60	139.0
160		NS	100	1.62	2.43	78.5	4.94	1.57	154.7
0	Pioneer 3475	---	---	1.69	1.98	66.8	4.33	1.07	92.0
0		---	100	1.59	2.09	66.5	4.39	1.34	115.8
80		---	---	1.66	2.64	88.0	4.94	1.59	156.4
80		NS	---	1.39	2.52	70.4	4.37	1.50	131.4
80		---	100	1.55	2.46	76.6	3.99	1.45	116.0
80		NS	100	1.66	2.50	82.8	4.41	1.36	119.5
160		---	---	1.59	2.62	83.6	4.80	1.55	148.1
160		NS	---	1.78	2.48	87.9	4.72	1.61	151.2
160		---	100	1.64	2.49	81.4	4.26	1.42	120.3
160		NS	100	1.50	2.64	79.2	4.98	1.61	159.4
0	LH74 X LH51	---	---	1.68	2.32	78.1	4.57	1.36	126.0
0		---	100	1.73	2.09	72.1	4.43	1.22	106.7
80		---	---	1.77	2.52	89.6	4.71	1.59	150.7
80		NS	---	1.68	2.43	81.6	4.71	1.62	152.1
80		---	100	1.72	2.51	86.2	5.12	1.55	160.0
80		NS	100	1.72	2.37	81.5	4.82	1.45	141.0
160		---	---	1.61	2.45	78.9	4.84	1.78	171.3
160		NS	---	1.65	2.52	82.8	4.79	1.83	178.0
160		---	100	1.54	2.61	80.2	4.37	1.71	149.6
160		NS	100	1.59	2.67	85.3	4.84	1.82	174.8
0	A632 X LH38	---	---	1.49	2.31	69.1	3.87	1.37	106.6
0		---	100	1.53	2.03	61.7	3.97	1.26	99.5
80		---	---	1.51	2.64	79.2	4.17	1.65	137.8
80		NS	---	1.63	2.59	84.8	4.44	1.79	158.8
80		---	100	1.62	2.62	84.6	4.29	1.80	154.9
80		NS	100	1.62	2.61	84.5	4.25	1.52	129.8
160		---	---	1.61	2.66	84.8	4.04	1.75	141.2
160		NS	---	1.62	2.61	84.7	4.31	1.67	145.0
160		---	100	1.38	2.59	71.5	4.37	1.72	149.8
160		NS	100	1.61	2.64	85.0	4.34	1.74	150.9

Table 12. Influence of N-Rates,K-Rates, nitrification inhibitors on four corn hybrids on grain yields, and drymatter production at the predent stage of plant growth. Waseca,MN 1987.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
#/A			#/A	Bu/A	------------T/A-----------			
0	Pioneer 3732	---	---	134.6	3.19	4.09	0.57	7.84
0		---	100	111.9	2.65	3.96	0.50	7.11
80		---	---	154.3	3.65	4.28	0.72	8.65
80		NS	---	140.9	3.33	3.82	0.70	7.85
80		---	100	125.4	2.97	4.21	0.64	7.83
80		NS	100	130.0	3.08	3.77	0.64	7.48
160		---	---	144.4	3.42	3.98	0.72	8.12
160		NS	---	140.0	3.31	3.97	0.69	7.98
160		---	100	138.3	3.27	4.11	0.66	8.05
160		NS	100	144.0	3.41	4.16	0.69	8.26
0	Pioneer 3475	---	---	106.0	2.51	3.98	0.54	7.04
0		---	100	116.6	2.76	4.22	0.60	7.59
80		---	---	145.5	3.44	4.55	0.77	8.75
80		NS	---	134.3	3.18	4.43	0.73	8.34
80		---	100	133.8	3.17	4.47	0.69	8.32
80		NS	100	120.7	2.86	4.45	0.68	7.99
160		---	---	134.0	3.17	4.29	0.72	8.18
160		NS	---	135.6	3.21	4.36	0.72	8.29
160		---	100	116.8	2.76	4.06	0.67	7.49
160		NS	100	132.0	3.13	4.77	0.70	8.60
0	LH74 X LH51	---	---	118.8	2.81	4.64	0.50	7.95
0		---	100	94.7	2.24	4.02	0.45	6.71
80		---	---	122.4	2.90	4.38	0.48	7.75
80		NS	---	130.7	3.09	5.28	0.58	8.96
80		---	100	116.8	2.77	4.57	0.54	7.88
80		NS	100	120.3	2.85	4.88	0.57	8.29
160		---	---	123.1	2.91	4.67	0.54	8.13
160		NS	---	131.9	3.12	4.81	0.59	8.52
160		---	100	117.3	2.78	4.69	0.56	8.03
160		NS	100	116.6	2.76	5.01	0.59	8.36
0	A632 X LH38	---	---	109.8	2.60	3.47	0.49	6.56
0		---	100	91.5	2.17	3.40	0.43	5.99
80		---	---	132.3	3.13	3.77	0.58	7.49
80		NS	---	121.3	2.87	3.70	0.56	7.14
80		---	100	126.4	2.99	4.01	0.68	7.67
80		NS	100	125.8	2.98	4.45	0.68	8.10
160		---	---	131.3	3.11	4.30	0.60	8.01
160		NS	---	135.9	3.22	3.95	0.69	7.86
160		---	100	143.7	3.40	4.66	0.72	8.78
160		NS	100	125.5	2.97	3.91	0.64	7.52

Table 13. Influence of N-Rates, K-Rates, nitrification inhibitors on four corn hybrids on grain, stover, and cob N content total N removal at the predent stage of plant growth Waseca, MN 1987.

N-Rate	Hybrid	Inh.	K-Rate	N-Concentration Stover	Grain	Cob	N-Removal Stover	Grain	Cob	Total
#/A			#/A	-----------%-----------			---------------#/A------------			
0	Pioneer 3732	---	---	0.97	1.32	0.54	79.5	84.3	6.1	169.9
0		---	100	0.65	1.17	0.47	53.3	62.7	4.5	120.5
80		---	---	0.99	1.36	0.51	84.5	98.8	7.3	190.6
80		NS	---	0.96	1.35	0.43	74.2	89.4	5.9	169.6
80		---	100	1.01	1.44	0.48	85.0	85.1	6.1	176.3
80		NS	100	0.95	1.35	0.44	71.9	83.0	5.6	160.6
160		---	---	1.21	1.39	0.47	96.5	94.5	6.7	197.9
160		NS	---	1.22	1.47	0.45	96.5	97.5	6.3	200.3
160		---	100	1.02	1.43	0.48	83.9	93.7	6.4	184.1
160		NS	100	1.01	1.41	0.47	83.7	95.8	6.4	186.0
0	Pioneer 3475	---	---	0.55	1.16	0.42	44.6	58.1	4.5	107.3
0		---	100	0.75	1.21	0.42	62.2	66.7	5.0	134.0
80		---	---	0.98	1.36	0.49	89.4	93.7	7.4	190.6
80		NS	---	1.19	1.34	0.45	105.1	85.1	6.6	196.8
80		---	100	1.08	1.38	0.51	96.7	87.0	6.9	190.7
80		NS	100	0.99	1.37	0.47	86.9	77.9	6.4	171.3
160		---	---	1.01	1.45	0.46	86.5	92.3	6.6	185.5
160		NS	---	1.12	1.43	0.48	97.2	91.7	6.9	195.8
160		---	100	1.22	1.42	0.57	99.1	78.4	7.6	185.1
160		NS	100	1.04	1.41	0.50	99.9	87.8	7.0	194.8
0	LH74 X LH51	---	---	0.78	1.23	0.38	73.2	69.6	3.7	146.6
0		---	100	0.60	1.12	0.40	48.1	50.2	3.5	101.9
80		---	---	1.16	1.48	0.38	100.5	86.0	3.6	190.2
80		NS	---	0.97	1.32	0.39	101.3	81.4	4.5	187.3
80		---	100	1.03	1.39	0.41	93.6	76.5	4.4	174.5
80		NS	100	0.86	1.39	0.40	82.9	79.2	4.4	166.6
160		---	---	1.09	1.53	0.41	101.6	89.0	4.4	195.1
160		NS	---	1.23	1.53	0.40	118.3	95.4	4.7	218.5
160		---	100	0.98	1.55	0.46	91.5	86.4	5.1	183.0
160		NS	100	1.19	1.61	0.46	119.1	88.9	5.3	213.4
0	A632 X LH38	---	---	0.65	1.22	0.37	45.5	63.6	3.6	112.8
0		---	100	0.65	1.32	0.43	44.0	57.5	3.6	105.3
80		---	---	0.95	1.48	0.35	71.3	92.5	4.0	168.0
80		NS	---	1.18	1.60	0.43	86.1	92.6	4.8	183.1
80		---	100	1.06	1.52	0.43	85.3	91.6	5.8	182.8
80		NS	100	1.02	1.59	0.39	91.5	94.5	5.3	191.4
160		---	---	1.21	1.67	0.41	102.2	103.6	4.8	210.7
160		NS	---	1.32	1.67	0.40	104.1	107.6	5.6	217.3
160		---	100	1.19	1.72	0.43	110.9	117.2	6.1	234.3
160		NS	100	1.17	1.55	0.44	91.5	91.7	5.6	188.9

Table 14. Influence of N-Rates,K-Rates, nitrification inhibitors on four corn hybrids on grain yields, and drymatter production at physiological maturity Waseca,MN 1987.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Total
#/A			#/A	Bu/A	---------T/A-----------		
0	Pioneer 3732	---	---	157.6	3.73	4.10	7.83
0		---	100	128.3	3.04	3.97	7.00
80		---	---	175.6	4.15	4.30	8.45
80		NS	---	180.1	4.26	4.22	8.49
80		---	100	175.0	4.14	4.30	8.44
80		NS	100	173.8	4.11	4.32	8.44
160		---	---	179.2	4.24	4.44	8.68
160		NS	---	186.2	4.41	4.40	8.81
160		---	100	182.3	4.31	4.62	8.93
160		NS	100	168.1	3.98	4.61	8.58
0	Pioneer 3475	---	---	136.5	3.23	3.83	7.07
0		---	100	156.2	3.70	4.09	7.78
80		---	---	189.2	4.48	4.52	9.00
80		NS	---	193.1	4.57	4.50	9.06
80		---	100	188.9	4.47	4.53	9.01
80		NS	100	179.0	4.24	4.31	8.54
160		---	---	196.1	4.64	4.78	9.42
160		NS	---	193.5	4.58	4.67	9.25
160		---	100	191.4	4.53	4.90	9.43
160		NS	100	190.8	4.52	4.88	9.39
0	LH74 X LH51	---	---	170.9	4.04	4.22	8.26
0		---	100	161.8	3.83	4.21	8.04
80		---	---	185.5	4.39	4.49	8.88
80		NS	---	184.1	4.36	4.13	8.49
80		---	100	182.6	4.31	4.52	8.82
80		NS	100	198.3	4.69	4.53	9.22
160		---	---	193.9	4.59	4.36	8.95
160		NS	---	191.3	4.53	4.69	9.22
160		---	100	177.2	4.19	4.57	8.77
160		NS	100	208.3	4.93	4.71	9.64
0	A632 X LH38	---	---	143.4	3.39	3.41	6.81
0		---	100	115.9	2.74	3.28	6.02
80		---	---	188.5	4.46	3.91	8.37
80		NS	---	183.1	4.33	3.64	7.98
80		---	100	182.9	4.33	4.11	8.44
80		NS	100	184.3	4.36	4.13	8.49
160		---	---	177.4	4.20	3.85	8.05
160		NS	---	187.8	4.45	4.04	8.49
160		---	100	198.1	4.69	4.39	9.07
160		NS	100	196.9	4.66	4.28	8.94

Table 15. Influence of N-Rates, K-Rates,nitrification inhibitors on four corn hybrids on grain, stover,and cob N content total N removal at physiological maturity Waseca, MN 1987.

N-Rate	Hybrid	Inh.	K-Rate	N-Concentration Stover	Grain	N-Removal Stover	Grain	Total
#/A			#/A	-------%-------		-----------#/A-----------		
0	Pioneer 3732	---	---	0.55	1.25	44.9	94.3	139.3
0		---	100	0.46	1.18	36.6	71.4	108.1
80		---	---	0.69	1.41	59.7	116.5	176.3
80		NS	---	0.67	1.39	56.2	118.4	174.6
80		---	100	0.61	1.37	48.2	113.5	161.8
80		NS	100	0.56	1.36	48.9	112.0	160.9
160		---	---	0.70	1.34	61.9	113.3	175.3
160		NS	---	0.75	1.45	66.1	127.4	193.5
160		---	100	0.71	1.33	65.8	114.5	180.4
160		NS	100	0.71	1.39	65.0	110.6	175.6
0	Pioneer 3475	---	---	0.37	1.14	28.6	73.5	102.2
0		---	100	0.46	1.22	37.9	90.6	128.6
80		---	---	0.64	1.39	58.0	123.9	182.0
80		NS	---	0.59	1.36	53.0	124.6	177.7
80		---	100	0.63	1.36	55.9	122.0	177.9
80		NS	100	0.49	1.27	42.0	107.7	149.7
160		---	---	0.70	1.43	67.8	133.2	201.0
160		NS	---	0.68	1.43	63.7	130.6	194.4
160		---	100	0.65	1.40	63.0	126.5	189.5
160		NS	100	0.66	1.40	64.1	126.5	190.6
0	LH74 X LH51	---	---	0.52	1.09	44.9	96.3	141.2
0		---	100	0.42	1.11	35.7	85.5	120.7
80		---	---	0.53	1.33	47.2	117.0	164.2
80		NS	---	0.57	1.30	46.6	113.1	159.8
80		---	100	0.53	1.34	48.0	115.2	163.3
80		NS	100	0.51	1.25	46.6	116.7	163.4
160		---	---	0.72	1.38	62.7	126.4	189.1
160		NS	---	0.68	1.42	63.4	128.5	191.9
160		---	100	0.67	1.36	60.8	114.4	175.2
160		NS	100	0.63	1.34	59.0	132.0	191.0
0	A632 X LH38	---	---	0.47	1.31	32.2	88.8	121.1
0		---	100	0.42	1.22	27.9	66.9	94.8
80		---	---	0.58	1.55	45.6	138.0	183.6
80		NS	---	0.71	1.54	51.5	133.1	184.6
80		---	100	0.51	1.46	42.2	127.3	169.5
80		NS	100	0.57	1.48	47.5	129.2	176.7
160		---	---	0.71	1.70	54.4	143.0	197.4
160		NS	---	0.76	1.66	61.1	147.3	208.4
160		---	100	0.67	1.49	59.1	139.6	198.5
160		NS	100	0.64	1.58	54.6	147.7	202.3

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Table 16. Continued from table 1 and 2. 0 # K-Rate only RCB (Hybrid X N-Rate)	Whole Plant 12 Leaf Stover			Whole Plant Tassling Stover		
Hybrids	T/A	% N	#/A	T/A	% N	#/A
Pioneer 3732	1.73	2.43	84.4	4.58	1.54	141.7
Pioneer 3475	1.64	2.41	79.5	4.68	1.40	132.2
LH74 X LH51	1.68	2.43	82.2	4.70	1.57	149.3
A632 X LH38	1.53	2.53	77.7	4.02	1.58	128.5
P-Value	95	75	66	99	98	99
BLSD (.05)	0.16			0.35	0.14	18.6
N-Rate						
0	1.62	2.24	72.8	4.28	1.31	113.1
80	1.68	2.58	87.1	4.62	1.59	148.2
160	1.64	2.53	83.0	4.58	1.66	152.6
P-Value	44	99	99	94	99	99
Hybrid X N-Rate	42	99	53	4	83	72

Predent 0 # K-Rate only RCB	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
Hybrid	Bu/A	-------------T/A----------			
Pioneer 3732	144.4	3.41	3.41	0.66	8.20
Pioneer 3475	128.5	3.03	4.27	0.67	7.98
LH74 X LH51	121.4	2.87	4.55	0.50	7.93
A632 X LH38	124.4	2.93	3.84	0.55	7.34
P-Value	99	99	99	99	98
BLSD (.05)	9.8	0.23	0.36	0.05	0.60
N-Rate					
0	117.3	2.77	4.04	0.52	7.34
80	138.6	3.27	4.23	0.63	8.15
160	133.2	3.14	4.30	0.63	8.10
P-Value	99	99	79	99	99
Hybrid X N-Rate	83	83	81	90	91
Physiological Mature					
0 # K-Rate only RCB					
Hybrid					
Pioneer 3732	170.8	4.03	4.27	---	8.31
Pioneer 3475	173.9	4.11	4.37	---	8.48
LH74 X LH51	183.4	4.33	4.35	---	8.69
A632 X LH38	169.7	4.01	3.71	---	7.73
P-Value	87	87	99	---	99
BLSD (.05)			0.26		0.55
N-Rate					
0	152.1	3.59	3.88	---	7.48
80	184.7	4.36	4.29	---	8.67
160	186.6	4.41	4.35	---	8.76
P-Value	99	99	99		99
Hybrid X N-Rate	93	93	67		86

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Table 17. Continued from table 1 and 2.	Whole Plant			Whole Plant		
100 # K-Rate only RCB (Hybrid X N-Rate)	12 Leaf Stover			Tassling Stover		
Hybrids	T/A	% N	#/A	T/A	% N	#/A
Pioneer 3732	1.67	2.25	75.7	4.28	1.40	121.0
Pioneer 3475	1.59	2.34	74.8	4.20	1.40	117.4
LH74 X LH51	1.65	2.40	79.5	4.63	1.49	138.7
A632 X LH38	1.50	2.41	72.6	4.20	1.58	134.7
P-Value	97	97	81	91	94	97
BLSD (.05)	0.13	0.13				18.6
N-Rate						
0	1.63	2.05	67.1	4.22	1.23	103.5
80	1.66	2.47	82.6	4.44	1.57	140.7
160	1.52	2.52	77.3	4.33	1.61	139.7
P-Value	97	99	99	57	99	99
Hybrid X N-Rate	67	46	59	76	81	89

Predent	Grain	Dry Matter Production			
100 # K-Rate only RCB	Yields	Grain	Stover	Cob	Total
Hybrid	Bu/A	-------------T/A-----------			
Pioneer 3732	125.2	2.95	4.09	0.59	7.65
Pioneer 3475	122.4	2.89	4.24	0.64	7.79
LH74 X LH51	109.6	2.59	4.41	0.51	7.53
A632 X LH38	120.5	2.84	4.01	0.60	7.47
P-Value	99	99	93	99	42
BLSD (.05)	8.9	0.21	0.37	0.03	
N-Rate					
0	103.7	2.44	3.89	0.49	6.84
80	125.6	2.96	4.30	0.63	7.91
160	129.0	3.05	4.37	0.64	8.08
P-Value	99	99	99	99	99
Hybrid X N-Rate	99	99	98	99	99

Physiological Mature					
100 # K-Rate only RCB					
Hybrid					
Pioneer 3732	161.8	3.82	4.29	---	8.12
Pioneer 3475	178.8	4.22	4.50	---	8.73
LH74 X LH51	173.7	4.10	4.42	---	8.53
A632 X LH38	165.6	3.91	3.92	---	7.84
P-Value	99	99	99		99
BLSD (.05)	11.5	0.27	0.23		0.43
N-Rate					
0	140.5	3.32	3.87	---	7.20
80	182.2	4.30	4.36	---	8.67
160	187.2	4.42	4.61	---	9.04
P-Value	99	99	99		99
Hybrid X N-Rate	99	99	73		99

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Table 18. Continued from table 3 and 4.	N-Concentration			N-Removal			
0 # K-Rate only RCB (Hybrid X N-Rate)	Stover	Cob	Grain	Stover	Cob	Grain	Total
Hybrids Predent	---------	%	---------	---------	#/A	---------	---------
Pioneer 3732	1.05	0.50	1.35	86.8	6.7	92.5	186.1
Pioneer 3475	0.85	0.45	1.32	73.5	6.2	81.4	161.1
LH74 X LH51	1.00	0.38	1.41	91.8	3.9	81.5	177.3
A632 X LH38	0.93	0.37	1.45	73.0	4.1	86.5	163.8
P-Value	99	99	99	99	99	95	98
BLSD (.05)	0.13	0.04	0.06	11.5	0.2	10.0	19.5
N-Rate							
0	0.73	0.42	1.22	60.7	4.5	68.9	134.1
80	1.02	0.43	1.41	86.4	5.6	92.7	184.9
160	1.13	0.43	1.50	96.7	5.6	94.9	197.3
P-Value	99	18	99	99	99	99	99
Hybrid X N-Rate	93	75	99	98	92	89	98
0 # K-Rate only RCB Physiological Mature							
Hybrid							
Pioneer 3732	0.64	---	1.33	55.5	---	108.9	163.6
Pioneer 3475	0.57	---	1.31	51.5	---	110.2	161.7
LH74 X LH51	0.59	---	1.29	51.6	---	113.2	164.8
A632 X LH38	0.58	---	1.51	44.1	---	123.2	167.4
P-Value	99		99	99		96	9
BLSD (.05)	0.06		0.06	7.4		12.5	
N-Rate							
0	0.47	---	1.22	37.7	---	88.2	125.9
80	0.61	---	1.41	52.6	---	123.8	176.5
160	0.70	---	1.46	61.7	---	128.9	190.7
P-Value	99		99	99		99	99
Hybrid X N-Rate	99		94	96		96	88
100 # K-Rate only RCB Predent							
Hybrid							
Pioneer 3732	0.89	0.47	1.34	74.0	5.7	80.5	160.3
Pioneer 3475	1.01	0.49	1.33	86.0	6.5	77.3	169.9
LH74 X LH51	0.86	0.42	1.35	77.7	4.3	71.0	153.1
A632 X LH38	0.96	0.43	1.52	80.0	5.2	88.8	174.1
P-Value	85	99	99	62	99	99	87
BLSD (.05)		0.03	0.08		0.55	7.2	
N-Rate							
0	0.66	0.42	1.20	51.9	4.1	59.3	115.4
80	1.04	0.45	1.42	90.1	5.8	85.0	181.1
160	1.10	0.48	1.53	96.3	6.3	93.9	196.6
P-Value	99	99	99	99	99	99	99
Hybrid X N-Rate	12	90	76	60	39	99	95
100 # K-Rate only RCB Physiological Mature							
Hybrid							
Pioneer 3732	0.57	---	1.29	50.2	---	99.8	150.1
Pioneer 3475	0.57	---	1.32	52.3	---	113.0	165.3
LH74 X LH51	0.53	---	1.27	48.0	---	105.0	153.1
A632 X LH38	0.53	---	1.39	43.0	---	111.3	154.4
P-Value	54		99	92		97	82
BLSD (.05)			0.07			10.7	
N-Rate							
0	0.43	---	1.18	34.4	---	78.6	113.0
80	0.55	---	1.38	48.6	---	119.5	168.1
160	0.67	---	1.39	62.2	---	123.7	186.0
P-Value	99		99	99		99	99
Hybrid X N-Rate	26		26	9		98	83

Table 19 Waseca 1987 Continued from table 1 and 2.

Split Plot without the 0 # N-Rate	Whole Plant 12 Leaf Stover			Whole Plant Tassling Stover		
	T/A	% N	#/A	T/A	% N	#/A
K-Rate						
0	1.64	2.54	84.0	4.56	1.64	151.1
100	1.60	2.52	81.0	4.53	1.57	143.2
P-Value	56	46	73	40	83	86
Hybrid X N-Rate X Inhibitor						
Hybrid						
Pioneer 3732	1.69	2.45	83.2	4.66	1.55	145.2
Pioneer 3475	1.59	2.54	81.2	4.55	1.51	137.8
LH74 X LH51	1.65	2.50	83.2	4.77	1.67	159.7
A632 X LH39	1.57	2.62	81.4	4.27	1.70	146.0
P-Value	99	99	20	99	99	99
BLSD(.05)	0.08	0.06		0.20	0.07	11.6
N-Rate						
80	1.64	2.50	82.8	4.54	1.55	141.7
160	1.60	2.55	82.3	4.58	1.66	152.7
P-Value	82	95	22	37	99	99
Inhibitor						
None	1.62	2.52	82.5	4.49	1.61	145.3
N-Serve	1.62	2.53	82.6	4.63	1.60	149.1
P-Value	6	17	6	92	18	65
Hybrid X N-Rate	82	95	22	37	99	99
Hybrid X Inhibitor	79	59	55	26	17	5
N-Rate X Inhibitor	94	95	99	87	95	98
Hybrid X N-Rate X Inhibitor	12	35	20	22	22	36
Hybrid X N-Rate X Inhibitor X K-Rate						
Hybrid X K-Rate	7	81	53	61	12	52
N-Rate X K-Rate	97	84	80	33	61	39
Hybird X N-Rate X K-Rate	10	46	40	94	1	38
Inhibitor X K-Rate	55	69	76	60	54	42
Hybrid X Inhibitor X K-Rate	1	65	10	90	27	87
N-Rate X Inhibitor X K-Rate	58	31	66	47	80	75
Hybrid X N-Rate X Inhibitor X K-Rate	93	67	90	27	51	40

Table 20 Predent Waseca 1987

Split Plot without the 0 # N-Rate	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
	Bu/A	------------T/A------------			
K-Rate					
0	134.9	3.18	4.28	0.64	8.12
100	127.1	3.00	4.38	0.64	8.03
P-Value	99	99	57	19	52
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3732	139.6	3.30	4.03	0.67	8.02
Pioneer 3475	131.6	3.10	4.41	0.70	8.24
LH74 X LH51	122.4	2.89	4.78	0.55	8.23
A632 X LH39	130.3	3.07	4.08	0.63	7.81
P-Value	99	99	99	99	98
BLSD(.05)	5.7	0.12	0.19	0.02	0.33
N-Rate					
80	130.0	3.07	4.30	0.63	8.02
160	131.9	3.11	4.35	0.65	8.13
P-Value	66	65	46	86	66
Inhibitor					
None	131.6	3.11	4.30	0.63	8.06
N-Serve	130.3	3.07	4.35	0.64	8.09
P-Value	48	51	46	64	19
Hybrid X N-Rate	82	82	50	57	19
Hybrid X Inhibitor	75	75	99	82	99
N-Rate X Inhibitor	85	85	24	37	36
Hybrid X N-Rate X Inhibitor	83	83	99	28	98
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	93	93	55	99	92
N-Rate X K-Rate	86	86	26	20	57
Hybird X N-Rate X K-Rate	86	86	43	77	63
Inhibitor X K-Rate	36	36	33	50	33
Hybrid X Inhibitor X K-Rate	90	90	36	85	68
N-Rate X Inhibitor X K-Rate	73	73	29	48	17
Hybrid X N-Rate X Inhibitor X K-Rate	89	89	75	85	91

Table 21 Predent Waseca 1987

Split Plot without the 0 # N-Rate	N-Concentration Stover	Cob	Grain	N-Removal Stover	Cob	Grain	Total
	-----------	%	---------	--------------	#/A	------------	
K-Rate							
0	1.11	0.43	1.46	94.7	5.6	93.2	193.6
100	1.05	0.45	1.47	92.1	5.9	88.4	186.5
P-Value	80	95	34	73	80	97	97
Hybrid X N-Rate X Inhibitor							
Hybrid							
Pioneer 3732	1.03	0.46	1.39	84.5	6.3	92.2	183.2
Pioneer 3475	1.07	0.48	1.39	95.1	6.9	86.7	188.8
LH74 X LH51	1.06	0.41	1.47	101.1	4.5	85.3	191.1
A632 X LH39	1.13	0.41	1.59	92.8	5.3	98.9	197.1
P-Value	86	99	99	99	99	99	89
BLSD(.05)		0.02	0.04	8.6	0.3	4.4	
N-Rate							
80	1.02	0.43	1.41	87.9	5.6	87.1	180.6
160	1.13	0.45	1.51	98.9	6.0	94.5	199.4
P-Value	99	98	99	99	99	99	99
Inhibitor							
None	1.07	0.45	1.47	92.4	5.8	91.6	190.0
N-Serve	1.08	0.43	1.46	94.4	5.7	89.9	190.1
P-Value	35	90	46	49	61	69	3
Hybrid X N-Rate	59	35	83	77	38	85	91
Hybrid X Inhibitor	33	70	6	62	89	41	62
N-Rate X Inhibitor	73	41	4	64	62	73	77
Hybrid X N-Rate X Inhibitor	97	22	96	94	38	94	97
Hybrid X N-Rate X Inhibitor X K-Rate							
Hybrid X K-Rate	36	35	18	58	95	64	71
N-Rate X K-Rate	34	78	51	8	69	39	15
Hybird X N-Rate X K-Rate	64	7	59	64	48	42	42
Inhibitor X K-Rate	93	68	52	83	65	22	81
Hybrid X Inhibitor X K-Rate	76	48	97	33	72	84	60
N-Rate X Inhibitor X K-Rate	33	24	75	42	19	90	20
Hybrid X N-Rate X Inhibitor X K-Rate	3	72	11	24	21	88	64

Table 22 Physiological Mature Waseca 1987

Split Plot without the 0 # N-Rate	Grain Yields	Dry Matter Production Grain	Stover	Total
	Bu/A	----------T/A---------		
K-Rate				
0	186.5	4.40	4.30	8.71
100	186.1	4.39	4.47	8.88
P-Value	20	20	97	86
Hybrid X N-Rate X Inhibitor				
Hybrid				
Pioneer 3732	177.5	4.19	4.39	8.59
Pioneer 3475	190.2	4.49	4.63	9.13
LH74 X LH51	190.1	4.49	4.49	8.99
A632 X LH39	187.4	4.42	4.03	8.47
P-Value	99	99	99	99
BLSD(.05)	5.8	0.13	0.14	0.24
N-Rate				
80	184.0	4.34	4.27	8.62
160	188.6	4.45	4.50	8.97
P-Value	97	97	99	99
Inhibitor				
None	185.2	4.37	4.40	8.79
N-Serve	187.4	4.43	4.37	8.81
P-Value	70	70	45	17
Hybrid X N-Rate	4	4	32	12
Hybrid X Inhibitor	86	86	13	63
N-Rate X Inhibitor	42	42	85	76
Hybrid X N-Rate X Inhibitor	28	28	44	42
Hybrid X N-Rate X Inhibitor X K-Rate				
Hybrid X K-Rate	84	84	92	92
N-Rate X K-Rate	47	47	64	61
Hybird X N-Rate X K-Rate	72	72	44	45
Inhibitor X K-Rate	17	17	17	19
Hybrid X Inhibitor X K-Rate	99	99	6	79
N-Rate X Inhibitor X K-Rate	5	5	80	51
Hybrid X N-Rate X Inhibitor X K-Rate	66	66	72	58

Table 23 **Physiological Mature Waseca 1987**

Split Plot without the 0 # N-Rate	N-Concentration Stover	Grain	N-Removal Stover	Grain	Total
	-------%---------		--------#/A----------		
K-Rate					
0	0.66	1.44	57.4	127.1	184.6
100	0.60	1.38	54.4	122.2	176.7
P-Value	50	90	84	99	93
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3732	0.66	1.37	59.0	115.8	174.8
Pioneer 3475	0.62	1.38	58.4	124.4	182.8
LH74 X LH51	0.60	1.34	54.3	120.4	174.7
A632 X LH39	0.64	1.55	52.0	138.1	190.2
P-Value	99	99	99	99	99
BLSD(.05)	0.03	0.03	3.6	4.5	6.3
N-Rate					
80	0.58	1.38	49.8	120.5	170.4
160	0.68	1.44	62.0	128.8	190.9
P-Value	99	99	99	99	99
Inhibitor					
None	0.63	1.41	56.3	124.0	180.3
N-Serve	0.63	1.41	55.6	125.3	180.9
P-Value	9	7	42	54	20
Hybrid X N-Rate	51	92	24	86	68
Hybrid X Inhibitor	95	71	87	64	89
N-Rate X Inhibitor	7	97	50	96	94
Hybrid X N-Rate X Inhibitor	93	20	60	8	13
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	66	76	24	20	32
N-Rate X K-Rate	83	50	88	7	53
Hybird X N-Rate X K-Rate	76	34	81	23	38
Inhibitor X K-Rate	88	24	71	6	38
Hybrid X Inhibitor X K-Rate	21	70	16	69	41
N-Rate X Inhibitor X K-Rate	30	37	32	22	5
Hybrid X N-Rate X Inhibitor X K-Rate	66	24	78	42	70

INFLUENCE OF CROP HISTORY AND MANURE USE ON NITROGEN RATES FOR CORN PRODUCTION IN SOUTHEASTERN MINNESOTA

George Rehm, Tim Wagar, Greg Cremers, Andy Scobbie

Background and Justification:

Because of the karst topography, southeastern Minnesota is vulnerable to rather rapid movement of nitrate - nitrogen (NO_3-N) to the groundwater if this NO_3-N is leached below the root zone. In recent months, the attention of the public has been focused on the nitrate situation by published reports of excessive levels of NO_3-N in several samples of ground water collected from the region.

While it is impossible to completely eliminate the leaching of NO_3-N to the ground water, it is possible to keep additions to an absolute minimum. To do this, it is important to recognize that NO_3-N can be contributed to the soil system by the natural breakdown of organic contributions as well as the commercial fertilizers that are the backbone of our present agricultural economy. To keep additions of NO_3-N to the groundwater to a minimum, it is necessary to pay special attention to management of N in the soil system.

There are several important components of good N management; but selection of an adequate, but not excessive, N rate is the first and major consideration. Choice of an N rate is largely influenced by yield goal, organic matter content of the soil, use of legumes in the crop rotation, and rate of manure applied. There are N credits for legumes and manure that are currently used in making fertilizer N recommendations. These credits, however, are very general and were developed a number of years ago. For accurate management of N today, it is important that more precise credits be developed for legumes in rotation and manure use. This study was established in an effort to develop more precise N credits for these two major inputs for crop production in southeast Minnesota.

Experimental Procedures:

This study was established in Winona County in 1986 and continued in 1987. Three sites were selected for study in 1986. The history of each site was:

#1 - corn in 1986 following alfalfa which had received a heavy application of manure.

#2 - corn in 1986 following continuous corn that had been heavily manured in the past.

#3 - corn in 1986 following continuous corn which had received no manure and there was no recent history of an alfalfa crop.

Sites #4 through #7 were added to the study in 1987. At sites #4 and #7, alfalfa was grown for three years prior to planting corn in 1987. No manure had been applied to these alfalfa fields. The alfalfa at sites #5 and #6 had received manure in the past. The rate of manure applied, however, was not known.

Soil samples were collected from 0-6, 6-12, 12-24, 24-36, 36-48, and 48-60 in increments at each site before fertilizer application at locations except site #4. Limestone prevented collection of samples below 48 inches at this site. Four samples were collected from the research area at all locations except site #2. Because of the history of manure use, 28 samples were collected from site #2. Results of the analysis of these samples for NO_3-N are summarized in Table 1. Other appropriate soil test values are in Table 2.

supplied by the alfalfa, the manure applied in the past, or the soil organic matter itself. The research techniques used in this study do not identify the source of N.

Yields recorded from site #2 are shown in Figure 2. The amount of manure applied before 1986 did not supply enough N for the highest yield in either 1986 or 1987. In 1986, the optimum rate of N at this site was between 50 and 100 lb./acre. With no additional manure applied, the application of 120 lb N/acre produced optimum yield in 1987.

The relationship between residual NO_3-N in the root zone measured in the fall of 1986 and grain yield in 1987 at site #2 is shown in Figure 3. Highest grain yield was associated with a carryover of 150 lb.N/acre with no further yield increases resulting from higher amount of carryover N. Although grain yield was related to carryover N at this site, this information still does not provide a justification for adjusting N recommendations for amounts of carryover N.

At site #3, where no manure had been applied and there was no legume in rotation, highest grain yields were produced by the application of 120 lb. N/acre in both 1986 and 1987 (Figure 4). Late planting reduced yields in 1986 but relatively good yields were measured in 1987. The data from this site show that fertilizer N use can certainly produce economical increases in corn yield where there is no history of manure use or legumes in rotation.

Yields were lower at site #4 (Figure 5). The application of 80 lb. N/acre produced near maximum yields. It should be noted, however, that yield increases from fertilizer N at this site were relatively small. The N supplied from the soil at this site is apparently not as high as the N supplied from the soil at site #1.

There was no response to applied N at site #7 (Figure 5). Although grain yields were high, the previous crop of alfalfa in combinations with N mineralized from the soil organic matter was apparently able to supply the amount of N required by the corn crop.

At sites #5 and #6, manure is routinely applied at heavy rates at some point in the corn-alfalfa rotation. There was no response to the use of fertilizer N at either site (Figure 6). As was the case at site #7, yields were high and the soil system was apparently able to supply the amount of N required by the corn crop.

It would be ideal if there was a soil test available that could be used as a basis for accurately predicting the amount of fertilizer N needed. This type of test is available and works for western Minnesota but the data collected in this study show that the soil nitrate test, by itself, will not work in southeast Minnesota. For example, there was no response to fertilizer N when the soil nitrate test showed an initial level of 55.5 lb./acre (site #1). There was, however, a substantial response to fertilizer N at a site where the initial soil nitrate level was 82.9 lb./acre (site #3). Perhaps the soil nitrate test can be combined with another measure of usable N to provide an accurate prediction of the amount of fertilizer N to use.

<u>Summary:</u>

A study of the data collected from this study to date leads to two generalized conclusions. These are:

1. Manure use and the presence of alfalfa in rotation can have a major impact on N recommendations for corn in southeast Minnesota. Nitrogen credits for alfalfa can be substantial for the first year of corn following alfalfa. Nitrogen credits for the second year have not been well established. Nitrogen credits for manure may be of major value only in the first year after application.

2. A measure of the amount of NO_3-N in the root zone before planting will not improve our ability to accurately predict the amount of fertilizer N needed. The soil nitrate test in combination of

Table 1. Distribution of NO_3-N in the root zone at the experimental sites before initiation of the study.

Site #	Depth (in.)						
	0-6	6-12	12-24	24-36	36-48	48-60	Total
	lb. NO_3-N/acre						
1	17.5	7.0	6.5	11.5	8.3	4.7	55.5
2	13.9	12.7	26.2	21.8	15.7	8.8	99.1
3	12.5	7.4	18.7	19.2	13.7	11.4	82.9
4	16.0	4.0	2.0	2.0	2.0	-	26.0
5	14.9	11.9	10.5	6.4	5.1	3.9	52.7
6	13.2	6.2	6.0	3.0	2.1	3.5	34.0
7	29.7	7.7	11.0	12.2	5.2	4.3	70.1

Table 2. Selected relevant soil properties (0-6 in.) for the experimental sites used in this study.

Soil Property	Site #						
	1	2	3	4	5	6	7
pH	6.7	6.7	6.9	6.9	6.5	6.4	7.2
P, lb./acre	73	86	38	13	145	41	25
K, lb./acre	293	286	296	150	296	216	311
organic matter, %	4.5	4.0	3.9	2.1	3.8	3.6	-

There was not a large amount of variability in the results from sites 1, 3, and 4. There was, however, a substantial amount of variation in the amount of NO_3-N to a depth of 5 feet at site 2. The total amount of NO_3-N measured varied from 45 to 191 lb. per acre. This variability is attributed to the previous heavy use of manure.

Seven rates of N (0, 40, 80, 120, 160, 200, 240 lb./acre) as 46-0-0 were broadcast to sites 1, 3, and 4. The rates used in 1986 were repeated in 1987 at sites 1 and 3. The N rates at site #2 in 1986 were 0, 50, 100, 150, 200, 250, and 300 lb./acre. Rates were lowered to those previously listed at this site in 1987. In all cases, the urea was incorporated with a secondary tillage operation.

An added comparison was added to site #2 in 1987. One half of the original plots received no additional N. The remaining half was fertilized with the various N rates used in 1987. Residual NO_3-N for each plot was determined from soil samples collected to a depth of 5 feet in the fall of 1986. The 1987 yields from the portion of the plots not fertilized in 1987 were related to the amount of carryover NO_3-N measured in the fall of 1986.

Cooperating farmers were responsible for planting and cultivating at all sites. Management practices needed to achieve high yields were used whenever possible at all sites. Grain yields were measured by hand harvest techniques each year and corrected to 15.5% moisture.

Results and Discussion:

Results from site #1 are summarized in Figure 1. Relatively high yields were recorded each year. Yet, there was no response to fertilizer N. The high yields would remove relatively high rates of N. These results also show that the soil at this site is supplying substantial amounts of usable N. The N could be

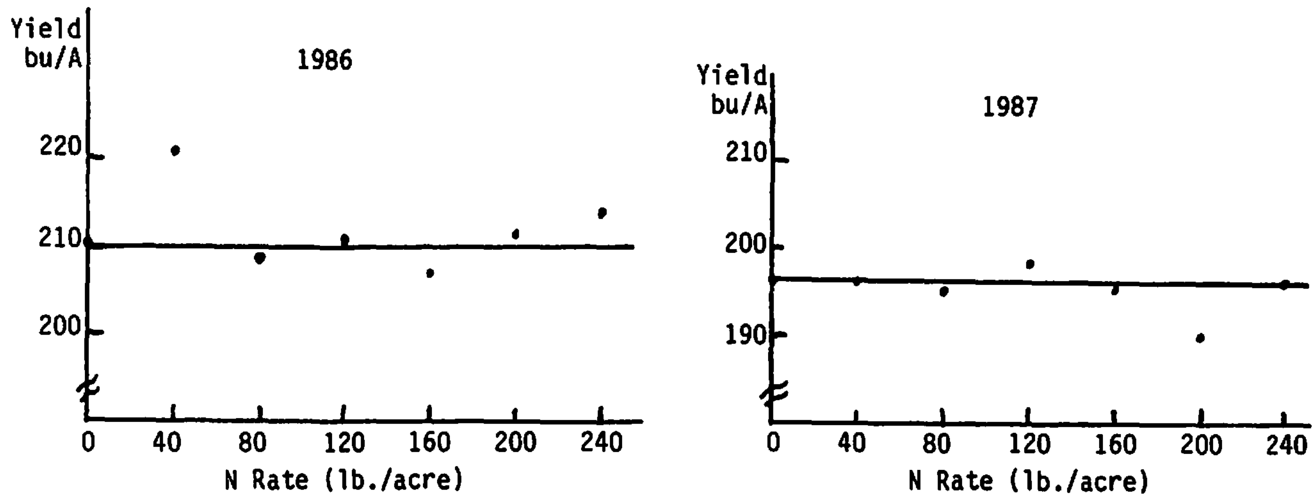

Figure 1. Effect of rate of fertilizer N on corn yield at site #1.

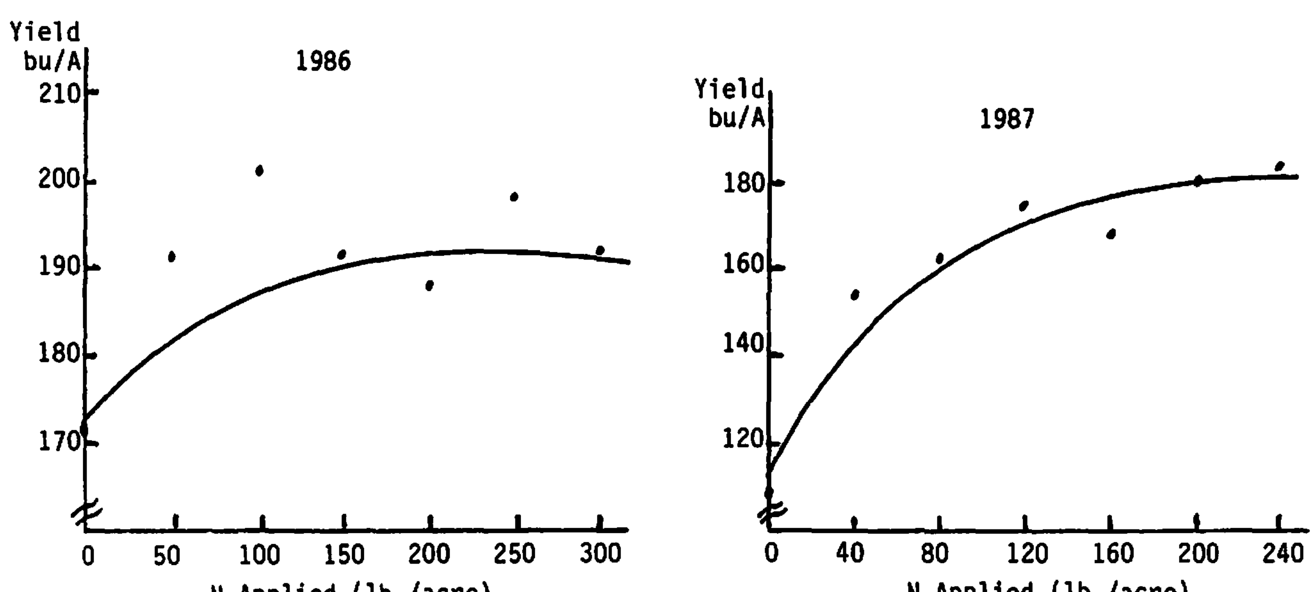

Figure 2. Effect of rate of fertilizer N on corn yield at site #2.

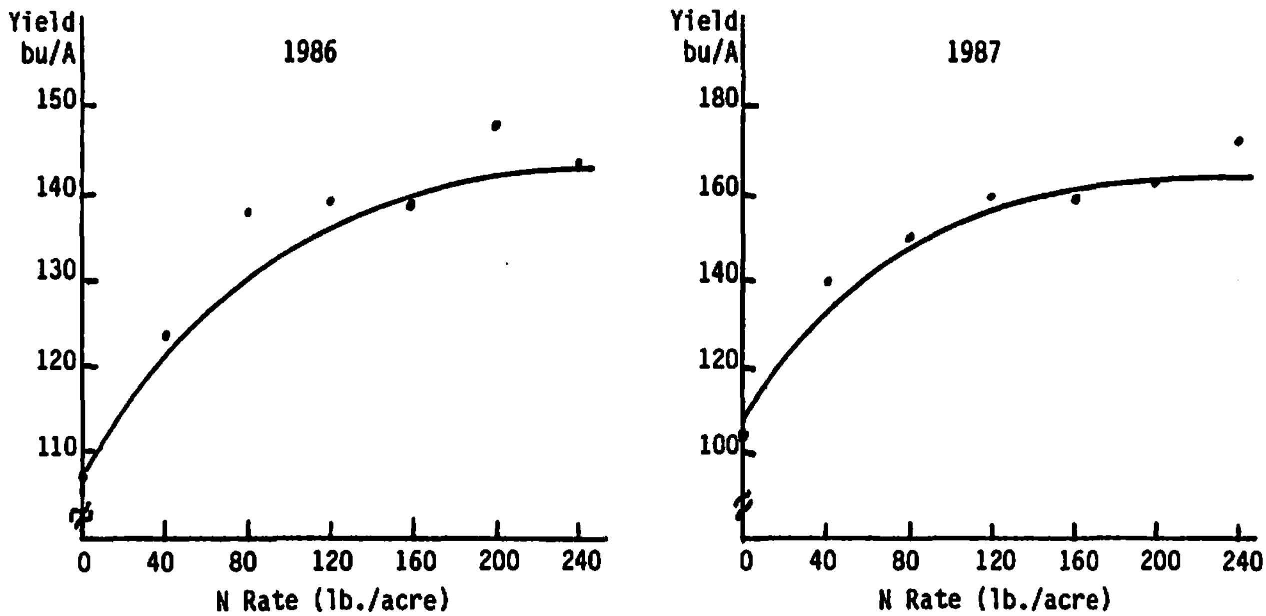

Figure 4. Effect of rate of fertilizer N on corn yield at site 3.

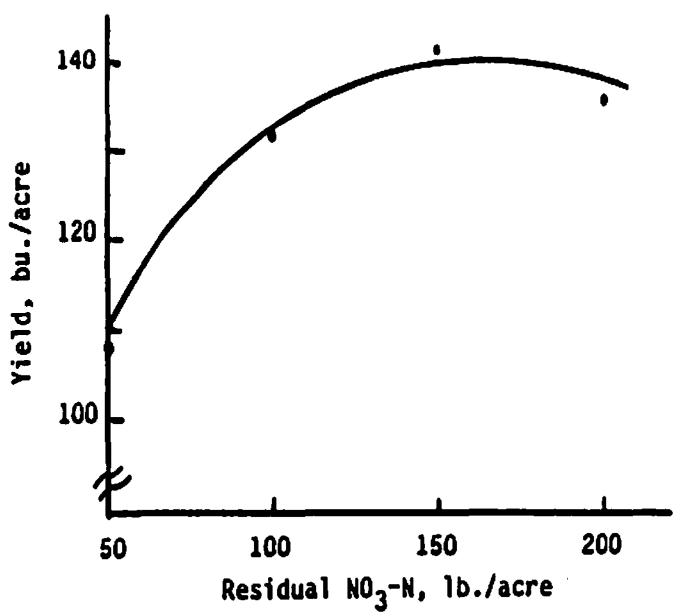

Figure 3. Response of corn to amount of residual NO_3-N found to a depth of 5 feet at site #2 in 1987.

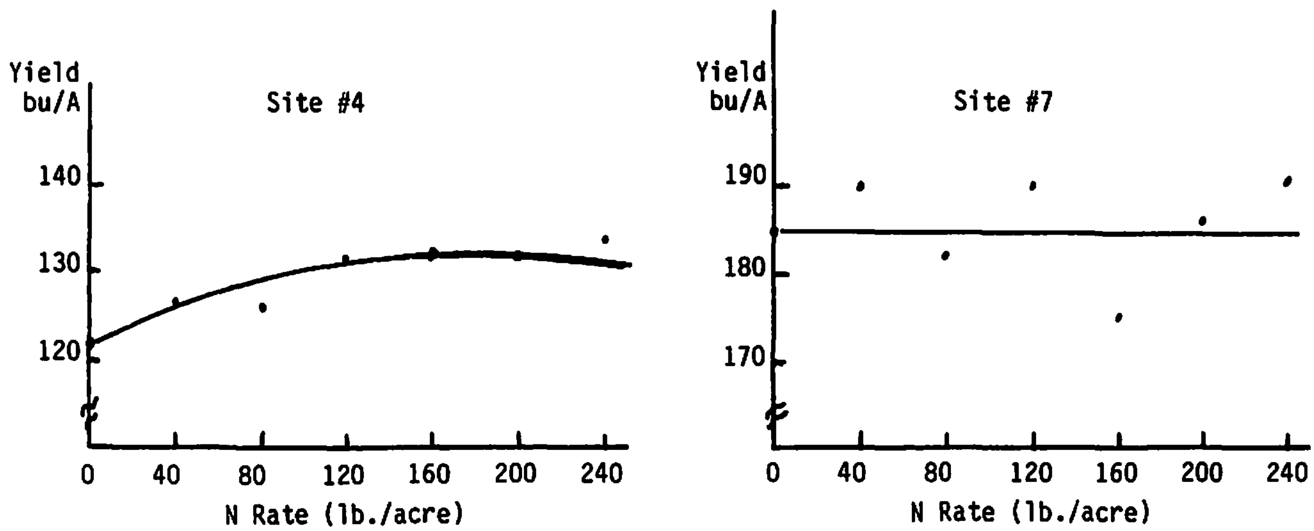

Figure 5. Effect of rate of fertilizer N on yield of corn following alfalfa where no manure is applied.

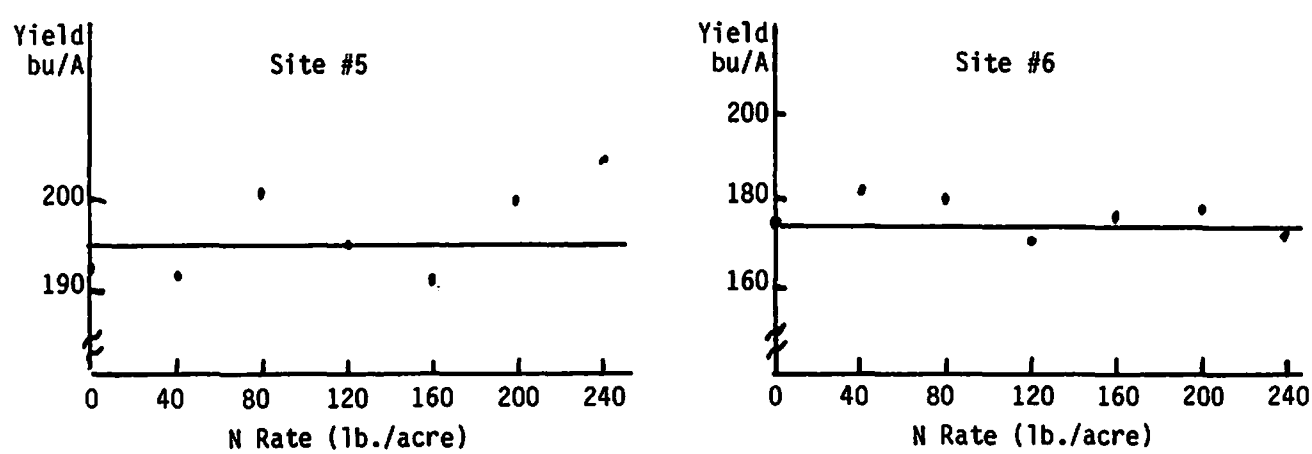

Figure 6. Effect of rate of fertilizer N on yield of corn following alfalfa where manure had been applied.

DECLINE RATES OF SOIL TEST P AND K IN A CORN-SOYBEAN ROTATION

1987

G. W. Randall and S. D. Evans

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

EXPERIMENTAL PROCEDURES

High rates of P and K were applied over a 12-year period (1973-84) in studies at the Southern Experiment Station at Waseca (Table 2) and the West Central Experiment Station at Morris (Table 3). These rates created a wide range of soil test values upon which we can evaluate the decline rates of soil test P and K when no additional fertilizer is added. Treatments 2, 3, and 4 have not received additional P since 1984 while treatments 6 and 7 at Waseca have not received K. The K treatments were not included at Morris because of very high native soil test K levels. Treatment 5, which had a moderately high level of fertilization prior to 1985, continues to receive P and K, and thus, serves as the high fertility control.

The P and K materials (0-46-0 and 0-0-60) were broadcast on the soil surface and incorporated by chisel plowing the soybean residue in the fall of 1986. Specific experimental procedures used for corn at the two locations are presented in Table 1. Management practices providing for optimum yields were employed at each location. Starter fertilizer was not used. Planting was early at both locations because of the warm, dry spring.

Table 1. Experimental procedures for corn on the high P and K rate study at the two branch stations in 1987.

Variable	Location: Morris	Location: Waseca
Planting date	4/24	4/27
Row spacing	30"	30"
Planting rate (plants/A)	27,800	30,200
Variety	DeKalb 461	P3732
Herbicide	3# Lasso + 2.2# Bladex/A (Bdct)	3.5# Lasso + 3# Bladex/A (Bdct)
Harvest date	9/24	10/7
Soil type	Aastad clay loam	Webster clay loam

RESULTS AND DISCUSSION

Total phosphate (P_2O_5) and potash (K_2O) applied over the 12-yr period ranged from 0 to 1200 lb/A (Tables 2 and 3). These application rates plus the 1985-86 rates resulted in highly significant differences in soil test P at both locations and in soil test K at Waseca. At Waseca soil test P ranged from 15 to 123 lb P/A (Table 2). Corn yields were increased significantly by P but plateaued at soil P levels higher than 40 lb/A. Slightly lower corn yields were seen at the 208 and 224 lb K/A tests compared to treatments 4 and 5 with K tests averaging 257 lb/A, but this average 8% yield reduction was not significant at the P = 95% level.

At Morris, Bray P_1 ranged from 11 to 58 lb/A while Olsen's $NaHCO_3$ test ranged from 9 to 47 lb P/A (Table 3). Increasing Bray P_1 from 11 to 31 lb/A resulted in a 33.7 bu/A yield response, but because of an extremely high CV (18%) this was not significant at the P = 90% level. The high CV was due primarily to one of the control plots with a Bray P_1 of 17 lb/A and a yield of 150.9 bu/A. Deleting that plot would have resulted in a highly significant 50+ bu/A response and a lower CV. No additional yield response was noted with the 58 lb/A soil test level compared to the 31-lb level.

Table 2. Soil test values, corn grain moisture, and corn yield as influenced by 13 years' application of P and K at Waseca.

No.	P and K Treatments: Total 1973-84	P and K Treatments: 1985-86[1/]	Soil Test[2/]: pH	Soil Test: P	Soil Test: K	Corn: Moisture	Corn: Yield
	----- lb P_2O_5 + K_2O/A -----			--- lb/A ---		%	bu/A
2	0 + 1200	0 + 100	6.8	15	265	18.0	156.4
3	600 + 1200	0 + 100	6.6	40	274	17.1	183.2
4	1200 + 1200	0 + 100	6.7	86	257	17.2	186.4
5	600 + 1200	100 + 100	6.6	72	257	17.4	182.8
6	1200 + 0	100 + 0	6.7	123	208	16.4	165.6
7	1200 + 600	100 + 0	6.7	119	224	16.3	173.1
	Signif. Level (%):		6	99	99	95	97
	BLSD (.05) :			15	29	1.2	20.1
	CV (%) :		4.2	12	6.4	3.6	5.8

1/ Treatments applied each Fall.
2/ Samples were taken in October before 1987 treatments were applied.

Table 3. Soil test values, corn grain moisture, and corn yield as influenced by 14 years' application of P and K at Morris.

No.	P and K Treatments: Total 1973-84	P and K Treatments: 1985-86[1/]	Soil Test[2/]: pH	Soil Test: P_1	Soil Test: P_{01}	Soil Test: K	Corn: Moisture	Corn: Yield
	---- lb P_2O_5 + K_2O/A -----			------ lb/A		-------	%	bu/A
2	0 + 1200	0 + 100	7.8	11	9	451	22.4	99.9
3	600 + 1200	0 + 100	7.7	31	27	391	18.8	133.6
4	1200 + 1200	0 + 100	7.9	58	47	394	19.8	137.4
5	600 + 1200	100 + 100	7.8	40	32	396	19.1	135.8
	Signif. Level (%):		85	99	99	88	93	87
	BLSD (.05) :			15.	14.			
	CV (%) :		1.8	27.	30.	8.7	9.1	18.

1/ Treatments applied each Fall.
2/ Samples were taken in October before 1987 treatments were applied.

CONCLUSIONS

Long-term (12-yr) P additions to these two soils created a wide range in soil test P levels. Corn yields were optimized over the no P treatments at soil test P levels of 31 lb/A at Morris and 40 lb/A at Waseca. Yields were optimized at soil K levels >250 lb/A at Waseca. In this second year of the study following the 12-year P and K applications, we obtained fairly consistent soil test P and K declines when fertilizer P and K were not added. Additional years will be needed to more accurately determine the decline rates.

IMPACT OF NITROGEN AND TILLAGE MANAGEMENT PRACTICES ON CORN YIELD AND POTENTIAL GROUNDWATER CONTAMINATION IN SOUTHEASTERN MINNESOTA

Center for Agricultural Impacts on Water Quality
Gyles Randall, J. Anderson, G. Malzer, D. Wyse,
J. Nieber, B. Anderson & B. Sorenson

Current agricultural production systems are being linked closely to the occurrence of agricultural chemicals in the groundwater. This concern is especially prevalent in southeastern Minnesota where agriculture is quite intensive and the soils are rather shallow over a fractured limestone and sandstone bedrock geology (karst). The purposes of these studies are to: (1) determine the cause and effect relationship of specific N and tillage management practices on corn production and NO_3 and pesticide accumulation/movement through the soil and (2) identify best management practices that minimize groundwater contamination while maintaining economic profitability.

EXPERIMENTAL PROCEDURES

Three sites were established for the 1987 studies. The primary site with the most intensive investigation is being conducted in Olmsted Co. on the Lawler Farm. The other sites are in Goodhue Co. on the Foss Farm and in Winona Co. on the Kalmes Farm.

Olmsted County - Lawler Farm

In April of 1986 a 6½ acre site of Port Byron soil was identified on the Richard Lawler and Sons Farm approximately 6 miles east of Rochester. A very comprehensive field history for the last 7 years was provided. Corn was grown in 1986. No herbicides and no nitrogen (N) fertilizer were applied to the corn which was cultivated three times.

Soil cores were taken in 1-foot increments to the bedrock (ranges from 7' to 12') in a 100-foot grid pattern in June 1986 and in October 1986 to determine inorganic-N in the profile. The June 1986 sampling showed a large variation in the amount of NO_3-N in the top 4 feet with a lesser amount of variation in the 4-7' zone. By November 1986, variation in NO_3-N among the profiles was less. The background levels of residual NO_3-N were reduced to rather low levels and the variability was largely removed through crop uptake or apparent leaching during the 1986 growing season. Over 10" of rain occurred at this site during September 1986 which more than likely had a profound effect on the removal of nitrates from the 0-4' zone. The concentration of nitrates in the 4-7' profile also was rather low in November 1986. Additional samples were taken in 1-foot increments from each of the check plots in the N study. These data indicated an average of 68 lbs of nitrate-N per acre in the top 4' and was considered to be low.

Nitrogen Study

A randomized, complete-block with 4 replications was established in the fall of 1986. Ten N treatments including both anhydrous ammonia and manure were established for a total of 40 plots (Table 1). Each plot was 30' wide and 65' long. The fall N treatments were applied on Nov. 5, 1986. Spring N fertilizer treatments were applied on April 24 and again on June 19, 1987. Liquid hog manure was obtained from a neighbor, James Stellplug, on April 15 and applied to the soil surface using his equipment. The manure was incorporated with a disk within 3 hours. The rates of application were 5000 and 8900 gal/A. Six manure samples were taken and sent to Minnesota Valley Testing for analyses. Nitrogen, P_2O_5 and K_2O concentrations averaged 69.5, 34.5 and 23.9 lb/1000 gallons, respectively. All plots except the no-till treatment were disked again on April 29.

Corn (Pioneer 3737) was planted on April 30 at 30,200 plants/A. Lasso (3 lb/A) and atrazine (2½ lb/A) were applied preemergence. Counter was applied in the furrow at a rate of 8 oz/1000' of row to control rootworms. Cultivation was not performed during the season.

Small plant stem tissue samples and soil samples from 0-1' and 1-2' layers were taken for nitrate analyses at the V-6 stage to see if these measurements can be used to predict N needs. In addition, lysimeters were installed at the 5' and 7½' depths in the soil profile during late June and in July. These lysimeters are being used to extract soil water from these depths to measure NO_3 concentrations in the water.

Whole plants were harvested from selected rows at silking, were weighed, dried, ground and analyzed for total N to determine pre-silk N uptake. Stover and grain yields were taken from 20' and 80' of row, respectively, at physiological maturity (Sept. 24). All samples were weighed, dried, ground and analyzed for total N.

Soil samples were obtained from each plot on Oct. 26 by taking two 2-inch cores in 1-foot increments to the bedrock and then compositing the cores from each increment. The samples were forced-air, oven dried at 120°F, ground, and are being analyzed for inorganic N (NH_4-N and NO_3-N).

Pesticide Study

An area adjacent to the N study was established in the fall of 1986 to accommodate a study to evaluate the movement of Lasso, atrazine, Banvel and Counter through the soil profile as influenced by four tillage systems. The four tillage treatments (moldboard plow, chisel plow, ridge tillage, and no tillage) were initiated in November, 1986. Nitrogen was applied on April 24 at a rate of 180 lb N/A as anhydrous ammonia. All other planting operations were the same as in the N study. The herbicides were applied using specialized plot equipment. Potassium bromide was broadcast applied at a rate of 120 lb/A to the end 15' of each plot. The Br serves as a tracer to which pesticide movement can be compared. The corn was cultivated two times. The ridge plots were ridged for the first time in mid-June.

Each plot was intensively soil sampled throughout the season to monitor herbicide movement. Stainless steel suction lysimeters were installed at 5' and 7½' depths to extract soil water. Grain and stover yields were taken at physiological maturity (PM) from both the Br and non-Br treated areas.

Goodhue County - Foss Farm

In May of 1986 an area of 5.1 acres of Port Byron soil was identified on the Selmer Foss and Sons (James Foss) farm in Goodhue County. A good field history was provided for the past 6 years. Corn was grown in 1986 and received a minimal amount of N (75 lb N/A) because it was in continuous corn. Weeds were controlled with 4 lb atrazine/A. Due to wet conditions no primary tillage was performed in the fall of 1986.

A randomized, complete-block design with 4 replications was established at this site in April, 1987. Sixteen N treatments all consisting of anhydrous ammonia applied to chiseled and no-till plots were established. Each of the 64 plots measures 30' wide and 65' long. Chisel plowing was done with a John Deere Mulch Tiller on April 13. Anhydrous ammonia was applied preplant on April 21. All chisel plots were disked on April 27.

Corn (Pioneer 3790) was planted at 30,200 plants/A on April 28. Lasso (3 lb/A) and atrazine (2½ lb/A) was applied preemergence. Furadan was applied at 1 lb a.i./A to control corn rootworms. The chisel plowed plots were cultivated to remove weeds and volunteer corn. Sidedress applications of N as anhydrous ammonia were applied at the 4-leaf stage (June 1) and 11-leaf stage (June 19).

Soil samples were taken in 1-foot increments to a 10' depth from 16 sites located in alleys throughout this experiment in April. Ammonium-N and nitrate-N data indicated rather consistent and low levels of nitrate-N in the 0-4' depth throughout this site with some indication of increased NO_3 accumulation in the 4-7' zone. Nitrate levels between 7 and 10' were lower and again fairly uniform. Soil cores were also taken to a 10' depth from each of the check plots. Ammonium-N, nitrate-N, and mineral-N (total of ammonium-N plus nitrate-N) levels within the 0-4' zone were rather low with a total of 69 lb NO_3-N/A (Low).

Plant sampling procedures at silking and at PM were essentially the same as at the Olmsted Co. site with one exception. One of the insecticide attachments plugged, resulting in one row out of every 4 not receiving any insecticide. It gradually unplugged during planting of the last 1/3 of the study.

Soil sampling to the 10-foot depth on October 28 was accomplished using the same procedures as in Olmsted Co. Suction lysimeters were installed in six treatments (24 plots) to a 5' depth in October.

Winona County - Kalmes Farm

A 3.0 acre contour strip of Seaton soil was identified in early April, 1987. This farm is owned by Eugene Kalmes and his son, Robert Kalmes. A field history was provided for the last 4 years. Corn was grown in 1986 and received 70 lb N/A and 2 lb atrazine/A. Alfalfa was grown in 1983-85 and received 6 T manure/A in the fall of 1985.

A randomized, complete-block design with 4 replications was established at this site in mid-April. Twelve N treatments were established for a total of 48 plots. Each plot measures 20' wide by 65' long. A transect of 2" soil cores was taken in mid-April. Each core taken to limestone was divided into 1-foot increments and analyzed for ammonium-N and nitrate-N. Extremely high and variable levels of NO_3-N were found in the top 4' at this site. Nitrate levels between 4' and 7' were also variable but were not nearly as high. Reasons for this high level of residual NO_3-N perhaps are due to the alfalfa crop grown from 1983 through 1985 and the 6 tons/A of dairy manure applied per acre in 1985. Depth to limestone fragments ranged from 4' at one core site to 10' at 5 of the 11 core sites.

Spring chiseling was conducted on April 24. The preplant anhydrous ammonia treatments were applied immediately afterward. A culti-packer was used as secondary tillage just prior to planting.

Corn (Pioneer 3790) was planted at 30,200 plants/A on May 1. Lasso (3 lb/A) and atrazine (2½ lb/A) was applied preemergence. Counter (8 oz/1000') was used to control corn rootworms. The chisel plowed plots were cultivated to remove weeds. Sidedress applications of N were applied at the 4-leaf stage (June 4) and the 10-leaf stage (June 19).

Plant and soil sampling procedures were identical to those used in Olmsted Co. Stainless steel and PVC suction lysimeters were installed in August and September at the 5' depth in six treatments (24 plots).

RESULTS AND DISCUSSION

Olmsted Co.

Corn grain yields were increased significantly by both the fertilizer and manure N treatments (Table 1). The addition of 75 lb N/A increased yield by 73 bu/A resulting in very high fertilizer N efficiency. The 150-lb N rate applied preplant (PP) gave the highest yield among the fertilizer treatments. Yields were 7 to 9 bu/A higher with the two hog manure treatments, but this difference was not significantly (P = 95% level) above the 150-lb N/A PP treatments. Corn yields with the fall and split 150-lb treatments were not significantly different from the 150-lb PP treatment. There was no significant yield difference between the chisel and no tillage systems.

Table 1. Effect of N treatments on the 1987 corn grain yields in Olmsted Co.

No.	Tillage	Treatment N Rate	Time/Method	Grain Yield
		lb N/A		bu/A
1	Chisel	0	-----	109.3
2	Chisel	75	Spr., preplant	182.3
3	Chisel	150	Spr., preplant	200.4
4	Chisel	225	Spr., preplant	184.1
5	Chisel	150	Fall, post tillage	195.7
6	Chisel	150 + NI 1/	Fall, post tillage	191.2
7	Chisel	150 split	50% Spr., preplant 50% SD, 8-leaf	193.0
8	No tillage	150	Spr., preplant	198.4
9	Chisel	175 2/	Spr., disked	207.3
10	Chisel	310 2/	Spr., disked	209.5
	Significance Level (%):			99
	BLSD (.05) :			14.5
	CV (%) :			5.9

1/ N-Serve

2/ Applied liquid swine manure at rates of 5000 and 8900 gal/A, respectively. Total N rates were 348 and 618 lb N/A or approximately 175 and 310 lb "available" N/A.

Corn yields in the pesticide study were not influenced by tillage system at the P = 90% level but were reduced significantly by the Br tracer application (Table 2). The 20 bu/A reduction due to Br did not vary with tillage system.

Table 2. Effect of tillage and bromide treatments on the 1987 corn yields in Olmsted Co.

Tillage	Bromide treatment		Avg.
	No Br	Br	
	bu/A		
Moldboard plow	196.7	171.2	184.0
Chisel plow	193.6	172.5	183.1
"Ridge till"[1/]	185.2	170.2	177.7
No tillage	182.3	163.8	173.0
Avg.	189.4	169.4	

Statistical analysis

Factor	Signif Level (%)
Tillage	84
Bromide	99
Tillage x Bromide	22
CV (%) = 5.8	

1/ Not ridged until June, 1987.

Corn was planted on a 1½ acre area which is being saved for "future" investigations. Neither fertilizer N nor pesticides were applied. The corn was cultivated twice to control weeds as best possible. Corn yields averaged only 65 bu/A primarily due to weed pressure (early season moisture stress) and insufficient N. It is interesting to note the 44 bu/A difference between this site and the 0-lb N plots that were kept weed-free by herbicides.

Nitrogen analyses are being conducted currently on all plant samples to evaluate N uptake by the plant as affected by the treatments. Numerous soil samples were taken throughout the season from each plot in both of the studies. As of this writing these soil samples are still being analyzed.

Water samples were obtained twice a month from August through late-November from the suction lysimeters installed in the N plots. Sampling appeared to be quite successful with about 60 samples obtained each time from 64 lysimeters. This success was undoubtedly enhanced by the 20.9 inches of rain that occurred from May 21 through Sept. 30. Samples analyzed to date show very little difference among treatments in August and early September with concentrations averaging around 6 to 7 mg NO_3-N/L at the 5' depth. By late October there was evidence of increasing NO_3-N levels (10 mg/L) at the 5' depth with the 225-lb N and the two manure treatments.

Goodhue Co.

Grain yields were increased significantly over the control by all of the N treatments (Table 3). Yields were optimized with the 100-lb spring PP treatment. The highest yield, although not statistically speaking, was obtained with the 150-lb PP treatment containing N-Serve. There was no difference between the two tillage systems except at the 0-lb rate where chiseling increased yields 22.2 bu/A compared to no tillage. None of the split and sidedress treatments enhanced yields over the spring PP anhydrous applications. Plant analyses are being conducted to determine which treatments resulted in greatest N uptake by the plants and fertilizer N efficiency.

Corn rootworm pressure at this site was extremely high. Root ratings on the non-insecticide treated plants ranged from 5 to 6 and severe lodging occurred. Corn yields were also measured in this non-insecticide row of each plot within the study area where the insecticide applicator was plugged (3 replications). These yields reported in Table 3 show yield losses from 16 to 96 bu/A without the insecticide. These substantial losses demonstrate the importance of proper pesticide use if N efficiency is to be maximized. Nitrogen not taken up by the rootworm-damaged plants would be highly susceptible to movement to the groundwater.

Table 3. Corn yield as affected by N and insecticide treatments in Goodhue Co.

No.	N rate	Application time	Tillage[1/]	Insecticide with	Insecticide without	Response to insecticide
	lb/A			---- Grain Yield (bu/A) ----		
1	0	-----	Chisel	137.8	78.8	+58.9
2	50	Spr. preplant (PP)	"	170.5	94.9	+75.5
3	100	"	"	186.0	102.6	+83.4
4	150	"	"	184.3	114.5	+69.7
5	200	"	"	189.5	107.6	+81.9
6	0	-----	No Tillage	115.6	99.5	+16.1
7	100	Spr. preplant (PP)	" "	187.5	142.6	+44.9
8	150	"	" "	190.0	93.8	+96.2
9	200	"	" "	191.6	107.2	+84.4
10	50 + 50	Spr. PP + SD 11-1f	Chisel	179.8	134.7	+45.0
11	50 + 100	" "	"	182.2	107.1	+75.0
12	100 + 50	" "	"	186.0	104.7	+81.2
13	100	SD 4-1f	"	180.4	120.7	+59.7
14	150	"	"	187.6	120.0	+67.6
15	150 + NI[2/]	Spr. PP	"	194.5	115.3	+79.1
16	150 + NI	SD 4-1f	"	180.0	136.0	+43.9
	Significance Level (%):			99		
	BLSD (.05) :			12.5		
	CV (%) :			5.4		

1/ Chiseling was done in April, 1987.
2/ NI = N-Serve

Soil samples taken to a depth of 10' from each plot in October are presently being analyzed. Water samples were not taken from this site in 1987.

Winona County

Corn grain yields were excellent at this site but no response to N was obtained (Table 4). This was surprising since this was second year corn following alfalfa. However, after receiving the soil NO_3 analyses from the spring sampling, this lack of response was expected because of the high residual NO_3 values. These elevated levels probably were due to the alfalfa plus manure previous history plus the 70 lb N/A applied to the 1986 corn crop.

Table 4. Effect of N treatments on the corn grain yield in Winona County

No.	N Rate	Time	Tillage[1/]	Yield
	lb N/A			bu/A
1	0	-----	Chisel	185.7
2	50	Spr. preplant (PP)	"	189.8
3	100	" "	"	188.6
4	150	" "	"	190.7
5	200	" "	"	191.6
6	0	-----	No Tillage	189.9
7	100	Spr. preplant (PP)	" "	189.6
8	150	" "	" "	183.9
9	200	" "	" "	184.2
10	50 + 50	Spr. PP + SD 10-1f	Chisel	190.1
11	50 + 100	" " "	"	193.3
12	150	SD 4-1f	"	188.8
	Significance Level (%):			15
	BLSD (.05) :			NS
	CV (%) :			4.1

1/ Chiseling was done in April, 1987.

Plant, soil and water samples are presently being analyzed from this site. Initial soil and water samples from the 5' depth also indicate high levels of residual NO_3-N.

SUMMARY

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

1) N rate was optimized at 150 lb/A for second year corn even though N was not applied in 1986 while at a second site 100 lb N/A was optimum when N was applied in 1986.
2) Yields were slightly but not significantly higher with the manure treatments.
3) No apparent yield advantages were found with split or sidedress applications of N at any of the three sites.
4) There was no yield difference between the no tillage and chisel tillage systems at any of the three sites.
5) A tremendous impact of pesticides and previous crop and manure history was shown on corn yield and N management.
6) The role of alfalfa and manure contributions to available N for succeeding corn crops needs to be carefully examined and understood before improved N management is a reality on these soils.

ACKNOWLEDGEMENT

This interdisciplinary investigation would not have been possible without the financial assistance from the Legislative Commission on Minnesota Resources (LCMR), the fine cooperation and dedication of the farmer-cooperators, and the participation of the Soil Conservation Service and the Minnesota Extension Service.

NITROGEN SOURCES, RATES, AND TIME OF APPLICATION FOR HARD RED SPRING WHEAT

J.A. Lamb, S.D. Evans, and G.W. Rehm

A renewed interest in foliar application of nitrogen on spring wheat has recently occurred. This interest arises from a hefty discount on protein below 14% at the elevator and increased attention by producers to intensify their management of small grains similar to what has occurred in western Europe and Eastern United States. Another factor is although the producers have superior varieties (Marshall and Wheaton) at their disposal with regard to yield and lodging, these varieties produce notoriously low protein grain.

With these facts in hand a study was designed with the following objectives:

1. Determine proper source, rate, and time of application of foliar applied N for greatest grain yield and protein content on spring wheat.

2. Determine the effect of source, rate and time of application on leaf burn.

MATERIALS AND METHODS: This study was conducted at two locations, Crookston and Morris, MN, in 1987. These locations represent a majority of the 3 million acres of spring wheat grown in western Minnesota. The treatments involved all combinations of three sources (liquified Urea, Urea Ammonium Nitrate solution, and N-Sure an Arcadian product), three times of application (tiller, boot, and heading - Zadoks 2.1, 4.3, and 5.6 respectively), and five N rates (0, 10, 20, 40, and 80 lb N A^{-1}). The plot area was soil tested and fertilized with Urea to a level of 120 lb N A^{-1}, Soil NO_3^--N 0-2' + fertilizer N). This corresponds to the Minnesota N recommendation for a 60 bu A^{-1} yield goal. The spring wheat variety 'Marshall' was used at both locations. This is a high yielding semi-dwarf variety planted on 70% of the Minnesota wheat acreage which produces low protein grain. The seeding rate was 100 lb A^{-1}. The wheat was seeded with a double disc press wheel drill April 16 and April 21, 1987 at Morris and Crookston, respectively.

The treatments were applied with a sprayer delivering a volume of 50 gallon A^{-1} at 30 psi pressure. Table 1 indicates the application dates.

Table 1. Application dates for 1987.

	Location	
Stage	Morris	Crookston
	--------date-------	
Tiller	5/20	6/5
Boot	6/3	6/17
Head	6/11	6/22

Leaf burn was visually evaluated one week after each application. Whole plant samples were taken at soft dough and N concentration was determined. The grain was harvested by small plot combine July 23 and July 28 at Morris and Crookston, respectively. Grain protein content was determined on the grain.

RESULTS AND DISCUSSION: Leaf Burn: Leaf burn occurred at both locations and on each application. At both locations the amount of leaf burn increased as the N rate increased. The N source did effect the severity of burn. At Morris, UAN caused the most burn, approximately 75% of the leaf at the 80 lb N A^{-1} rate. The urea caused the next most severe burn and N Sure having the least, approximately 25 to 33% of the leaf at the 80 lb N A^{-1} rate. Urea did not burn at the 10 or 20 lb N/A rate. N Sure did not cause burn at the 10, 20 and 40 lb N A^{-1} rates. The difference between Urea and N Sure was not large and both were considerably less than the UAN. At Crookston the UAN burned 75% of the leaf at 80 lb N A^{-1}. Unlike Morris, the Urea and N Sure burned similarly, 25-30% of the leaf at 80 lb N A^{-1} rate it caused some burn at all N rates.

Grain Yield: At Crookston the application of foliar N significantly increased grain yield over the check by 1.5 bu A^{-1} at the 20 and 40 lb N A^{-1} rate. Table 2.

At Morris no increase to grain yield occurred from N rate with a trend towards a decrease at the 80 lb N A^{-1} rate. At Morris, source and time of application did not effect the grain yield. At Crookston there was a time by source interaction for grain yield. Figure 1 illustrates that at the tiller application date, urea produced a higher grain yield than N Sure or UAN. At the boot application all three N sources performed the same and at heading UAN and N Sure out-performed Urea. With the amount of leaf burn that occurred, larger grain yield differences between sources were expected. In 1987 at both locations, very dry weather conditions occurred. This limited the production of tillers and thus caused additional stress to the plant which may have masked the leaf burn effects on grain yield.

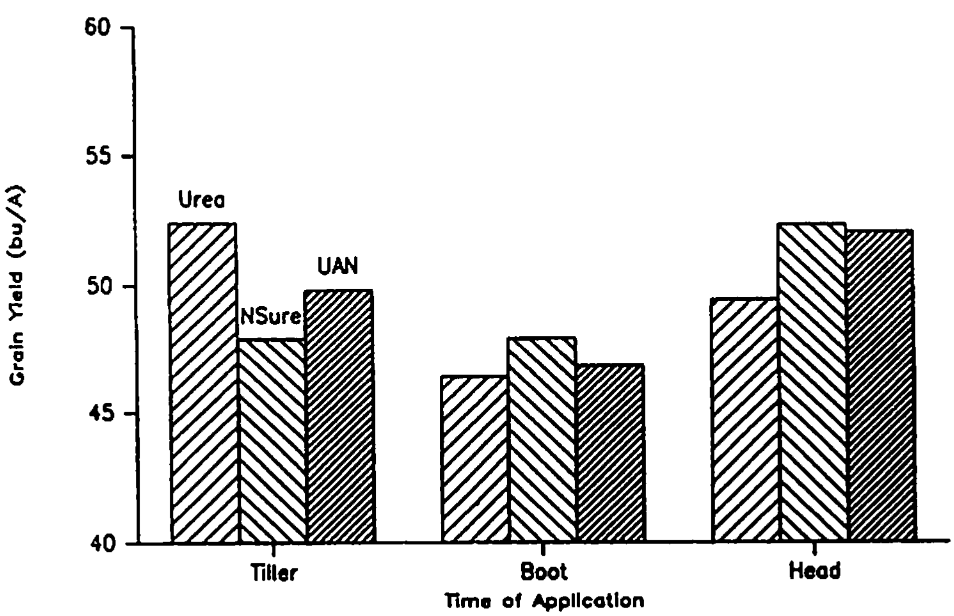

Figure 1. The interaction of N source and time of application on grain yield at Crookston, MN, 1987.

Forage Dry Matter Yield: At Morris the forage yield was not effected by any treatment. At Crookston the N rate increased the forage yield but the source x time x rate interaction was highly significant and in examining the data is not interuptable.

<u>N Uptake</u>: The N uptake was significantly increased at Crookston by only the N rate. It was increased from 85 lb to 98 lb N A^{-1} at the 80 lb N A^{-1} rate. The N uptake at Morris was not significantly effected by treatment although a trend towards increased N uptake with increasing N rate.

<u>PROTEIN</u>: Protein content in past several years in spring wheat has been a significant economic quality factor. At both Crookston and Morris the application of foliar N increased the protein content significantly 1.0% and 0.5% at Crookston and Morris, respectively (Table 2.). Source and time of application did not effect protein content. This is not what was expected. Normally, it is thought that the later N is applied, the more it will effect protein content where the earlier application will effect grain yield. This nonresponse may also be attributed to the dry weather conditions.

<u>WHOLE PLANT N</u>: To answer whether the addition of N did get into the plant, whole plant samples were taken at soft dough stage. At both locations, the addition of foliar did increase the whole plant N concentration. There were no time of application or N source effects.

Table 2. Grain yield, protein, forage yield, whole plant N, and N uptake at soft dough for foliar N study, Crookston and Morris, MN, 1987.

	Crookston					Morris				
Rate lb N A^{-1}	Grain Yield bu A^{-1}	Protein %	Forage Yield lb A^{-1}	Whole Plant N %	N Uptake @ Soft Dough lb N A^{-1}	Grain Yield bu A^{-1}	Protein %	Forage Yield lb A^{-1}	Whole Plant N %	N Uptake @ Soft Dough lb N A^{-1}
0	48.9	12.2	4614	1.83	85	58.7	13.5	6556	1.59	104
10	47.1	12.7	4305	1.89	81	58.1	13.7	6365	1.59	102
20	50.6	12.8	4893	1.85	91	58.5	13.7	6770	1.68	110
40	50.6	12.9	4871	1.88	91	56.8	13.9	6779	1.68	115
80	49.5	13.2	4875	2.03	98	55.2	14.0	6456	1.76	113
Urea	49.5	12.9	4765	1.90	90	58.0	13.9	6794	1.66	113
N Sure	49.4	12.8	4748	1.92	92	58.0	13.8	6546	1.68	110
UAN	49.5	12.9	4695	1.92	89	56.4	13.8	6438	1.67	107
Tiller	50.1	12.8	4784	1.91	91	55.4	14.0	6404	1.68	108
Boot	47.0	12.9	4525	1.95	88	57.6	13.8	6796	1.68	114
Head	51.4	12.9	4899	1.88	92	59.4	13.6	6576	1.65	108
Time	NS	NS	NS	NS	NS	NS	+	NS	NS	NS
Source	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate	*	**	**	*	**	+	**	NS	**	+
Source*Rate	NS	NS	NS	NS	NS	+	NS	NS	NS	NS
Time*Source	*	NS	+	+	+	NS	NS	NS	NS	NS
Time*Rate	NS	NS	NS	NS	NS	+	+	NS	NS	NS
Time*Source*Rate	NS	NS	**	NS	+	NS	NS	NS	NS	NS
C.V.	10.3	3.3	16.8	14.9	20.7	9.6	2.3	13.5	12.3	18.9

**, *, and NS are 0.01, 0.05, and 0.20 significant levels, respectively.

SUMMARY: The use of foliar applications of N for spring wheat in 1987 did cause small increases in grain protein. These increases may be economically important if the protein premium is substantial as it has been since 1985. The effect of source was mixed and in all probability muted by the moisture conditions which occurred at both locations early in the growing season. The N source did significantly effect the amount of leaf burn and in the next year of this study a better documentation of this will be done. Another question raised by this study is: would increased preplant soil application of N increase the protein content the same as a foliar application? Hopefully this can be answered in the future.

Split Application Study: In conjunction with the foliar N study, a second study was conducted to determine if a split application of foliar N would be more effective than the single application.

MATERIALS AND METHODS: Similar procedures to the foliar N study were followed in this study. Table 3 indicates the treatments.

Table 3. Treatments in split N study, 1987.

Treatment	Crookston	Morris
	-----lb N A^{-1} Applied Foliar----	
1. Check - base soil N rate	0 + 0	0 + 0
2. Tiller and boot	40 + 40	20 + 20
3. Tiller and head	40 + 40	20 + 20
4. Boot and head	40 + 40	20 + 20

RESULTS: At both locations the grain yield was not effected by the addition of foliar N (Table 4). At Morris the protein was not effected by the additional N, but at Crookston a trend toward increased protein did occur. This difference in protein response between locations could be caused by the fact that at Crookston twice as much N was applied foliar to the crop.

Table 4. Grain Yield and protein for split N study, Crookston and Morris, MN, 1987.

	Crookston					Morris	
	Grain Yield bu A^{-1}	Protein %	Plant Dry Wt. lb A^{-1}	Whole Plant N %	N Uptake lb N A^{-1}	Grain Yield bu A^{-1}	Protein %
Check	54.3	12.8	5496	1.69	93	54.1	13.5
T + B*	52.1	13.2	4296	2.02	89	52.5	13.6
B + H	53.0	13.4	5086	1.93	100	53.8	13.6
T + H	50.5	13.0	5001	2.20	111	49.5	13.6
Trt	NS	.14	NS	NS	NS	NS	NS
C.V.	8.1	1.4	19.3	17.1	28.5	10.1	1.0

* T=Tiller, B=Boot, and H=Head.

RESPONSE OF SPRING WHEAT TO RATE OF NITROGEN AND TIME OF APPLICATION

George Rehm, Ervin Oelke, Brian Schreiber

Fertilizer nitrogen management is one of the production factors when following the concepts of the Intensive Wheat Management Program. Adequate but not surplus amounts of nitrogen need to be available to the plants when following this approach for soils in Southeast Minnesota. The level of nitrogen in the soil is an environmental concern for wheat production as it is for corn and other crops grown.

Procedure

This study was conducted to evaluate (1) wheat plant response to nittogen rates and time of application, (2) monitor amount of NO_3-N in the soil during the growing season based on fertilizer nitrogen rates and time of application, and (3) grain protein content based on nitrogen and sulfur treatments.

The site of the study was on the Bob Johnson farm in Goodhue County on a Seaton Silt-Loam soil. Soil test results at planting time were: pH - 6.9; P - 39#/acre; K-252#/acre; organic matter of 2.5; and total NO_3-N of 90#/acre to a three foot depth.

Wheaton variety was planted on April 8. Plant count at the tillering stage was 20-22 plants per square foot. Stampede CM was applied at the rate of 2.5 pints/acre when the wheat plants were in the four leaf stage for foxtail weed control. Two applications of Mancozeb were applied at the rate of 2 pounds/acre - one at flag leaf stage followed by a second treatment 14 days later.

Weather conditions were dry prior to flag leaf stage followed by some timely rains. Temperatures were between 90-100°F. during and shortly after flowering stage. Stem maggot infestation affected 5-10 percent of the plants.

The nitrogen (ammonium nitrate) rates were 60-120#/acre. The time of application was 1) all prior to planting, 2) 1/2 rate prior to planting and 1/2 rate at flag leaf stage, 3) 1/2 rate prior to planting, 1/4 rate at tillering and 1/4 rate at flag leaf stage. A sulfur treatment of 30# actual S per acre was added to the 60 and 120# rate of nitrogen. All plots received 100# P_2O_5 and 200# K_2O per acre prior to planting.

Wheat plant response was measured in four ways - grain yield, straw yield, grain test weight and grain protein content.

Soil samples were taken from each treatment three times during the growing season - at tillering, flag leaf and after harvest. Four soil depths were measured - 0 to 6 inch, 6 to 12 inch, 12 to 24 inch and 24 to 36 inch.

Results and Discussion

There was no significant interaction between rate of nitrogen and time of application for any of the plant responses measured.

The nitrogen rate had a significant effect on the grain and straw yield and the grain protein content corrected to 12% moisture (Table 1). The rate of 60# N/acre was adequate for yield, but the protein content increased linearly with increased rates of nitrogen. Test weight was not effected by rate of nitrogen.

When compared to the treatment of all nitrogen applied prior to planting, the split applications of fertilizer nitrogen had no effect on straw or grain yields, test weight or grain protein content (Table 2).

The amount of NO_3-N in the soil increased with the rate of applied nitrogen for all three sampling times, except the 60# rate and when measured after harvest. Sampling times - 1 being tillering stage, 2 being flag leaf and 3 being after harvest (Table 3).

Frequency of nitrogen application had no significant effect on the amount of NO_3-N measured to a depth of three feet (Table 4).

At the 60# rate of nitrogen, the addition of sulfur had no effect on any of the plant responses measured. At the 120# rate of nitrogen grain yield response was significant, but there were no other plant responses (Table 5). This response however was from a limited number of treatments and from only one years results.

Conclusion

The results of this study are from only one year. Climatic conditions have a major influence on plant response and soil interaction. 1987 grain yields were low - county average is generally 45-55 bushels per acre.

To determine if time of application and rate of nitrogen would be economically beneficial, more sites should be selected and studied.

Acknowledgement

Appreciation is extended to Tim Wagar and Fritz Breitenbach, Extension Area Agents, Rochester for their help during the growing season.

Table 1. The effect of rate of fertilizer N on spring wheat grain and straw yield, test weight of the grain and protein content of the grain.

N Applied	Straw Yield	Grain Yield	Test Weight	Grain Protein
lb./acre	lb./acre	bu./acre	lb./bu.	%
0	4358	32.2	55.8	11.5
60	5253	38.2	55.7	13.3
120	5478	35.9	55.5	14.0

Table 2. The effect of frequency of N application on spring wheat grain and straw yield, test weight of the grain and protein content of the grain.

N Application Schedule	Straw Yield	Grain Yield	Test Weight	Grain Protein
	lb./acre	bu./acre	lb./bu	%
All preplant	5219	35.7	55.5	13.6
50% preplant 50% at flag leaf	5339	37.0	56.2	13.6
50% preplant 25% at tillering 25% at flag leaf	5540	38.5	55.9	13.8

Table 3. The effect of rate of fertilizer N on total amount of NO_3-N measured to a depth of 3 feet.

N Applied	Sampling 1	Sampling 2	Sampling 3
lb./acre	lb. NO_3-N /acre		
0	72.8	29.3	46.9
60	103.1	33.2	36.5
120	140.4	57.3	51.7

Table 4. The effect of frequency of N application on the total amount of NO_3-N measured to a depth of 3 feet.

N Application Schedule	Sampling 1	2	3
	------------lb. NO_3-N/acre-------------		
all preplant	134.2	55.4	50.3
50% preplant 50% at flag leaf	106.6	29.9	36.9
50% preplant 25% at tillering 25% at flag leaf	124.5	50.4	45.3

Table 5. Effect of sulfur applied with two rates of N on straw and grain yield of spring wheat, bushel weight of the grain and protein content of the grain.

Treatment N	S	Straw Yield	Grain Yield	Test Weight	Grain Protein
lb./acre		lb./acre	bu./acre	lb./bu	%
60	0	5135	36.7	56.0	13.1
60	30	5352	35.3	56.3	12.7
	Sig:	NS	NS	NS	NS
120	0	5303	34.7	57.9	14.1
120	30	5177	37.5	56.4	13.3
	Sig:	NS	*	NS	NS

* Difference between treatment means is significant at the .05 probability level.

EFFECT OF BROADCAST SULFUR ON CORN YIELD IN SOUTHEAST MINNESOTA

M.J. O'Leary and G.W. Rehm

Past research has shown that sulfur is needed on many of the sandy soils in Minnesota for optimum crop production. Questions arise concerning the possible need for S in a fertilizer program in southeast Minnesota. Many of the soils in this region are well drained with silt loam textures and low organic matter content. These soil properties increase the probability of a S response.

The objective of this study was to determine the effects of broadcast S on corn production in southeast Minnesota. Research was initiated in 1984 and results of previous years studies are reported in A Report on Field Research in Soils - Miscellaneous Publication 2, 1985 to 1987. Only results of 1987 field results are reported here.

Experimental Procedure:

Experiments were conducted in 1987 at two sites in Goodhue county. Soil classification and appropriate soil properties are listed in Table 1. There was no recent history of manure application at either site. Four rates of S (0, 10, 20, 40 lbs./acre) and four rates of N (0, 75, 150, 225 lbs./acre) were examined in a factorial arrangement replicated four times. Nitrogen and sulfur treatments along with recommended amounts of P and K were broadcast in early spring and incorporated with primary tillage. Granulated gypsum was used as the S source and urea was used as the N source. Ear leaf samples were collected at silking, dried, ground and analyzed for N and S. Plots were harvested in October for yield determination.

Results and Discussion:

Grain yields and the S and N concentration for ear leaf tissue are shown in Table 1. As would be expected, yields increased with the addition of N. Considering the relatively high yields response to N was not dramatic. A rate of 75 lbs. N/acre optimized yield at the Z87 site and 150 lbs. N/acre optimized yields at the J87 site. Sulfur had no effect on yield at the J87 site. Routine statistical analysis indicated a significant negative affect from the high rate of S on corn yield at the Z87 site. A more detailed analysis indicated that the yields from the control treatment was not significantly different from the yield of treatments that did receive S. A significant N x S interaction was measured at the J87 site, but a discernible trend is not obvious and the data does not provide an explanation for this observation.

Soil tests for S at these sites would be considered low or marginal based on the index that is used for sandy soils. Since no response was obtained, these result support previous findings which show that the soil test for S has no value in predicting a S response on non sandy soils.

Nitrogen concentration in ear leaf tissue increased with rate of applied N at each site but was not affected by S application. Sulfur concentration was affected in a similar manner. Concentration of S in ear leaf tissue at these sites was above the level generally considered to be critical (.18 - 20 % S).

Table 1. Selected soil properties and classification of the experimental sites used in 1987.

Property	Depth	Site Z87	Site J87
soil series		Timula	Seaton
pH	0-6	5.6	6.7
P, lb./acre	0-6	44	34
K, lb/acre	0-6	268	274
SO_4-S, ppm	0-6	6.5	8.0
"	6-12	6.5	5.8
"	12-24	4.5	1.8
"	24-36	5.2	2.8
"	36-48	5.0	2.5
"	48-60	4.8	3.5
Organic Matter,%	0-6	2.2	1.6
"	6-12	1.0	.4
"	12-24	.3	.1
"	24-36	.3	.2
"	36-48	.3	.2
"	48-60	.4	.3

Table 2. Effect of rate of broadcast N and S on yield and the ear leaf concentration of N and S of corn grown on silt loam soils in 1987.

Main Effects

S	J87	Z87	J87	J87	Z87	J87
lb./acre	-- bu/acre --		--- %S ---		----- %N -----	
0	179.7	177.5	.21	.21	3.10	2.89
10	180.8	179.1	.21	.23	2.90	2.81
20	176.6	172.2	.21	.22	3.08	2.88
40	180.6	166.7	.21	.23	2.99	2.95
sig.	ns	*	ns	ns	ns	ns
N						
lb.acre						
0	153.0	150.1	.18	.19	2.65	2.56
75	183.3	181.9	.21	.22	3.06	2.92
150	192.1	181.7	.22	.23	3.03	3.00
225	189.2	182.0	.23	.25	3.33	3.04
sig.	**	**	**	**	**	**
C.V. %	5.5	4.4	7.1	17.3	14.2	6.0

**, *, signifcant at .01 and .05 confidence level, respectively.

APPLICATION OF SULFUR IN A STARTER FERTILIZER FOR CORN PRODUCTION ON SILT LOAM SOILS

George Rehm, Andy Scobbie, Greg Cremers

Background and Justification:

Sulfur recommendations for corn production in Minnesota currently call for the use of this nutrient on sandy soils with medium to low organic matter levels. Since soil organic matter is the reservoir for sulfur in soils, many have asked if this nutrient should be added to fertilizer programs for corn where there are low organic matter soils with a silt loam texture.

Recent studies on similar soils in southeast Minnesota have shown a corn yield increase from broadcast sulfur at 2 of 8 experimental sites. Use of a starter fertilizer is a common practice in the region. Therefore, it seemed appropriate and logical to evaluate the effect of rate of sulfur applied in a starter for corn grown on these silt loam soils.

Experimental Procedure:

This study was conducted at four locations in southeast Minnesota in 1987. Soils that had an organic matter content of approximately 2% were selected. Prior to planting, soil samples were collected from 0-6, 6-12, 12-24, 24-36, 36-48, and 48-60 inches for purposes of site characterization. Selected soils properties are summarized in Table 1.

Sulfur was applied as 21-0-0-24 in a band to the side of and below the seed at planting at rates of 0, 6, 12, and 24 lb./acre. All plots also received 9-23-30 at a rate of 100 lb./acre as a starter fertilizer. The 9-23-30 was prepared by mixing equal quantities of 18-46-0 and 0-0-60. The N needed was supplied as 46-0-0- to provide 200 lb. N/acre. This N was broadcast and incorporated before planting.

A proven high yielding hybrid (Pioneer 3737) was planted in late April at a population of approximately 27,000 plants per acre at all sites. Weed control was achieved by using a preemergence application of a Lasso/Bladex combination.

Ear leaf samples were collected at silking, dried, ground, and analyzed for S. Grain yields were measured in mid-October and corrected to 15.5% moisture.

Results and Discussion:

Grain yields are summarized in Table 2. Although relatively high yields were recorded at all sites, use of S in a starter fertilizer had no significant effect on yield. There was some variability in yields but the low CV values indicate that there was an acceptable amount of precision in the study at each site.

Considering the soil test values for SO_4-S and organic matter and results from similar soils in 1984, 1985, and 1986, a response to S use was expected at the Goodhue (J) and Goodhue (Z) sites. These two sites had not been manured in recent years. Therefore, it appears that it is still not possible to predict with confidence silt loam sites in Minnesota where corn will respond to the use of fertilizer S.

The concentration of S in ear leaf tissue is summarized in Table 3. At each site, the rate of S applied in the starter fertilizer had no significant effect on the S concentration in the ear leaf tissue. It should be noted that S concentration values from control treatments at all sites were greater than .180 or .200 which are currently accepted "critical" levels for S in ear leaf tissue of corn. These levels of S from the control treatment indicate that, even with relatively high yields, the soils were capable of supplying adequate S for corn production. With adequate supplies of S in the root zone, dramatic increases in the S concentration of the ear leaf tissue would not be expected. The major portion of the S supplied by the soil is probably a result of mineralization of soil organic matter.

Table 1. Selected soil properties of the experimental sites used in 1987.

Property	Depth	Site Goodhue(J)	Goodhue(Z)	Goodhue(E)	Winona
pH	0-6	6.7	5.2	7.5	6.9
P, lb./acre	0-6	39	51	23	13
K, lb/acre	0-6	275	201	256	150
SO_4-S, ppm	0-6	8.0	2.0	6.0	-
"	6-12	5.8	4.8	6.8	-
"	12-24	3.5	4.3	5.8	-
"	24-36	2.5	3.5	7.3	-
"	36-48	2.8	4.3	4.8	-
"	48-60	1.8	3.8	5.8	-
Organic Matter,%	0-6	1.6	1.3	2.3	-
"	6-12	.5	.7	1.1	-
"	12-24	.3	.3	.5	-
"	24-36	.2	.2	.2	-
"	36-48	.2	.1	.2	-
"	48-60	.1	.1	.4	-

Table 2. Effect of rate of S applied in a starter fertilizer on yield of corn grown on silt loam soils in 1987.

S Applied	Goodhue(J)	Site Goodhue(Z)	Goodhue(E)	Winona
lb./acre		bu./acre		
0	204.5	195.9	187.3	179.4
6	207.2	199.5	195.6	191.3
12	211.0	189.2	191.5	181.2
24	208.0	192.6	186.3	178.2
CV:%	3.1	3.3	4.7	4.6

Table 3. Effect of rate of S applied in a starter fertilizer on the S concentration in ear leaf tissue of corn grown on silt loam soils in 1987.

	Site			
Applied	Goodhue(J)	Goodhue(Z)	Goodhue(E)	Winona
lb./acre	%S			
0	.225	.224	.210	.233
6	.239	.229	.223	.250
12	.239	.217	.208	.243
24	.245	.228	.231	.248
CV:%	6.3	5.3	6.5	6.8

EVALUATION OF THE RELATIONSHIP BETWEEN TILLAGE AND PLACEMENT OF P AND K IN A CORN - SOYBEAN ROTATION

George Rehm, Sam Evans, Wally Nelson and Gyles Randall

Background and Justification

Until recently farmers had limited choices for placement of P and K fertilizers for corn and soybean production. They could broadcast and incorporate the P and K before planting or apply these nutrients to the side of and below the seed at planting (starter). There has, however, been a renewed interest in placement of P and K fertilizers. This interest has been stimulated by a shift to conservation tillage systems where broadcast fertilizer is not incorporated and a desire to improve the efficiency of use of P and K. This study, therefore, was designed to evaluate the impact of placement of P and K fertilizers on the yield of corn and soybeans grown in two contrasting tillage systems.

Experimental Procedure

This study was initiated at 3 branch experiment stations (Waseca, Lamberton, Morris) in the fall of 1983 and continued through the 1987 growing season. Relevant soil properties measured at the initiation of the study are listed in Table 1. Corn was the test crop in 1984, 1985, and 1987. Soybeans were grown in 1986.

Four factors (tillage system, rate of applied P_2O_5 and K_2O, placement of P_2O_5 and K_2O, and starter fertilizer use) were evaluated at the Waseca and Morris locations. Space limitations dictated that fewer treatments be used at the Lamberton location. Therefore, only one rate of P_2O_5 and K_2O was used at Lamberton. The study was conducted on both low and high fertility sites at Waseca and Lamberton. Only one site (high fertility) was used at Morris.

A suspension fertilizer, 4-12-24, was used to supply the P_2O_5 and K_2O. One rate of P_2O_5 and K_2O (44 and 87 lb. per acre respectively) approximates removal of P and K by a typical corn crop. The second rate used was 1.5 times greater than the first rate cited.

The P_2O_5 and K_2O were either broadcast on the soil surface, applied in a band on the soil surface in the middle of existing rows or knifed in to a depth of 5 to 6 inches below the soil surface in the middle of existing rows. These treatments were repeated on the initial plots each year. Treatments were applied in late October. The fall chisel tillage operation is completed after fertilizer application.

For the ridge-till system, there is no tillage operation prior to planting. The fall chisel plots are disked in the spring before planting. A 7-21-7 at 100 lb. per acre is used as a starter fertilizer at the Waseca and Lamberton locations. At Morris, a 10-34-0 applied at 117 lb./acre is used as a starter fertilizer. Every effort is made to use management practices that will contribute to the highest yield at each location. Corn yields were measured with a plot combine at all locations. Yields are corrected to 15.5% before reporting.

Table 1. Selected soil properties (0-6 in.) for the experimental sites measured at the initiation of the study.

Soil Property	Location and Fertility Level: Waseca High	Waseca Low	Lamberton High	Lamberton Low	Morris High
pH	6.6	6.1	5.8	6.0	7.5
P (B&K #1), lb./acre	48	14	33	14	39
K (1N $NH_4C_2H_3O_2$), lb./acre	433	190	305	222	259
Organic Matter, %	3.5	3.5+	3.0	3.0	3.5+
Texture	CL*	CL	CL	CL	SIL

*CL = clay loam; SIL = silt loam

Results and Discussion

Morris Trials

None of the variables used had a significant effect on corn yield at this location (Table 2). Since rate of application did not affect yield, results from the use of the lower rate are listed.

The results recorded in 1987 are consistent with those from previous years. Placement of the P_2O_5 and K_2O had no effect where soil fertility levels are high. The effect of tillage has not been consistent at this site. Because of the warm, dry planting season, tillage system should not be expected to have any effect on yield.

Table 2. Effect of tillage system, fertilizer placement, and starter fertilizer use on corn yield at Morris when 44 lb. P_2O_5 and 87 lb. K_2O per acre were used.

Placement	Tillage System: Ridge-Till Starter	Ridge-Till No Starter	Ridge-Till Avg.	Fall Chisel Starter	Fall Chisel No Starter	Fall Chisel Avg.
	bu./acre					
None	155	162		172	163	
Broadcast	175	164	169	167	169	168
Surface Band	177	163	170	171	172	172
Subsurface Band	175	175	175	163	162	163
Avg.	176	167		167	168	

Lamberton Trials

Both tillage system and the placement of the P_2O_5 and K_2O and a significant effect on yield at the low fertility site at this location in 1987 (Table 3). There was no significant tillage x placement interaction.

Considering the tillage component, yields were higher where the fall chisel system was used. When averaged over all other variables, the yield difference due to tillage was approximately 3 bu./acre.

When averaged over the other variables, the broadcast treatment produced the highest grain yield. The lowest yield was produced by use of the subsurface band while the application of P_2O_5 and K_2O in a band on the surface produced yields that were intermediate. These results are somewhat inconsistent with those recorded in previous years and there is no apparent explanation for this lack of consistency.

Table 3. Effect of tillage system, fertilizer placement and starter fertilizer use on corn yield at the low fertility site at Lamberton when 44 lb. P_2O_5 and 87 lb. K_2O per acre were used.

	Tillage System					
	Ridge-Till			Fall Chisel		
Placement	Starter	No Starter	Avg.	Starter	No Starter	Avg.
	bu./acre					
None	---	102		---	112	
Broadcast	135	134	135	142	141	142
Surface Band	126	132	129	140	141	141
Subsurface Band	134	126	130	134	138	136
Avg.	132	131		139	140	

Both tillage system and method of fertilizer placement had a significant effect on corn grain yield at the high fertility site in 1987 (Table 4). When averaged over the other variables used, yields were 9 bu./acre higher when the fall chisel system was used. Considering placement, highest yields were produced by the broadcast application of the P_2O_5 and K_2O. The use of the surface band produced the lowest yield while yields resulting from the use of the subsurface band were intermediate.

The results from this site in 1987 are not consistent with results recorded in previous years. Except for a response from use of starter fertilizer in 1985, fertilizer use had not previously increased yield of either corn or soybeans when soil test levels for P and K were in the high range. There is no immediate explanation for the response measured in 1987.

Table 4. Effect of tillage system, fertilizer placement, and starter fertilizer use on corn yield at the high fertility site at Lamberton when 44 lb. P_2O_5 and 87 lb. K_2O per acre were used.

	Tillage System					
	Ridge-Till			Fall Chisel		
Placement	Starter	No Starter	Avg.	Starter	No Starter	Avg.
	bu./acre					
None	---	132		---	141	
Broadcast	139	139	139	150	145	148
Surface Band	132	128	130	148	134	141
Subsurface Band	139	134	137	141	147	144
Avg.	137	134		146	142	

Waseca Trials

The 1987 grain yields from the low fertility site at Waseca were significantly affected by the tillage system and the placement of the P_2O_5 and K_2O. The tillage x placement interaction was also significant (Table 5).

When averaged over other variables included in the study, average yield was 5 bu./acre higher when the ridge-till planting system was used.

The effect of placement was influenced by the tillage system used. For the ridge-till system, the band application produced the highest yield with broadcast and surface band placements producing lower yields. In the fall chisel system, the lowest yield was produced by the surface band application. The broadcast and subsurface band placement produced equal but higher yields.

These results are consistent with those recorded at this site in previous years when the use of the subsurface band in combination with a starter fertilizer has produced the highest yield.

Table 5. Effect of tillage system, fertilizer placement, and starter fertilizer on corn yield at the low fertility site at Waseca when 44 lb. P_2O_5 and 87 lb. K_2O per acre were used.

	Tillage System					
	Ridge-Till			Fall Chisel		
Placement	Starter	No Starter	Avg.	Starter	No Starter	Avg.
	bu./acre					
None	126	118		121	120	
Broadcast	158	163	161	163	159	161
Surface Band	161	159	160	150	151	151
Subsurface Band	166	163	165	161	157	159
Avg.	162	162		158	156	

Grain yield at the high fertility site was not significantly affected by any of the variables used in this study (Table 6). These results are consistent with those obtained at this site in previous years.

Table 6. Effect of tillage system, fertilizer placement, and starter fertilizer on corn yield at the high fertility site at Waseca when 44 lb. P_2O_5 and 87 lb. K_2O per acre were used.

	Tillage System					
	Ridge-Till			Fall Chisel		
Placement	Starter	No Starter	Avg.	Starter	No Starter	Avg.
	bu./acre					
None	162	168		166	165	
Broadcast	169	170	170	167	168	168
Surface Band	171	170	171	161	164	163
Subsurface Band	168	163	166	167	168	168
Avg.	169	168		165	167	

EFFECT OF RATE AND PLACEMENT OF POTASSIUM ON GROWTH AND YIELD OF CORN

George Rehm, Greg Cremers, Andy Scobbie

Background and Justification:

During recent years, there has been a substantial amount of interest in fertilizer placement. This is especially true for P and K. In addition to the traditional uses of either broadcast or starter application (fertilizer applied to the side of and below the seed at planting), equipment is now available to place either liquid or dry fertilizers some precise distance from the seed. With most of this new equipment, the fertilizer is placed in a band below the soil surface.

Earlier research in Minnesota had shown that the use of subsurface bands in combination with a starter fertilizer at low soil test levels for P and/or K looked promising as a management tool for more precise placement.

Soils in southeast Minnesota typically have low to medium levels of soil test K. These soils also usually have the ability to fix or "tie up" some of the fertilizer K used for crop production. In addition, substantial amounts of K are removed from the soil system when corn silage (a common use of corn) is harvested as part of the dominant dairy enterprise in the region.

The effect of placement of fertilizer K on corn production had not been studied extensively in Minnesota. Therefore, the study described in this report was designed to measure the effect of rate and placement of fertilizer K on growth and yield of corn in southeast Minnesota.

Experimental Procedures:

This study was conducted in Olmsted County. Prior to planting, soil samples were collected from 0-6, 6-12, 12-24, 24-36, 36-48, and 48-60 inches for site characterization. Results of the analysis of these samples are summarized in Table 1.

Table 1. Relevant soil properties of the experimental site.

Soil Property	Depth(in.) 0-6	6-12	12-24	24-36	36-48	48-60
pH	6.2	-	-	-	-	-
P, lb./acre	22	-	-	-	-	-
K, lb./acre	146	153	194	206	169	136
Organic Matter, %	3.3	-	-	-	-	-

A conventional tillage system was used. The plot area was plowed in early April and treatments were applied after the first disking operation.

The fertilizer K was either broadcast and incorporated, applied as a starter at planting, or applied as a subsurface band before planting. The K was supplied as 0-0-60. When broadcast, the rates of applied K were 0, 40, 80, 160, and 320 lb./acre. The rates were reduced to 0, 15, 30, 60, 120 lb. K/acre when applied in either the starter or the subsurface band. The subsurface band was placed at a depth of 5 to 6 inches in mid-April in the middle of 30 inch rows. All plots received a preplant application of 200 lb.N/acre as 46-0-0. The preplant N and broadcast K rates were incorporated with a light disking on the day of application.

Pioneer 3737 was planted on April 28 at a population of approximately 27,000 seeds/acre. All plots received a starter fertilizer which supplied 18 lb-N and 46 lb. P_2O_5/acre. A preemergence application of

Lasso and Bladex was used for weed control. Quackgrass was controlled by a post-emergence application of atrazine and oil.

Whole plant samples (6 plants/plot) were taken approximately 30 days after emergence. Ear leaf samples were collected at early silk. These plant samples were dried, ground and analyzed for K by routine ICP procedures. Uptake of K by the young plants was computed by multiplying early plant growth by K concentration. Grain yields were measured in mid-October and corrected to 15.5% moisture.

Data collected were analyzed statistically by standard regression and analysis of variance procedures. Because of the higher rates used for the broadcast applications, data from the broadcast treatments were analyzed separately.

Results and Discussion:

Grain Yield

When applied in a starter fertilizer or as a subsurface band, grain yield was increased by the rate of K applied (Table 2). Yield increases, however, were small, but were not affected by the position of the fertilizer band. When averaged over the starter and subsurface band placement, the application of 15 lb. K/acre produced an additional 6 bu. of corn/acre with no further increases from additional K.

When the applied K was broadcast and incorporated before planting, grain yields were not affected by the rate of K used (Table 3). The data collected do not provide a complete explanation for the lack of response to broadcast K.
Based on the soil test K values for the surface 0-6 in., a response to fertilizer K would be expected. The levels of soil test K in the subsoil, however, were much higher than typically found in the region. These relatively high levels of K in the subsoil can be used to explain the small increase in yield from banded applications of fertilizer K.

Early Growth

Considering the starter fertilizer and subsurface band, average early growth increased as rate of applied K increased to 30 lb./acre with no further increases from added K. The early growth was not affected by the placement of the band (starter vs. center of row).

In contrast to yield, early growth was improved by broadcast K applications (Table 3). The weight of the young plants increased linearly as rate of broadcast K was increased. These data show that effects of K on early growth are not necessarily reflected in yield.

K Concentration in Plant Tissue

The concentration of K in young corn plants increased as the rate of applied K increased (Tables 2 and 3). The K concentration in young plants was also affected by placement (Table 2) with concentrations being higher when K was applied in a starter rather than a subsurface band between the rows. This would be expected because of a higher percentage of the root system of the young plants being closer to the fertilizer K when a starter fertilizer is used. The K concentration in young plants also increased linearly as increased rates of K were broadcast (Table 3).

When applied in either a starter fertilizer or a subsurface band, the K concentration in the ear leaf tissue increased linearly with rate of K applied (Table 2). The placement of the band had no effect on K concentration. The K concentration in the ear leaf tissue also increased linearly with rate of K that was broadcast and incorporated (Table 3).
It should be noted that K concentrations in the ear leaf tissue are much lower than currently accepted critical levels. The data gathered in this study do not provide the explanation for these low values.

Table 2. Effect of rate of K applied in either a starter or subsurface band on grain yield, early growth and the K concentration in whole plant and ear leaf tissue.

K Applied	Grain Yield	Early Growth	K Conc. Whole Plant	K Conc. Ear Leaf
lb./acre	bu./acre	gm/6 plants	%	%
Starter:				
0	188	49	1.86	1.08
15	193	61	2.33	1.13
30	191	61	3.00	1.27
60	193	61	4.35	1.55
120	194	55	4.67	1.75
Subsurface Band:				
0	188	47	1.50	.99
15	191	55	2.10	1.20
30	186	62	2.26	1.19
60	192	54	2.65	1.46
120	191	62	3.82	1.77

Table 3. Effect of rate of broadcast K on grain yield, early growth and K concentration in whole plant and ear leaf tissue.

K Applied	Grain Yield	Early Growth	K Concentration	
			Whole Plant	Ear Leaf
lb./acre	bu./acre	gm/6 plants	------ % ------	
0	192	52	1.86	1.20
40	195	54	2.12	1.22
80	193	58	2.41	1.41
160	195	57	3.20	1.65
320	198	63	4.23	2.10

Summary

Although soil test values for K in the surface soil were in the low to medium range, K applied in either a starter fertilizer or a subsurface band between the rows produced only small increases in grain yield with 15 lb. K/acre being adequate. Broadcast applications of fertilizer K had no impact on yield. Subsoil K values were higher than what is considered to be typical. This ample supply of K in the subsoil probably reduced the degree of response to fertilizer K.

The rate of K applied did increase the K concentration in whole plant and ear leaf tissue. The K concentration, however, was not related to yield.

EVALUATION OF THE EFFICIENCY OF BAND PLACEMENT OF P FERTILIZER FOR CORN, SOYBEAN, AND WHEAT

J.A. Lamb, G.W. Rehm, G.W. Randall, and W.W. Nelson

INTRODUCTION: Efficient P fertilizer use is continuing to be an important area of production management for finding the least cost method of production. Little information is available in the Northern Corn Belt about which methods of application are best. Winter wheat growing areas (Kansas, Nebraska and Colorado), have found that a starter or row application of P can be many times more efficient than a broadcast application. This report is concerned with the results of the second year of a study conducted in Minnesota with the overall objective to evaluate the efficiency of band placement methods (starter, and knife) for spring wheat, corn an soybean over the northern corn belt. Under this broad objective the two following specific objectives will be addressed.

1) Determine the efficiency of band applications of P as compared to broadcast on a spring wheat - soybean rotation in northwestern Minnesota and corn-soybean rotation at two locations in southern Minnesota.

2) Determine residual effects of band and broadcast placements of fertilizer P on P uptake and crop yield.

MATERIALS AND METHODS: The second of three years of this study was conducted in 1987 at Waseca, Lamberton, and Crookston, MN. Corn and soybean were grown at Waseca and Lamberton with spring wheat and soybean grown at Crookston. Table 1 presents the soil test information for each location. The following variables were measured on corn at Waseca and Lamberton; grain yield, forage yield, forage P concentration and uptake, ear leaf P concentration at silking, and grain moisture content. Soybean variables measured at all locations were: grain yield, forage yield, forage P concentration and uptake, leaf P concentration at mid-flower, and grain moisture. At Crookston the parameters measured on the wheat were grain yield, grain protein content, bushel weight, grain moisture content, forage yield, and whole plant P concentration and uptake at anthesis. The grain moisture has been incorporated into the grain yield data. The corn, soybean, and wheat grain yields have been corrected to 15.5, 13.5 and 13.5% moistures, respectively. The wheat protein values are reported on a 13.5% moisture basis.

Table 2 lists the treatments that were established on all six sites. Four replications of a complete factorial arrangement of three methods of phosphorus placement and five phosphorus rates were established. The broadcast method was incorporated at all locations. The knife method at Waseca (corn and soybean) and Lamberton (corn and soybean), placed a preplant band of fertilizer at a 6-inch depth between the 30 inch width rows. At the Crookston (spring wheat) site the knife method placed preplant fertilizer 6 inches deep with a shank spacing of 15 inches. The knife method for Crookston soybean was two 15" width preplant bands between the 30" rows applied at a 6" depth. The starter method at Waseca (corn and soybean), Lamberton (corn and soybean), and Crookston (soybean) involved a band of fertilizer applied at planting 5 to 7 inches from the row and 2.5 to 3 inches deep. The Crookston (spring wheat) site starter treatment involved placement of fertilizer directly with the seed at Waseca and Lamberton. The phosphorus rates were 0, 10, 20, 30 and 40 lb P A^{-1}. At Crookston, the rates were 0, 5, 10, 15 and 20 lb P A^{-1}. Ammonium polyphosphate, 10-34-0, was the P source at all locations. Three extra treatments were added to the factorial to test effect of combined application methods. These were 20 + 20 lb P A^{-1} (5 + 5 lb P A^{-1} at Crookston) broadcast + knife, broadcast + row, and row + knife (Table 2). They were analyzed statistically as a method comparison with the broadcast, knife, and row treatment at the 40 lb P A^{-1} levels (10 lb P A^{-1} at Crookston).

Table 1. Soil test values for P-efficiency study, 1987.

	Crookston*		Waseca**		Lamberton**	
	Soybean	Wheat	Soybean	Corn	Soybean	Corn
pH	7.8	7.9	5.9	5.9	6.2	6.1
OM%	3.0	2.4	3.5	3.5	3.8	3.9
Salts mmho	0.2	0.4	-	-	-	-
NO_3^--N 0-24"	31	18	-	-	-	-
P lb A^{-1}	10	9	10	10	3	7
K lb A^{-1}	230	240	331	382	259	290

* $NaHCO_3$-P
** Bray-P

Table 2. Treatment description for project MN-1L.

Treatment Number	Factor: Placement	Factor: P Rate # P/A
1	Broadcast	0**
2	Broadcast	10
3	Broadcast	20
4	Broadcast	30
5	Broadcast	40
6	Knife *	0
7	Knife *	10
8	Knife *	20
9	Knife *	30
10	Knife *	40
11	Starter +	0
12	Starter +	10
13	Starter +	20
14	Starter +	30
15	Starter +	40
16	Broadcast + Knife	20 + 20***
17	Broadcast + Starter	20 + 20***
18	Knife + Starter	20 + 20***

* 15-inch width at wheat-soybean location.
\+ 5-7 inches from row in soybean and corn - applied with seed in spring wheat.
** P rates are 0, 5, 10, 15, and 20 pounds P per acre at Crookston in 1987.
*** At Crookston the P rate was 5 + 5.

Broadcast and knife applied: Crookston October 15, 1986
Lamberton October 28, 1986
Waseca November 4, 1986

Starter applied: Crookston June 1, 1987 - Soybean
Crookston April 21, 1987 - Spring Wheat
Lamberton April 23, 1987 - Corn
Lamberton May 21, 1987 - Soybean
Waseca May 5, 1987 - Corn and Soybean

<u>Factorial Experiment</u>: <u>Corn</u> - Grain yield, ear leaf P, forage yield, whole plant P, and P uptake were increased significantly by P fertilization at both Waseca and Lamberton, Tables 3 and 4. The rate response for grain yield was quadratic in nature maximizing yield at 30 lb P A^{-1} at Waseca and 40 lb P A^{-1} at Lamberton. At Waseca, there was no difference in any of the measured parameters from method of application.

At Lamberton there was a significant method response for grain yield and ear leaf P. With grain yield, broadcast application performed best, knife intermediate and finally starter performing the poorest. This is contrary to other results reported for corn. Normally if there is an advantage to method of application the starter application method is superior to broadcast. The ear leaf P contents indicate the highest concentration occurred in plants treated with the knife application method. The starter application had the lowest P concentration with the broadcast treatment intermediate. Forage yield response to the P fertilizer at Lamberton was quadratic and yield was maximized at 30 lb P A^{-1}. The P concentration data for method effects does not indicate the same result. At Waseca, forage yield response was linear with the greatest yield occurring at 40 lb P A^{-1}. At both Lamberton and Waseca, whole plant P concentration and P uptake increased linearly to P applications. Forage yield, whole plant P, and P uptake were not effected by method of application at either location.

<u>Soybeans</u> - The application of P fertilizer caused positive responses in grain yield, leaf P, forage yield, whole plant, and P uptake at Waseca and Lamberton, Table 3. Forage yield, Plant P and P uptake was effected at Crookston, Table 5. Lamberton forage yield, Waseca whole plant P, Waseca P uptake, and Crookston forage yield had quadratic responses while the other effects responded linearly. The maximum forage yield occurred at 40 lb P A^{-1} and 5 lb P A^{-1} at Lamberton and Crookston, respectively. The maximum whole plant P and P uptake at Waseca occurred at 40 lb P A^{-1}. The method of application significantly effected leaf P at Waseca, whole plant P at Lamberton, grain yield at Lamberton, and forage yield and P uptake at Crookston. At Waseca, the leaf P concentrations were significantly lower in the plants with the broadcast application of P than the knife or starter applications. The leaf P concentrations in starter and knife treatments were similar. The whole plant P concentrations at Lamberton were greater with broadcast application compared with knife and starter. No difference occurred between knife and starter application. The broadcast method produced the greatest grain yield (36 bu A^{-1}) at Lamberton. The starter and knife treatments performed similarly (33.4 and 34.8 bu A^{-1}, respectively). This response is similar to 1986 data. At Crookston the starter application treatment produced the greatest forage yields and P uptake. The broadcast treatments did the poorest with the forage yields and P uptake from knife applied plants intermediate.

<u>Wheat</u> - Grain yield, forage yield and P uptake were increased by P fertilization at Crookston, Table 5. The grain yield was greatest at the 20 lb P A^{-1} rate and was not maximized. The forage yield response was quadratic and maximized at 15 lb P A^{-1}. P uptake response was linear and corresponded to grain yield results. No method of application response occurred to any of the measured parameters.

<u>Summary</u>: Of the six site locations, five had grain yield increases from P fertilization. In most instances, there was no method of application response (Crookston wheat, Waseca corn, and Waseca soybeans). At Lamberton on corn and soybean, broadcast application produced superior grain yields with the band applications (knife and starter) comparing similarily to each. This infers an advantage to dealers in Minnesota. A cheaper and easier application, broadcast, can be used, thus special adaptation of knives is not needed. The soybean data coincides with past results. Because of the soybean's later corn andnot wheatdoes data planting and pattern of P uptake, no advantage to a banded application would occur. Thecorrespond with observations in other experiments. Normally the starter placement is the optimum placement. At Lamberton the broadcast performed the best. At this time no explanation can be given.

<u>Application Experiment</u>: The results from the split application experiment are listed in Tables 6, 7 and 8. The statistics suggest that there were some differences among treatments. In most cases, the differences are from the response to P fertilizer and not from the mixed applications. It can be concluded that the use of mixed applications is not more advantageous than a single application of one method.

Table 3. Means and statistical analyses for Lamberton soybean and corn, 1987.

		Soybean					Corn				
Method	P Rate lb P/A	Trifoliate P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A	Ear Leaf P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A
Broadcast	0	0.312	5615	0.199	11.21	31.1	0.182	12855	0.128	16.51	110.4
	10	0.331	5085	0.205	10.38	33.2	0.196	13285	0.136	18.07	121.8
	20	0.336	5540	0.230	12.76	36.8	0.230	13230	0.155	20.60	135.0
	30	0.403	5685	0.225	12.78	36.2	0.221	13785	0.144	19.80	128.3
	40	0.353	5780	0.228	13.31	37.9	0.239	13455	0.155	20.92	142.4
Knife	0	0.291	5745	0.188	10.70	32.1	0.180	12210	0.132	16.28	110.0
	10	0.340	5485	0.181	9.97	34.0	0.198	13455	0.127	17.06	125.0
	20	0.351	5550	0.206	11.43	33.5	0.224	13305	0.121	16.03	125.7
	30	0.378	5580	0.211	11.85	36.4	0.241	14485	0.138	20.09	127.1
	40	0.401	6005	0.220	13.22	35.3	0.253	14165	0.160	22.71	134.4
Row	0	0.285	5715	0.190	10.82	31.0	0.162	12150	0.123	15.00	113.6
	10	0.327	5285	0.182	9.60	30.6	0.185	13530	0.131	17.88	124.0
	20	0.357	5945	0.189	11.18	33.7	0.222	14200	0.145	20.61	122.2
	30	0.407	5990	0.217	12.91	31.9	0.200	13365	0.148	20.35	122.6
	40										
P Rate #/A	0	0.296	5692	0.193	10.93	31.4	0.174	12405	0.128	15.93	111.3
	10	0.332	5285	0.189	9.99	32.6	0.193	13423	0.131	17.67	123.6
	20	0.348	5678	0.208	11.79	34.7	0.225	13578	0.140	19.08	127.6
	30	0.396	5752	0.218	12.51	34.8	0.221	13878	0.134	18.64	126.9
	40	0.401	6097	0.222	13.54	36.9	0.239	13792	0.154	21.32	133.1
Method											
Broadcast		0.356	5522	0.222	12.31	36.0	0.221	13438	0.148	19.85	131.9
Knife		0.367	5656	0.204	11.62	34.8	0.229	13852	0.136	18.97	128.0
Starter		0.385	5932	0.201	11.95	33.4	0.208	13712	0.136	18.73	123.5
Method		NS	.16	.06	NS	.04	**	NS	.16	NS	.04
P Rate		**	.016	.02	**	**	**	**	**	**	**
Linear		**	.013	**	**	**	**	**	**	**	**
Quadratic		NS	.04	NS	NS	NS	.04	**	NS	NS	.07
Method x P Rate		NS	NS	NS	NS	NS	NS	.14	NS	.12	NS
C.V.		13.9	9.5	13.3	16.8	7.3	7.6	5.3	13.0	15.6	6.6

** is 0.01 significance levels.

Table 4. Means and statistical analyses for Waseca soybean and corn, 1987.

		Soybean					Corn				
Method	P Rate lb P/A	Trifoliate P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A	Ear Leaf P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A
Broadcast	0	0.379	4727	0.195	9.27	35.8	0.159	12175	0.110	13.64	119.1
	10	0.423	5150	0.247	12.62	41.9	0.186	13480	0.109	14.90	129.2
	20	0.461	5575	0.265	14.91	43.9	0.218	14860	0.128	19.27	144.0
	30	0.465	5480	0.251	13.67	44.3	0.260	15070	0.142	21.38	147.9
	40	0.503	5849	0.316	18.52	44.7	0.249	14795	0.133	19.69	146.9
Knife	0	0.409	5040	0.205	10.42	42.6	0.168	13880	0.111	15.60	135.5
	10	0.449	5390	0.251	13.62	43.3	0.219	14535	0.121	17.63	138.0
	20	0.478	5365	0.291	15.60	43.4	0.230	15345	0.122	18.79	152.7
	30	0.482	4935	0.274	13.57	43.4	0.248	14910	0.128	19.10	156.6
	40	0.531	5465	0.286	15.57	46.4	0.253	15900	0.131	20.78	143.7
Row	0	0.388	4825	0.189	9.08	39.2	0.146	12455	0.108	13.55	121.8
	10	0.438	4770	0.272	13.02	39.0	0.190	13410	0.103	13.98	144.0
	20	0.455	5460	0.291	15.90	42.8	0.226	14370	0.109	15.70	149.2
	30	0.498	5545	0.273	15.03	45.8	0.245	15865	0.136	21.68	150.9
	40	0.535	5640	0.298	16.83	47.4	0.263	15550	0.133	20.67	146.3
P Rate #/A	0	0.392	4863	0.196	9.59	39.2	0.158	12837	0.110	14.26	125.5
	10	0.437	5103	0.257	13.09	41.4	0.199	13808	0.111	15.50	137.1
	20	0.465	5467	0.282	15.47	43.4	0.225	14858	0.120	17.92	148.6
	30	0.482	5320	0.266	14.09	44.5	0.251	15282	0.136	20.71	151.8
	40	0.523	5653	0.300	16.97	46.2	0.255	15415	0.132	20.38	145.6
Method											
Broadcast		0.463	5515	0.270	14.93	43.7	0.228	14551	0.128	18.81	142.0
Knife		0.485	5289	0.275	14.59	44.1	0.238	15173	0.126	19.08	147.7
Starter		0.482	5354	0.284	15.20	43.7	0.231	14799	0.120	18.01	147.6
Method		.06	NS	NS	NS	NS	NS	NS	NS	NS	NS
P Rate		**	**	**	**	**	**	**	**	**	**
Linear		**	**	**	**	**	**	**	**	**	**
Quadratic		NS	NS	.02	.04	NS	**	.11	NS	NS	**
Method x P Rate		NS	NS	NS	NS	.15	NS	NS	NS	NS	NS
C.V.		6.0	10.5	13.7	16.1	6.6	11.3	9.1	12.6	17.5	9.0

** is 0.01 significance level.

Table 5. Means and statistical analyses for Crookston soybean and spring wheat, 1987.

		Soybean				Spring Wheat						
Method	P Rate lb P/A	Trifoliate P %	Plant P	Forage Yield lb/A	P Uptake %	Grain Yield Bu/A	Plant P	Forage Yield lb/A	P Uptake %	Grain Yield Bu/A	Bu. Wt. lb/Bu	Grain Protein %
Broadcast	0	0.389	0.247	4878	11.99	31.4	0.265	6034	15.85	65.2	61.9	12.1
	5	0.408	0.242	5149	12.59	33.1	0.284	6500	18.43	70.3	61.9	12.0
	10	0.385	0.220	4902	10.70	32.3	0.289	6621	18.86	69.2	62.0	12.0
	15	0.424	0.242	5337	12.89	33.3	0.247	7680	19.13	72.0	61.8	11.7
	20	0.393	0.267	5252	14.07	30.7	0.281	6762	19.26	68.8	61.9	12.2
Knife	0	0.388	0.222	5264	11.68	32.5	0.257	5213	13.45	57.7	61.9	12.4
	5	0.401	0.258	5562	14.30	32.2	0.265	6995	18.64	69.9	61.7	11.7
	10	0.400	0.232	5278	12.37	31.5	0.243	6837	16.60	63.3	61.6	12.3
	15	0.403	0.249	5587	14.12	31.5	0.279	7001	19.63	65.8	61.8	12.1
	20	0.414	0.250	5321	13.48	31.4	0.274	6805	19.07	72.0	61.5	12.0
Starter	0	0.396	0.229	4868	11.16	32.2	0.275	5505	15.00	57.3	62.0	12.3
	5	0.404	0.225	6218	14.44	32.5	0.261	6509	16.64	61.0	61.5	12.1
	10	0.401	0.234	6194	14.62	32.4	0.284	6663	18.93	69.4	62.0	12.0
	15	0.384	0.269	5814	15.61	32.0	0.300	6997	20.56	69.1	61.9	11.7
	20	0.410	0.254	5267	13.48	32.6	0.301	6666	20.10	71.4	61.8	11.8
P Rate #/A	0	0.391	0.233	5004	11.61	32.1	0.265	5584	14.77	60.1	61.9	12.3
	5	0.404	0.242	5643	13.78	32.6	0.270	6668	17.90	67.1	61.7	11.9
	10	0.396	0.229	5458	12.56	32.1	0.272	6707	18.13	67.3	61.9	12.1
	15	0.405	0.252	5558	14.08	32.3	0.275	7226	19.77	69.0	61.8	11.8
	20	0.406	0.257	5280	13.67	31.6	0.285	6744	19.48	70.8	61.7	12.0
Method												
Broadcast		0.402	0.243	5160	12.56	32.4	0.275	6891	18.92	70.1	61.9	12.0
Knife		0.404	0.247	5437	13.57	31.7	0.265	6909	18.48	67.7	61.6	12.0
Starter		0.401	0.244	5877	14.47	32.4	0.287	6709	19.06	67.7	61.8	11.9
Method		NS	NS	.02	.06	NS	NS	NS	NS	NS	NS	NS
P Rate		NS	.08	.13	.04	NS	NS	**	.02	**	NS	NS
Linear		NS	.03	NS	.03	NS	NS	**	**	NS	NS	NS
Quadratic		NS	NS	.03	NS	NS	NS	**	.18	NS	NS	NS
Method x P Rate		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.		5.9	11.5	11.8	16.2	6.8	14.8	13.8	20.5	9.9	1.1	4.6

** is 0.01 significance level.

Table 6. Means and statistical analyses for split application study for Lamberton soybean and corn, 1987.

	Soybean					Corn				
Treatment	Trifoliate P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A	Ear Leaf P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A
B + K 20 + 20	0.380	5695	0.228	12.99	35.0	0.244	13780	0.158	21.62	134.1
B + S 20 + 20	0.384	5280	0.239	12.68	37.8	0.239	14300	0.166	23.74	134.6
K + S 20 + 20	0.421	5755	0.226	12.96	36.1	0.241	14950	0.169	25.33	133.3
B 40	0.353	5780	0.228	13.31	37.9	0.239	13455	0.155	20.92	142.4
K 40	0.401	6005	0.220	13.22	35.3	0.253	14165	0.160	22.71	134.4
S 40	0.448	6505	0.217	14.09	37.4	0.226	13755	0.148	20.35	122.6
Check	0.296	5692	0.193	10.93	31.4	0.174	12405	0.128	15.93	111.3
Treatment	**	.10	.14	.15	**	**	**	**	**	**
C.V.	11.6	9.2	14.1	16.8	5.8	7.9	6.3	11.6	14.4	5.1

** is 0.01 significance level.

Table 7. Means and statistical analyses for split application study for Waseca soybean and corn, 1987.

	Soybean					Corn				
Treatment	Trifoliate P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A	Ear Leaf P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A
B + K 20 + 20	0.487	5625	0.322	18.04	45.0	0.251	15255	0.133	20.44	149.3
B + S 20 + 20	0.492	6095	0.304	18.37	46.9	0.250	15500	0.130	20.13	162.0
K + S 20 + 20	0.515	5460	0.257	13.97	42.2	0.258	14150	0.137	19.43	149.0
B 40	0.503	5849	0.316	18.52	44.7	0.249	14795	0.133	19.69	146.9
K 40	0.531	5465	0.286	15.57	46.4	0.253	15800	0.131	20.78	143.7
S 40	0.535	5640	0.298	16.83	47.4	0.263	15550	0.133	20.67	146.3
Check	0.392	4863	0.196	9.59	39.2	0.158	12837	0.110	14.26	125.5
Treatment	**	**	**	**	**	**	**	**	**	**
C.V.	5.0	9.4	14.8	14.6	7.8	10.3	8.7	8.5	13.5	11.1

** is 0.01 significance level.

Table 8. Means and statistical analyses for split application study for Crookston soybean and wheat, 1987.

	Soybean					Spring Wheat					
Treatment	Trifol-late P %	Plant P %	Forage Yield lb/A	P Uptake lb/A	Grain Yield Bu/A	Plant P %	Forage Yield lb/A	P Uptake lb/A	Grain Yield Bu/A	Bushel Wt. lb/Bu	Grain Protein %
B + K 5 + 5	0.471	0.242	5452	13.16	30.2	0.284	7531	21.72	67.9	61.2	11.8
B + S 5 + 5	0.398	0.270	5392	14.52	33.6	0.266	7238	19.39	70.9	62.4	11.9
K + S 5 + 5	0.418	0.252	5766	14.52	33.6	0.260	7929	20.55	75.4	61.1	11.6
B 10	0.385	0.220	4902	10.70	32.3	0.289	6621	18.86	69.2	62.0	12.0
K 10	0.400	0.232	5278	12.37	31.5	0.243	6837	16.60	63.3	61.6	12.3
S 10	0.401	0.234	6194	14.62	32.4	0.284	6663	18.93	69.4	62.0	12.0
Check	0.391	0.233	5004	11.61	32.1	0.265	5584	14.77	60.1	61.9	12.3
Treatment	NS	NS	.10	.04	NS	NS	**	.05	**	.07	NS

** is 0.01 significance level.

EFFECT OF GYPSUM AND BORON AMENDMENTS ON POTATO YIELD AND INCIDENCE OF INTERNAL TUBER QUALITY DISORDERS

C. Rosen, J. Bartz and F. Lauer

Preharvest internal tuber quality disorders such as brown center and hollow heart are of great concern to potato growers. In severe cases, these disorders make the produce unmarketable and consequently may result in considerable losses for the grower. In many cultivars such as Russet Burbank, brown center is generally considered to precede hollow heart. Susceptibility to brown center and hollow heart has been related to environmental conditions and genotype. Conditions which promote large tubers and periods of fast growth favor the development of internal disorders. In Russet Burbank, cool temperatures coupled with high soil moisture often lead to a high incidence of hollow heart. Another potato cultivar which shows a high incidence of brown center and hollow heart under certain conditions is Reddale. When grown in the Red River Valley (non-irrigated fine-textured soils), Reddale generally has very good quality. However, when grown in the irrigated sands of central Minnesota, it generally performs poorly due to a high incidence of brown center and hollow heart. One major attribute of Reddale in either environment is that it shows a high degree of resistance to Verticillium wilt, a major cause of early dieback in potato. The most popular red potato grown in central Minnesota is Norland which is susceptible to Verticillium wilt. A reduction in the incidence of brown center in Reddale would make this cultivar more useful to growers which in turn would reduce losses due to early dieback. Because calcium and boron soil levels can be low in the sandy soils of central Minnesota, the role of these nutrients in brown center and hollow heart was investigated. The purpose of this experiment was to determine the influence of gypsum and boron soil amendments on potato productivity and incidence of tuber disorders in Reddale, Russet Burbank and Krantz potatoes. Krantz was included as a cultivar resistant to internal quality disorders.

Materials and Methods

This experiment was conducted at the Sand Plains Research Farm in Becker, MN. The soil, a Hubbard Loamy Sand had the following soil chemical properties prior to planting (0-6"): pH, 6.3; P, 109 lb/A; K, 239 lb/A; Ca, 1105 lb/A; S, 5 ppm; B, 0.2 ppm. The previous crop was sweet corn. Prior to planting, 0-0-22 at the rate of 250 lbs/A was broadcast and incorporated. Four nutritional treatments were evaluated: 1) control, 2) 1.0 lb/A B as solubor applied at hilling, 3) 500 lb/A Ca as gypsum preplant broadcast and incorporated, and 4) 1.0 lb/A B at hilling and 500 lb/A Ca preplant. Gypsum was applied by hand and incorporated one week prior to planting. Solubor treatments were applied by hand and then incorporated during hilling. Reddale, Russet Burbank, and Krantz certified seed were planted by hand on April 13 at a spacing of 3' between rows and 1' within the row. A 3 X 4 factorial treatment arrangement was used with 4 replications in a randomized complete block design. After planting, all cultivars received 1000 lbs/A of 8-10-30 as a band application. Nitrogen, as ammonium nitrate, was sidedressed at emergence (70 lb N/A) and at hilling (70 lb N/A). The most recently matured leaves from each cultivar were sampled on July 8. Samples were dried, ground, and then analyzed for Ca and B using ICP procedures. Two days prior to harvest, soil samples from the top 12 inches in the middle of the hill were collected air dried and analyzed for Ca, S, and B. All cultivars were harvested on September 22. Subsamples of 20 tubers per size category for each cultivar were collected for quality evaluation.

Results

Gypsum and boron soil amendments increased soil test levels of Ca, S, and B (Table 1). Boron levels in the treated plots were still in a range considered low for most crops. Soil Ca increased slightly with gypsum application; however, the check plot had Ca levels considered adequate for crop growth. Soil S increased from a level in the low range in the check plot to a relatively high level in the gypsum treated plots.

At the rates applied, gypsum and/or B amendments had no effect on potato yield (Table 2). Reddale died back early due to an apparent preferential infestation of European corn borer. Despite this early dieback, Reddale yield was greater than either Russet Burbank or Krantz. The yield of Reddale was made up largely of jumbo size potatoes which is an undesirable size for fresh market potato production.

Tissue levels of B and Ca varied with cultivar (Table 3). Krantz had the highest concentrations of B and Ca, Russet Burbank the lowest and Reddale was intermediate. Gypsum applications did not significantly increase leaf tissue Ca levels. Boron applications increased tissue B in all three cultivars.

Because of significant interactions between cultivar and soil amendments, the effect of B and/or gypsum on tuber quality was analyzed separately for each cultivar. Neither of the amendments alone or in combination reduced the incidence of brown center or hollow heart in jumbo Reddale potatoes (Table 4). In the smaller A size potatoes, gypsum and gypsum plus boron significantly reduced the incidence of internal quality disorders compared to the check plot. Boron alone tended to lower incidence of brown center and hollow heart, but the effect was not significant. In the B size category, brown center and hollow heart were virtually nonexistent. There was no effect of gypsum or B amendments on Russet Burbank tuber quality (Table 5). The internal disorders of Russet Burbank were somewhat different than those of Reddale. The hollow heart in Russet Burbank was located more near the end of the tuber as a horizontal cavity. In contrast, The hollow heart in Reddale was more in the center of the tuber, more widespread and usually was much darker. These differences may imply that the internal disorder of Reddale is not the same as the internal disorder of Russet Burbank. Krantz did not show any sign of hollow heart or brown center in treated or untreated plots (Table 6). If tuber quality disorders have been a problem in a particular area, Krantz would be a good cultivar to grow.

Further studies are planned with Reddale to determine whether higher rates of boron and cultural manipulation to reduce tuber size can be used to lower the incidence of internal tuber quality disorders.

Table 1. Effect of gypsum and boron amendments on soil test B, Ca and S (0-12") at harvest. (Averaged over cultivar).

Treatment	Element		
	Calcium lb/A	Boron	Sulfur
		-------- ppm ---------	
Check	1148	0.28	4.7
Boron	1182	0.41	5.3
Gypsum	1285	0.28	31.2
Boron + Gypsum	1363	0.44	60.4
Significance	**	**	**
BLSD (0.05)	115	0.07	12.1

Table 2. Effect of gypsum and boron on yield of Reddale, Russet Burbank and Krantz.

Treatment	Tuber Size Distribution				
	< 3 oz.	3-7 oz.	7-12 oz.	> 12 oz.	total
Reddale	cwt/A				
Check	8.7	87.7	321.5	230.5	648.4
Boron	10.1	91.1	311.4	231.6	644.2
Gypsum	7.7	79.7	331.0	207.0	625.4
Boron + Gypsum	6.2	77.5	289.8	269.5	643.0
Russet Burbank					
Check	13.1	350.1	200.3	19.1	582.6
Boron	11.8	286.9	272.1	23.8	594.6
Gypsum	15.0	300.9	265.3	41.4	622.6
Boron + Gypsum	14.1	268.3	287.4	29.8	599.6
Krantz					
Check	12.7	116.7	452.9	55.7	638.0
Boron	11.4	109.1	417.7	62.8	601.0
Gypsum	9.9	94.9	389.5	53.5	547.8
Boron + Gypsum	9.5	110.7	409.2	63.7	593.1
Statistics					
Cultivar					
Reddale	8.2	84.0	313.4	234.6	640.2
Russet Burbank	13.5	301.5	256.3	28.6	599.9
Krantz	10.9	107.8	417.3	58.9	595.0
Significance	**	**	**	**	**
BLSD (0.05)	2.2	27.2	31.6	24.5	30.5
Nutrition					
Check	11.5	184.8	324.9	101.8	623.0
Boron	11.1	182.4	333.7	106.1	613.3
Gypsum	10.9	158.5	328.6	100.6	598.6
Boron + Gypsum	9.9	152.1	328.8	121.1	611.9
Significance	NS	NS	NS	NS	NS
BLSD (0.05)	--	--	--	--	--
Cultivar x Nutrition					
Significance	NS	NS	NS	NS	NS

NS = not significant, * = significant at 5%, ** significant at 1%

Table 3. Effects of gypsum and boron soil amendments on leaf tissue concentrations of boron and calcium.

	Cultivar					
	Reddale		Russet Burbank		Krantz	
	Element					
Treatment	Calcium	Boron	Calcium	Boron	Calcium	Boron
	---%---	-ppm-	---%---	-ppm-	---%---	-ppm-
Check	1.01	31.7	0.91	23.3	1.35	41.2
Boron	1.19	42.3	0.85	27.0	1.38	47.9
Gypsum	1.05	34.2	0.91	23.7	1.32	41.4
Boron + Gypsum	1.10	39.1	0.86	27.4	1.35	45.5

Statistics	Calcium	Boron
	---%---	-ppm-
Cultivar		
Reddale	1.09	36.8
Russet Burbank	0.88	25.3
Krantz	1.35	44.0
Significance	**	**
BLSD (0.05)	0.06	1.3
Nutrition		
Check	1.09	32.1
Boron	1.14	39.1
Gypsum	1.09	33.1
Boron + Gypsum	1.10	37.3
Significance	NS	**
BLSD	--	1.6
Cultivar x Nutrition		
Significance	NS	NS

NS = not significant, * = significant at 5%, ** = significant at 1%

Table 4. Effect of gypsum and boron soil amendments on incidence of brown center and/or hollow heart - Reddale.

Treatment	Tuber Size Distribution		
	B	A	Jumbo
	% incidence		
Check	0.0	12.5	65.0
Boron	0.0	6.8	58.5
Gypsum	0.0	2.5	65.0
Boron + Gypsum	1.0	1.3	42.5
Significance	NS	*	NS
BLSD (0.05)	--	9.5	--

NS = not significant, * = significant at 5%, ** = significant at 1%.

Table 5. Effect of gypsum and boron soil amendments on incidence of brown center and/or hollow heart - Russet Burbank.

Treatment	Tuber Size Distribution	
	7-12 oz.	> 12 oz.
	% incidence	
Check	6.0	19.0
Boron	12.1	12.0
Gypsum	9.0	7.0
Boron + Gypsum	11.0	10.8
Significance	NS	NS
BLSD (0.05)	--	--

NS = not significant, * = significant at 5%, ** = significant at 1%

Table 6. Effect of gypsum and boron soil amendments on incidence of brown center and/or hollow heart - Krantz.

Treatment	Tuber Size Distribution	
	7-12 oz.	> 12 oz.
	% incidence	
Check	0	0
Boron	0	0
Gypsum	0	0
Boron + Gypsum	0	0
Significance	NS	NS
BLSD	--	--

NS = not significant, * = significant at 5%, ** significant at 1%.

MONITORING SPRING NITROGEN STATUS OF STRAWBERRIES

C. Rosen, J. Luby, E. Hoover

The influence of various nitrogen fertilizer rates and application times on strawberry ('Honeoye') yield and leaf/petiole nitrogen status was examined. The experiment was located at the Sand Plains Research Station (Hubbard loamy sand) in Becker, MN. A matted row system was used with 3 ft. between row centers. Yield data and tissue samples were taken during the spring of the third fruiting season. The treatments were as follows:

Treatment Number	Renovation 1986	Fall 1986	Spring 1987
	lb N/A		
1	50	0	0
2	50	0	25
3	50	0	50
4	50	50	0
5	50	50	25
6	50	50	50

Nitrogen, as ammonium nitrate, was topdressed and irrigated in after each application. Recently matured leaves (leaflets and petioles) were collected during initial flowering (5/13/87), fruit maturation (5/28/87), initial harvest (6/11/87), and final harvest (6/24/87). Samples were dried and ground to pass through a 30 mesh screen. Total Kjeldahl N was determined following digestion in H_2SO_4. Petiole samples from recently matured leaves were also collected at the same dates indicated above. The samples were placed in a plastic bag and kept in a cooler for subsequent nitrate analysis. Sap from 6 petioles was expressed into a small plastic container using needle nose pliers. EM Quant (EM Science Cherry Hill, NJ) nitrate strips were dipped into the sap mixture. After two minutes, color was subjectively evaluated using a chart which related color to ppm nitrate.

RESULTS

Strawberry maturity was initially delayed by spring applications of N (Table 1). Total yields were not significantly affected by N treatments. However, except for treatment 5, supplemental nitrogen (either in fall and/or spring) after renovation tended to increase yields. Spring nitrogen did not increase the amount of rotten berries (data not presented). It should be noted that this was a relatively dry spring. Except for treatment 5, berry size increased with spring N treatments (Table 2). The reason for anomalous behavior of treatment 5 is not presently known. Nitrogen treatment did not affect % soluble solids in ripe berries (data not presented). Concentrations of total N in strawberry leaves decreased as the season progressed and was related to nitrogen treatment (Table 3). Petiole nitrates also decreased as the season progressed (Table 4). E M Quant nitrate strips were easy to use and appeared to a sensitive indicator of strawberry plant N status.

Table 1. Influence of nitrogen fertilizer treatments on marketable strawberry yield.

	Nitrogen Treatment			Harvest Date					
	Ren.	Fall	Spring	6/8	6/11	6/15	6/18	6/24	Total
	lb N/A			1000 lb/A					
1.	50	0	0	2.1	2.8	3.6	3.4	4.6	16.5
2.	50	0	25	1.9	2.1	4.1	4.1	5.6	17.8
3.	50	0	50	0.9	2.2	4.4	4.7	7.3	19.6
4.	50	50	0	2.4	2.9	4.6	4.3	5.5	19.7
5.	50	50	25	1.4	2.3	3.9	2.6	5.4	15.7
6.	50	50	50	1.5	2.6	4.2	4.1	6.0	18.4
			Pr > F	0.09	0.08	0.50	0.17	0.34	0.24
			LSD (0.10)	0.8	0.5	-	-	-	-

Table 2. Influence of nitrogen fertilizer treatments on berry size.

	Nitrogen Treatment			Harvest Date					
	Ren.	Fall	Spring	6/8	6/11	6/15	6/18	6/24	Weighted Avg.
	------ lb N/A -----			--------------- g/berry --------------					
1.	50	0	0	15.1	13.8	10.0	6.9	6.7	9.9
2.	50	0	25	14.7	14.9	11.5	8.1	6.9	10.2
3.	50	0	50	15.0	16.0	12.1	8.4	7.7	10.1
4.	50	50	0	15.9	13.4	10.3	7.6	6.3	9.9
5.	50	50	25	14.5	14.1	9.7	6.5	7.1	9.5
6.	50	50	50	15.5	15.4	10.7	8.6	7.9	10.5
			Pr > F	0.59	0.01	0.03	0.01	0.09	0.08
			LSD (0.10)	-	1.1	1.3	1.0	0.9	0.5

Table 3. Influence of nitrogen fertilizer on total N in strawberry leaves.

	Nitrogen Treatment			Sampling Date			
	Ren.	Fall	Spring	May 13	May 28	June 11	June 24
	------- lb N/A -----			--------------- % N ---------------			
1.	50	0	0	2.60	1.78	1.65	1.44
2.	50	0	25	3.10	2.32	1.97	1.56
3.	50	0	50	3.08	2.45	2.14	1.67
4.	50	50	0	2.53	2.07	1.81	1.50
5.	50	50	25	3.08	2.40	1.93	1.55
6.	50	50	50	3.02	2.51	2.08	1.69
			Pr > F	0.01	0.01	0.01	0.01
			LSD (0.05)	0.31	0.28	0.22	0.10

Table 4. Influence of nitrogen fertilizer on nitrate in strawberry petioles.

	Nitrogen Treatment			Sampling Date			
	Ren.	Fall	Spring	May 13	May 28	June 11	June 24
	------- lb N/A -----			------------- ppm NO_3 -------------			
1.	50	0	0	320	10	137	20
2.	50	0	25	1000+	800	635	452
3.	50	0	50	1000+	900	900	700
4.	50	50	0	700	400	270	174
5.	50	50	25	1000+	850	825	656
6.	50	50	50	1000+	850	950	850
			Pr > F	0.01	0.01	0.01	0.01
			LSD (0.05)	170	280	242	358

PRELIMINARY EVALUATION OF CARBOSAN SEQUESTERED COPPER AND MANGANESE AS MICRONUTRIENT SOURCES FOR RADISH PRODUCTION ON ORGANIC SOILS

C.J. Rosen and H.J. Buchite

Soil or foliar application of micronutrients for vegetable crop production on organic soils is a cultural practice frequently used by growers. Organic soils tend to be inherently low in certain micronutrients and can form organic complexes that may reduce micronutrient availability to plants. The primary micronutrients involved are copper and manganese. Radish is a crop commonly grown on organic soils and also has a relatively high demand for copper and manganese. Low levels of these nutrients in radish leaves are frequently observed when the crop is grown on organic soils with a pH of 5.8 or greater. Polysaccharide compounds of varying chain lengths are commonly used in the animal industry to sequester micronutrients thereby increasing availability of the sequestered nutrient. Little research has been conducted to evaluate these compounds as sources of micronutrients for improving agronomic or horticultural crop production. The objective of the following experiments was to compare the effects of polysaccharide sequestered (Carbosan) copper and manganese with sulfate sources and commercially available chelate sources of these micronutrients on radish production. The primary reason for selecting radish is because of its high demand for these nutrients, relatively fast growth cycle and significant economic value in Minnesota.

Experimental Procedures:

Three experiments, one in the greenhouse and two in the field were conducted to evaluate the various copper and manganese treatments on radish growth and nutrition.

Experiment I - Greenhouse Experiment. A Rifle Muck Organic soil (0-6") from the experimental field in Andover, MN was collected and thoroughly mixed in the greenhouse. The mixed soil had the following chemical properties: pH (water) 6.0; P (Bray 1), 200+ lb/A; K (NH_4OAc) 370 lb/A; Mn (DTPA) 8.9 ppm; Cu (DTPA) 1.0 ppm. Nitrogen as ammonium nitrate was incorporated at the rate of 0.03 gram/1.0 lb soil (approximately 40 lb N/A). Three sources of copper and manganese were evaluated: 1) Carbosan Cu chelate (10.0% Cu) and Mn chelate (10.8% Mn) manufactured by Quali Tech, Inc. 2) Frit copper chelate (EDTA and Citric acid - 5% Cu) manufactured by Frit Industries Inc. and THIS Mn chelate (5% Mn) manufactured by Stoller Chemical Co. Inc. 3) Mn sulfate (32% Mn) and Cu sulfate (25% Cu).

Four radish seeds (cv. 'Fuego') were planted in plastic pots containing 2.5 lbs of the organic soil (60 % moisture). There were 21 treatments which included:

1) check, unsprayed
2) water sprayed
3) water + Tween 80 (0.05 ml/L)
4) Cu Carbosan - foliar 0.3 lb Cu/A
5) Cu Chelate - foliar 0.3 lb Cu/A
6) Cu Sulfate - foliar 0.3 lb Cu/A
7) Mn Carbosan - foliar 0.3 lb Mn/A
8) Mn Chelate - foliar 0.3 lb Mn/A
9) Mn Sulfate - foliar 0.3 lb Mn/A
10) Cu + Mn Carbosan - foliar 0.3 lb Cu/A + 0.3 lb Mn/A
11) Cu + Mn Chelate - foliar 0.3 lb Cu/A + 0.3 lb Mn/A
12) Cu + Mn Sulfate - foliar 0.3 lb Cu/A + 0.3 lb Mn/A
13) Cu Carbosan - soil 6.0 lb Cu/A
14) Cu Chelate - soil 6.0 lb Cu/A
15) Cu Sulfate - soil 6.0 lb Cu/A

16) Mn Carbosan - soil 12.0 lb Mn/A
17) Mn Chelate - soil 12.0 lb Mn/A
18) Mn Sulfate - soil 12.0 lb Mn/A
19) Cu + Mn Carbosan - soil 6.0 lb Cu/A + 12.0 lb Mn/A
20) Cu + Mn Chelate - soil 6.0 lb Cu/A + 12.0 lb Mn/A
21) Cu + Mn Sulfate - soil 6.0 lb Cu/A + 12.0 lb Mn/A

Soil treatments were mixed in thoroughly prior to planting. All foliar treatments were applied with Tween 80, a surfactant, at the rate of 0.05 ml/L. Foliar fertilizer treatments at the rates indicated above were applied at 12, 18 and 21 days after emergence with a hand held sprayer calibrated to deliver the required amount. A randomized complete block design was used with 4 replications. Pots were watered as required. Plants were harvested 23 days after emergence. Fresh and dry weight of roots and leaves were recorded. Roots less than 1/4 inch in diameter were considered as nonmarketable. Burn damage due to foliar spray was qualitatively scored. Soils samples were collected from the soil applied treatments and extracted with DTPA for subsequent Cu and Mn determination.

Experiment II - Field Experiment. The experimental site was located at Andover, MN on a Rifle Muck soil. Soil chemical properties are the same as those listed above. The field was planted in radish the previous year and radish was the previous crop in the current season. Fertilizer was broadcast and incorporated prior to planting the first radish crop at the rate of 55 lb N/A, 150 lb K_2O/A and 25 lb S/A. The second radish crop was planted June 22 in 6 row beds with 10" between rows and 2 feet between beds at a population of 426,000 seeds/A. Only foliar fertilizer treatments were applied in the field experiment (treatments 1-12). Because copper treatments severely burned foliage in the greenhouse experiment, half the rate (0.15 lb Cu/A) was used in the field experiment. Manganese rates were the same as in the greenhouse experiment. Treatments were applied 7, 16,and 19 days after emergence with a backpack CO_2 sprayer at 20 psi with 100 gal water/A. Each plot consisted of a bed 20 ft in length. A randomized complete block design with four replications was used. Two 4 ft rows from the center of each bed were harvested 24 days after emergence (July 9). Fresh weight of roots and leaves was recorded. Nonmarketable plants (roots less than 1/4 inch in diameter) were discarded before weighing. Subsamples of roots and leaves were weighed, rinsed twice in deionized water, dried, reweighed and ground for subsequent nutrient determinations. For each plot, the most recently matured leaf from 10 plants was evaluated for color using Pantone color paper as a reference. Burn damage due spray applications was subjectively evaluated for each treatment.

Experiment III - Field Experiment. A third study was conducted at the same site 11 days after the harvest of experiment II. Fertilizer was applied at planting at the rate of 55 lb N/A, 150 lb K_2O/A and 25 lb S/A. Foliar treatments were the same as in experiment II except that only foliar applications of Carbosan and conventional chelates were evaluated and the rate of copper application was dropped to 0.1 lb Cu/A. Treatments were applied 7, 12, 16, 19, and 21 days after emergence. On August 14, 23 days after emergence, radishes were harvested following the same procedures as in experiment II.

Results and Discussion

Experiment I. Fresh and dry weight yields of radish roots and leaves were significantly lower with foliar applications of all copper sources (Table 1). Lower yields generally corresponded to increased foliar damage due to copper sprays and poor root development. Damage to leaves and negative effects on yields tended to be ameliorated when manganese was applied with the copper. Soil-applied copper and manganese and foliar-applied manganese did not affect yields or % usable roots. Soil applications of copper and manganese increased DTPA extractable levels of these nutrients (Table 2). Manganese sulfate was not as effective as the chelated sources in increasing extractable manganese. All sources of copper appear to be equal in supplying copper. Extractions were made less than 4 weeks after application. Longer term studies are needed to determine whether differences in fixation occur over time.

<u>Experiment II.</u> Radish yields were not significantly affected by any of the copper or manganese treatments (Table 3). Despite the fact that half the rate of copper was used compared to that of experiment I, spray damage was still evident. The amelioration of spray damage with manganese observed in Experiment I was not evident in experiment II. Leaf color was examined because of the importance of having green leaves for the green top market. There were no differences in leaf color due to treatment. Foliar applications of copper increased concentrations and content of copper in both leaves and roots (Tables 4 and 5). Copper apparently was translocated from the leaves to the roots. In contrast, leaf manganese concentrations increased with manganese applications but, there did not appear to be significant translocation to the roots. The sulfate source of manganese was not as effective as the chelate sources in increasing leaf manganese levels.

<u>Experiment III.</u> Although there was no significant effect of copper or manganese on radish yields (Table 6), there was a trend for yields to be greater when manganese was applied. As in Experiment II, spray damage was evident from copper sprays. Leaf color was not affected by either copper or manganese treatments. Foliar applications of copper and manganese increased concentrations and content of these nutrients in both leaves and roots (Tables 7 and 8). Unlike experiment II, both copper and manganese were translocated to the roots. The main reason for this difference is probably due to the additional sprays - 5 in experiment III and only three in experiment II.

The results of these experiments suggest that the Carbosan micronutrient sources were as effective as the commercial chelate sources in increasing tissue levels of copper and manganese. In order to avoid foliar spray damage, rates of copper application should not exceed 0.1 lb Cu/A per application. It is probable that either source could be used to supply copper and manganese if a deficiency exists.

<u>Nutrient Composition and Uptake Experiments II and III.</u> Average nutrient concentrations in radish leaves and roots from Expts. II and III are presented in Table 9. Manganese and copper values are taken from the check plots only. From these values and percent moisture determinations, nutrient uptake by the radish crop was calculated (Tables 10 and 11). Of all the nutrients, potassium uptake was greatest followed by nitrogen. Most of the potassium accumulated in the roots while nitrogen accumulated in the leaves. As expected, higher yields resulted in greater nutrient uptake. Although nutrient uptake appears to be relatively low for a single crop, these values should be multiplied by the number of crops (3-5) grown during the season to obtain total nutrient removal.

Table 1. Effects of Cu and Mn soil and foliar applications on radish yields and leaf damage. Greenhouse study. Expt. I.

Treatment	Yield Roots	Yield Leaves	Yield Roots	Yield Leaves	Useable Roots	Spray Damage[1]
	- - g fw - -		- - g dw - -		--%--	
1. Control	32.0	19.8	1.93	1.88	87.5	1.0
2. Water spray	33.5	21.1	1.97	1.94	87.5	1.0
3. Water + Tween 80	32.1	21.0	1.91	1.94	95.0	1.0
4. Cu - Carbosan, foliar	19.9	18.9	1.25	1.82	62.5	2.1
5. Cu - Chelate, foliar	15.0	16.3	0.92	1.61	50.0	3.0
6. Cu - Sulfate, foliar	16.4	21.5	1.00	2.10	75.0	3.0
7. Mn - Carbosan, foliar	35.8	21.1	2.10	2.00	95.0	1.1
8. Mn - Chelate, foliar	30.4	22.4	1.73	2.04	87.5	1.0
9. MN - Sulfate, foliar	35.8	21.3	2.07	2.00	87.5	1.0
10. Cu + Mn - Carbosan, foliar	20.1	19.2	1.22	1.88	75.0	1.2
11. Cu + Mn - Chelate, foliar	25.1	18.3	1.52	1.87	75.0	1.2
12. Cu + Mn - Sulfate, foliar	26.2	21.8	1.55	2.10	82.5	2.3
13. Cu - Carbosan, soil	25.6	19.8	1.59	1.81	70.0	1.0
14. Cu - Chelate, soil	31.6	20.8	1.85	1.87	87.5	1.0
15. Cu - Sulfate, soil	36.2	20.2	2.14	1.89	95.0	1.2
16. Mn - Carbosan, soil	32.2	21.1	1.98	1.97	87.5	1.0
17. Mn - Chelate, soil	30.9	19.9	1.87	1.91	100.0	1.0
18. Mn - Sulfate, soil	33.2	19.1	2.05	1.81	87.5	1.0
19. Cu + Mn - Carbosan, soil	31.4	18.6	1.94	1.71	95.0	1.0
20. Cu + Mn - Chelate, soil	35.0	22.1	2.10	2.01	87.5	1.0
21. Cu + Mn - Sulfate, soil	29.0	19.8	1.81	1.88	87.5	1.0
Significance	**	**	**	**	*	**
BLSD (0.05)	10.4	3.5	0.63	0.26	47.5	0.3

[1] Spray damage score: 1 = no damage 2 = slight damage 3 = severe damage

Table 2. DTPA extractable copper and manganese soil levels after radish harvest. Greenhouse study - Expt. I.

Treatments	Mn	Cu
	--------ppm--------	
1. Control	20.1	2.3
3. Water + Tween 80	20.7	2.4
13. Cu Carbosan	19.4	47.7
14. Cu Chelate	20.4	33.0
15. Cu Sulfate	21.2	34.0
16. Mn Carbosan	49.0	2.5
17. Mn Chelate	63.5	2.5
18. Mn Sulfate	38.3	2.6
19. Cu + Mn Carbosan	57.9	45.0
20. Cu + Mn Chelate	49.5	25.2
21. Cu + Mn Sulfate	37.5	66.4
Significance	**	**
BLSD (0.05)	16.0	26.0

Table 3. Effect of Cu and Mn foliar applications on radish yield, leaf color and burn damage. Expt. II.

Treatment	Roots	Leaves	Total	Spray Damage[1]	Leaf Color[2]
	---------1000lb/A---------				
1. Control	7.06	3.65	10.71	1.4	6.4
2. Water	7.12	3.71	10.83	1.0	6.5
3. Water tween	6.68	3.54	10.22	1.0	6.9
4. Cu Carbosan	6.26	3.58	9.83	2.8	6.3
5. Cu Chelate	6.52	3.78	10.30	2.8	6.5
6. Cu Sulfate	5.55	3.17	8.72	2.9	6.7
7. Mn Carbosan	5.73	3.02	8.75	1.0	6.8
8. Mn Chelate	6.39	3.31	9.70	1.3	6.6
9. Mn Sulfate	6.24	3.50	9.74	1.0	6.3
10. Cu + Mn Carbosan	5.73	3.08	8.81	2.8	6.8
11. Cu + Mn Chelate	6.27	3.27	9.54	2.1	6.3
12. Cu + Mn Sulfate	5.88	3.48	9.37	3.0	6.9
Significance	NS	NS	NS	**	NS
BLSD (0.05)	-	-	-	0.5	-

[1] Spray damage score: 1 = no damage 2 = slight damage 3 = severe damage
[2] Leaf color score: 1 = yellow 9 - dark green

Table 4. Effect of (Cu and Mn) foliar applications on Cu and Mn concentrations in radish roots and leaves. Expt. II.

Treatment	Cu Roots	Cu Leaves	Mn Roots	Mn Leaves
	ppm			
1. Control	1.3	3	6.1	23
2. Water	1.3	3	6.3	27
3. Water + Tween 80	1.3	3	6.1	24
4. Cu Carbosan	2.7	34	5.9	25
5. Cu Chelate	2.5	34	5.7	24
6. Cu Sulfate	3.1	44	6.3	25
7. Mn Carbosan	1.2	5	6.6	208
8. Mn Chelate	1.1	3	6.5	214
9. Mn Sulfate	1.2	3	6.3	36
10. Cu + Mn Carbosan	2.7	36	6.9	215
11. Cu + Mn Chelate	2.6	30	6.9	209
12. Cu + Mn Sulfate	2.9	47	6.0	35
Significance	**	**	(0.07)	**
BLSD (0.05)	0.4	8	1.0	27

Table 5. Effect of Cu and Mn foliar application on content of Cu and Mn in radish roots and leaves. Expt. II.

Treatment	Cu		Mn	
	Roots	Leaves	Roots	Leaves
	--------------------------oz/A--------------------			
1. Control	0.007	0.010	0.033	0.079
2. Water	0.007	0.011	0.034	0.097
3. Water + Tween 80	0.007	0.010	0.032	0.078
4. Cu Carbosan	0.013	0.109	0.028	0.079
5. Cu Chelate	0.013	0.120	0.029	0.082
6. Cu Sulfate	0.014	0.133	0.027	0.076
7. Mn Carbosan	0.006	0.014	0.030	0.594
8. Mn Chelate	0.005	0.008	0.032	0.650
9. Mn Sulfate	0.006	0.010	0.031	0.118
10. Cu + Mn Carbosan	0.012	0.109	0.031	0.649
11. Cu + Mn Chelate	0.013	0.088	0.035	0.607
12. Cu + Mn Sulfate	0.013	0.159	0.029	0.118
Significance	**	**	NS	**
BLSD (0.05)	0.003	0.035	-	0.119

Table 6. Effect of Cu and Mn foliar application on radish yields, leaf color and spray damage. Expt. III.

Treatment	Roots	Leaves	Total	Spray Damage[1]	Leaf Color[2]
	-------1000 lb fw/A-------				
1. Control	6.64	5.10	11.74	1.0	4.5
2. Water + Tween	7.21	5.24	12.45	1.0	4.8
3. Cu Carbosan	6.59	4.99	11.58	1.7	3.8
4. Cu Chelate	6.03	4.49	10.52	1.7	4.9
5. Mn Carbosan	8.08	5.88	13.96	1.0	4.5
6. Mn Chelate	7.75	5.51	13.26	1.0	4.1
7. Cu + Mn Carbosan	7.95	5.48	13.43	2.0	3.8
8. Cu + Mn Chelate	7.48	5.92	13.41	2.0	4.3
Significance	NW	NS	NS	**	NS
BLSD (0.05)	-	-	-	0.7	-

Spray Damage Score: 1 = no damage, 2 = slight damage, 3 = severe damage
Leaf Color Score: 1 = yellow, 9 = green

Table 7. Effect of Cu and Mn foliar applications on Cu and Mn concentrations in radish roots and leaves. Expt. III.

Treatment	Cu		Mn	
	Roots	Leaves	Roots	Leaves
	ppm			
1. Control	2.2	4	7.6	32
2. Control + Tween	2.3	4	8.3	35
3. Cu Carbosan	3.0	40	8.7	33
4. Cu Chelate	3.0	78	7.0	32
5. Mn Carbosan	1.3	4	10.3	308
6. Mn Chelate	1.3	4	11.3	332
7. Cu + Mn Carbosan	2.3	37	11.0	313
8. Cu - Mn Chelate	2.6	44	10.3	275
Significance	NS	**	*	**
BLSD (0.05)	-	9	2.8	60

Table 8. Effect of Cu and Mn foliar application of on content of Cu and Mn in radish roots and leaves. Expt. III.

Treatment	Cu		Mn	
	Roots	Leaves	Roots	Leaves
	oz/A			
1. Control	0.009	0.014	0.031	0.120
2. Control + Tween	0.010	0.015	0.037	0.138
3. Cu Carbosan	0.012	0.149	0.033	0.119
4. Cu Chelate	0.013	0.251	0.029	0.102
5. Mn Carbosan	0.007	0.017	0.057	1.211
6. Mn Chelate	0.006	0.017	0.058	1.370
7. Cu + Mn Carbosan	0.012	0.137	0.061	1.169
8. Cu + Mn Chelate	0.014	0.189	0.053	1.175
Significance	-	**	*	**
BLSD	NS	0.056	0.019	0.33

Table 9. Nutrient concentrations in radish roots and leaves at harvest. Expt. II and III.

Plant Part	Experiment	Nutrient									
		N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
		----------%----------					--------ppm--------				
Leaves	II	4.98	0.39	4.36	3.71	0.38	188	25	33	3.0	24
Roots		2.55	0.36	6.43	0.52	0.19	39	6	29	1.3	22
Leaves	III	5.17	0.37	4.87	3.36	0.31	256	33	36	3.8	24
Roots		3.04	0.43	6.97	0.52	0.20	44	8	30	2.2	26

Table 10. Total nutrient removal by a radish crop - 63 cwt/A - Expt II.

Plant Part	Nutrient									
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------lb/A----------					----------oz/A----------				
Leaves	9.9	0.8	8.7	7.4	0.8	0.6	0.08	0.10	0.010	0.08
Roots	7.8	1.1	19.5	1.6	0.6	0.2	0.03	0.14	0.007	0.12
Total	17.7	1.9	28.2	9.0	1.4	0.8	0.11	0.24	0.017	0.20

Table 11. Total nutrient removal by a radish crop - 73 cwt/A - Expt III.

Plant Part	Nutrient									
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------lb/A----------					----------oz/A----------				
Leaves	12.4	0.09	11.7	8.0	0.8	1.0	0.13	0.14	0.014	0.10
Roots	9.0	1.27	20.5	1.5	0.6	0.2	0.03	0.14	0.010	0.12
Total	21.4	2.17	32.2	9.5	1.4	1.2	0.16	0.28	0.024	0.22

CORN - TILLAGE RESIDUE MANAGEMENT, LANCASTER, 1987

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The driftless soils area has the greatest county average estimated soil losses from cropland in Minnesota, ranging from 4.0 to 6.6 t/ac/yr in the six counties involved. Typical soils of the region such as Fayette-Dubuque, Seaton, and associated soils, are highly erodible, form dense crusts if unprotected from raindrop impact, and consequently, have low final infiltration rates and high runoff from the intense storm events common to the region. New and improved tillage practices are increasingly being relied upon to meet environmental goals under more intense cropping systems. These systems modify the soil and water losses as well as the kind and concentration of materials in the runoff. A more complete understanding of these tillage systems will allow a more accurate prediction of their effect on the environment and will permit them to be more effectively incorporated into the overall farming systems of the region.

Experimental Procedures

The experimental site is located on the Lancaster Experimental Farm. Four tillage treatments are replicated four times (Table 1), the first replicate is located on Palsgrove silt loam; the other three replicates are located on Rozetta silt loam. Each treatment is split into normal and mulched subtreatments. On the no-till (slot plant) plots an additional subtreatment (bare) is established by removing all residue prior to planting; this residue is then placed on the adjacent no-till mulched plot. Corn residue additions are made after tillage but before planting to obtain approximately 60 to 80 percent surface cover. Plots are approximately 90 to 100 feet in width and 80 feet in length. Row width was 36 inches in 1987. Pioneer 3747 was planted April 30, 1987 at 30,000 plants/acre. The conventional (Moldboard) treatment was plowed about April 23 and secondary tillage with a disk was done April 29 on the conventional and chisel treatments. The Ro-till unit replaced the paraplow treatment. No-till plots were planted with a 4-row John Deere 7000 Max-Emerge planter equipped with fluted coulters on one side and "trash whip" units on the other side which removed residue from an 8 to 9 inch area over the row. Fluted, coulters were used on all four rows on the conventional, chisel, and Ro-till treatments.

Nitrogen (250 lb N/acre as urea) was applied in April prior to planting. Starter fertilizer at planting was 200 lb/acre of 6-24-24. The insecticide was Furadan at 10 lb/acre. Pre-emergence herbicide was applied on April 30 (1.5 lb/A of Aatrex 4L and 1 qt/A of Dual 8E). Banvel was applied postemergence at 1 pint/A.

Percent cover was determined from slides taken May 13. Planting depth, rate of emergence, and silking date measurements were made on deisgnated portions of each plot. Hourly spring soil temperatures, leaf number, soil moisture, bulk density, and percent cover were measured on chisel, no-till, and Ro-till treatments in Rep 3 for mulch added, bare, and normal treatments. Soil temperature was measured at depths of 1, 5, 10, 15 and 50 cm. Yields for individual plots were determined by hand harvesting 60 foot of row (two subsamples each consisting of paired 15 ft. lengths of row) in October.

Ten plot frames (45 3/4 x 45 3/4 inches) were emplaced May 1 after planting before the surface was weathered by rainfall. Infiltration measurements were made on Ro-till mulch, no-till bare and mulch, and conventional normal and mulch treatments during the period May 11 to 14. Paired tensiometer measurements were made at three depths within the plot frame during the infiltration event.

Results - Corn yields

Precipitation amounts and distribution were very favorable at Lancaster in 1987 and corn yields ranged from 164 to 177 bu/A (tables 1 and 2). Corn yields of individual tillage, residue, and in-row residue management treatments were not significantly different at the 5 or 10 percent level of significance. Average corn yields of the four replicates were also not significantly different, ranging only from 168 bu/A in rep. one to 171 bu/A in rep. three (table 3). As in 1981 and 1982 soil depth was not related to corn grain yield; however, yield increased with depth in each of the four intervening years. Thus the effect of rooting depth and available water holding capacity in the root zone on yields depends greatly on climatic conditions in the individual year as well as on the crop grown.

Seedbed Conditions and Corn Growth

For the 12 treatments, the average planting depth and average standard deviation of planting depth were statistically different at the 0.01 and 0.025 level of significance, respectively. The planting depths of the coulter and trash whip no-till treatments were not significnalty different. The standard deviations of planting depth were significantly less at the 10% level for the trash-whip treatment compared to the coulter treatment. The standard deviations of planting depth increased with in row cover according to the relationship:

Eq 1: Standard Deviation = 5.9 mm + 0.05 (% cover) ; $R^2 = 0.78$

On the chisel, Ro-till and conventional mulch treatments the heavy mulch and loose seedbed frequently prevented the coulter from cutting through the residue and planting depths were 4 to 12 mm deeper on normal than on mulch treatments. In some cases, the residue was pushed into the loose soil by the coulter making it difficult for the disc opener on the planter unit to penetrate the residue. For no-till, average planting depth for coulter and trash whip units differed by less than 1 mm for bare and normal residue treatments. However, for the no-till mulch treatment average planting depth for the trash whip units was approximately 7 mm deeper than the coulter. The trash whip units were adjusted for no-till conditions and consequently ran excessively deep in the looser soil conditions on the moldboard and chisel treatments.

In-row residue cover was reduced about 20 to 30 percent by the trash whip attachment (TW) compared to the in-row cover resulting from the coulter unit (C) (table 1). The regression equation

Eq 2: % cover TW = -4.2 + 0.61 (% cover C)

explained 80% of the variation in % cover of the TW treatments for the combined 1984, 1985, 1986,and 1987 data. The effect of increasing in-row residue cover (by mulch additions) was to increase the number of day required to reach 75% emergence (table 4) and to delay the date of silking (table 1):

Eq 3: Days to 75% Emergence = 15.7 + 0.058 (% in-row cover); $R^2 = 0.67$

Percent in-row cover was less closely related to grain moisture in 1986 and 1987 than in 1985:

For 1985 Eq 4: % Grain Moisture = 20.5 + 1.97 x 10^{-2} (% in-row cover); $R^2 = 0.87$
For 1986 Eq 5: % Grain Moisture = 19.1 + 0.69 x 10^{-2} (% in-row cover); $R^2 = 0.47$
For 1987 Eq 6: % Grain Moisture = 17.1 + 1.24 x 10^{-2} (% in-row cover); $R^2 = 0.49$

Percent in-row cover was closely related to air growing degree days to 6-leaf in 1984, 1985, 1986 and 1987 (measured on rep 3):

For 1987 Eq 7: Air GDD (planting to 6 leaf) = 278 + 0.52 (% in-row cover); $R^2 = 0.79$
For 1986 Eq 8: Air GDD (planting to 6 leaf) = 296 + 0.54 (% in-row cover); $R^2 = 0.84$
For 1985 Eq 9: Air GDD (planting to 6 leaf) = 273 + 0.47 (% in-row cover); $R^2 = 0.91$
For 1984 Eq 10: Air GDD (planting to 6 leaf) = 285 + 0.53 (% in-row cover); $R^2 = 0.96$

On the no-tillage treatment, grain yields and populations were not significnatly different between trash whip and coulter treatments. Grain moisture was significantly increased (0.1% level of significance) by surface residue cover as was the case for when all treatments were analyzed together (Eq. 6).

The effect of in-row residue cover and tillage on soil temperature and corn growth was evaluated at Lancaster in 1983, 1984, 1985, 1986, and 1987. Hourly soil temperatures were recorded for 1, 5, 10, 15, 50, and 100 cm depths under the row on chisel normal and mulch, no-till bare and mulch, and paraplow normal and mulch treatments in 1984, 1985, and 1986. In 1987 the Ro-till treatment replaced the paraplow treatment. Soil temperatures were measured using 4-couples in parallel for 15 cm and shallower depths.

Leaf stage measurements were taken periodically. Eq. 7 was developed using station air temperatures and leaf stage observations; the results in 1987 agree with previous station air temperatures and leaf stage observations (Eq. 8, 9 & 10).

Increasing the absorption of solar radiation by painting the soil surface black increased soil temperature and early corn growth. Adjacent strips 15 feet long and 1 foot wide (centered over the row) were painted on May 11 or 73.6 air GDD (^{o}C) after planting. Black paint reduced the air GDD to 6-leaf by 3 and 6 GDD on the no-till bare and chisel normal treatments and by 10 GDD on the no-till mulch and chisel mulch treatments. A leaf number represents slightly over 30 GDD so the increase in leaf number ranged from 0.1 to 0.3 leaf number. In 1986 increases up to 0.5 leaf number were measured on the black painted treatments.

Large differences in "final" (50 to 60 minute average) infiltration rates were measured between treatments (tables 5 and 6). Final infiltration rates from conventional tillage mulch treatments equalled or exceeded the comparable normal conventional tillage treatment. Large differences in infiltration and matric potential were measured on both the no-till bare and mulch cover treatments. On the conventional mulch treatments, positive matric potential measured at the 8 and 18 cm depths indicate the presence of a flow restricting layer below the plow layer (table 7). The Ro-till treatment with mulch had final infiltrations rates equal to or greater than the no-till treatment and to the conventional normal treatment but less than the conventional mulch treatment.

Final infiltration rates for 1981-1987 are given in table 6. The ratio of (bare/mulch) infiltration rates for conventional tillage was 0.24 which was below the 6 year average of 0.52. The ratio of no-till mulch to conventional bare was 1.06 which is close to the long term average of 1.16.

The results again illustrate the requirement for rapid infiltration of 1) a porous surface layer with high saturated conducitivity, 2) a protective mulch cover, 3) absence of flow restricitng layers within the depth of infiltration. Residue cover by itself is not sufficient to produce a high infiltration rate when significant restirction to flow occurs within the infiltrating profile.

Summary

Five and eight year yield results with continuous corn at Lancaster show nearly equal yields from conventional tillage, ridge till, and chisel treatments (table 8). In both 1986 and 1987 no-till (slot plant) was the highest yielding treatment. Thus farmers in the driftless soil area can choose between a variety of tillage options which have yields comparable to conventional tillage, but which are superior in soil and water conservation and offer savings in time, labor, and fuel compared to the conventional moldboard plow tillage method.

Table 1. Effect of tillage and mulch treatments on percent cover, planting depth, emergence, silking date, population and grain yield - 1987 Lancaster, WI.

Treatments Tillage	Treatments Residue	In Row Residue Mtg.	Percent Cover In-Row	Percent Cover Entire Area	Planting Depth Ave mm	Planting Depth S.D. mm	Days Post Plant To 75% Emergence	Date 50% Plants Silked July	Ave. Pop. At Harvest Plants/Ac	Ave. Grain Yield Bu/Ac	Ave. Grain Moisture %
No Till	Normal (N)	C	59	67	32.5	8.99	17.5	12.5	30,000	177.3	17.6
		TW	38	58	33	5.08	17.0		29,280	170.3	17.3
	Bare (0)	C	15	12	36	5.80	16.0	12.0	28,660	164.7	16.9
		TW			36	5.94	15.2		28,200	165.2	16.7
	Mulch (2X)	C	85	91	30.5	6.80	20.3	15.3	28,200	170.7	17.7
		TW	53	72	37.0	3.91	19.8		29,160	173.4	17.8
Bush Hog	Normal (N)	C	14	40	34.5	6.15	16.5	12.8	29,220	172.2	16.9
	Mulch (1X)	C	41	71	27.5	8.44	21.0	14.8	28,680	165.0	18.2
Chisel	Normal (N)	C	18	23	27	7.00	17.0	12.0	28,680	168.4	17.5
	Mulch (1X)	C	81	86	23	11.23	19.5	13.5	29,220	164.7	18.4
Conv.	Normal (N)	C	2	3	36	6.18	16.0	12.0	28,070	168.2	17.5
	Mulch (1X)	C	72	75	24	8.06	20.8	13.3	28,130	164.2	18.3
	Significance Level				0.01	0.025		.	NS	NS	0.01

Table 2. 1987 Weather Summary Lancaster, WI Experiment Station.

Month	Precipitation inches Total	Precipitation inches Departure	Growing Degree Days 1987	Growing Degree Days Depart.	Air Temperature Avg. Max	Air Temperature Avg. Min	Air Temperature Avg.	Air Temperature Depart.
	----- inches -----		----------	----------	----------	'F----------	----------	----------
April	2.83	-0.33	--	--	62.2	39.0	51.0	+3.5
May	3.78	+0.33	385	+85	72.6	48.7	60.9	+3.1
June	4.15	-0.40	602	+87	81.8	58.9	70.3	+3.2
July	6.71	+2.42	729	+69	85.3	63.3	74.4	+3.0
August	6.78	+2.16	561	-34	77.8	59.3	68.2	-0.7
Sept.	2.34	-1.12	360	+ 8	71.3	50.5	61.1	+0.2
Total:	26.59	+3.07	2637	+215				

Table 3. Average Yields and Depth to Clay Residuum by Replicate and Monthly precipitation for 1981 through 1987, Lancaster, WI.

Year	Replicate Number 1	2	3	4	Monthly Precipitation May	June	July	August
	----------- Bu/Ac			----------	-------------- inches			-------------
1981	146.8	146.7	142.1	147.1	0.85	4.28	2.91	11.35
1982	150.0	143.4	142.8	147.3	5.46	3.45	5.29	4.06
1983	72.8	85.2	96.4	111.2	5.18	3.28	3.34*	3.12*
1984	107.3	110.4	118.0	120.1	3.92	7.77	2.57**	1.37**
1985	118.5	121.1	129.6	130.6	4.95	1.32***	2.11***	3.34
1986	159.5	162.4	168.6	164.8	3.90	5.47	1.85	3.65
1987	168.3	167.7	170.9	168.0	3.78	4.15	6.71	6.78
Avg. Depth to Clay Residuum inches	29	41	46	62				

1981 - Subplots with population < 17,000 omitted.
1982 - Missing values estimated for 8 plots out of a total or 48 plots.
1983 - Subplots with population < 18,000 omitted Rep. II, III, IV.
*1983 - 1.13 inches precipitation from July 3 to Aug. 25 (53 days).
**1984 - 1.52 inches precipitation from July 18 t Aug. 31 (45 days.
***1985 - 1.59 inches precipiation from May 28 to July 25 (57 days). Largest rain was 0.36 inches.

Table 4. Influence of tillage method and residue management on rate of emergence - 1987 Lancaster, WI.

Treatment Tillage	Residue	Coulter or trash whip unit	Percent Emergence Days Post Plant 12	14	16	19	21	24
No-Till	Normal	C	0	0	30	83	98	99
		TW	0	0	52	93	100	100
	Bare	C	6	32	78	83	97	10
		TW	8	45	95	99	100	100
	Mulch	C	0	0	0	9	91	95
		TW	0	0	5	36	94	99
Bush Hog	Normal	C	12	27	70	88	98	100
Ro-Till	Mulch	C	0	0	23	45	76	95
Chisel	Normal	C	5	39	68	80	93	100
	Mulch	C	0	0	26	59	88	96
Conventional	Normal	C	20	42	77	85	92	95
	Mulch	C	1	5	19	45	78	94
Air Growing Degree Days from planting		°F	148.5	169.5	192.5	245.0	278.5	302
(including plant date April 30)		°C	82.5	94.2	106.9	136.1	154.7	167.8

All treatments reached 100% emerged by Day 28.

Table 5. 1987 Lancaster, WI Infiltration Rate Measurement.

Tillage	Residue	Rep.	Application rate	Water applied before runoff	Infiltration rate X min. after runoff commences - in/hr. 2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5
			in/hr	inches	- - -	- - -	- - -	- - -	- - -	- - -	inches/hour	- - -	- - -	- - -	- - -	- - -
No Till	Bare	E	5.44	0.18	2.55	1.12	0.64	0.64	0.64	0.40	0.88	0.64	0.28	0.28	0.64	0.40
		W	5.60	0.28	2.24	1.28	1.28	1.76	1.76	1.76	2.00	2.00	2.00	1.52	2.00	2.00
	Mulch	E	5.36	0.25	3.68	2.00	1.28	1.52	1.28	1.04	1.28	1.52	1.52	1.76	1.28	1.52
		W	5.36	0.31	3.44	2.48	2.12	1.88	1.76	1.28	1.04	1.28	1.64	1.40	1.04	1.04
Conv.	Normal	E	5.76	0.96	4.32	3.36	2.40	1.68	1.92	1.44	1.20	1.80	1.80	1.20	1.20	1.20
		W	4.88	0.85	3.56	2.48	1.88	1.52	1.28	1.52	1.76	1.28	1.16	1.28	1.04	1.16
	Mulch	E	5.44	4.90	5.38	5.38	5.32	5.32	5.08	5.32	5.08	4.96	4.84	4.96	5.08	4.96
		W	5.44	3.62	5.32	5.08	4.96	5.20	4.83	4.96	4.71	4.71	4.60	4.60	--	--
Bush Hog	Mulch	E	5.28	0.97	2.88	2.16	1.68	1.92	2.16	1.92	1.92	2.40	2.28	2.28	1.80	1.80
Ro-Till		W	5.28	0.59	3.36	2.88	2.88	3.12	2.76	3.00	2.88	2.64	2.40	2.04	2.52	2.64

Table 6. Infiltration rate 55 minutes after runoff begins (paired observations).

Tillage	Treatment Residue	1981	1982	1983	1984	1985	1986	1987	Avg.
		----------	----------	----------	inches/hour	----------	----------	----------	
No Till	Bare	--	--	--	1.68	1.00	1.24	1.26	
	Mulch	1.46	1.10	3.53*	0.60	3.02	2.10	1.22	1.58+
Conventional	Bare	0.97	1.52	0.54	1.70	1.40	1.83	1.15	1.30
	Mulch	2.72	2.34	1.49	2.90	2.14**	2.25	4.81	2.66
		----------	----------	----------	Ratio	----------	----------	----------	----------
Conv. Bare/Conv. Mulch		0.36	0.65	0.36	0.58	0.65	0.81	0.24	0.52
No Till Mulch/Conv. Bare		1.51	0.72	6.53	0.35	2.16	1.15	1.06	1.16+

* Soil disturbed prior to planting by anhydrous ammonia injection.

** 1 observation only.

+ omit 1983

Table 7. Relationship of infiltration rates (Avg. 40 to 60 min. after runoff starts) to matric potential in 1987.

Treatment Tillage	Residue	Rep.	in./hr	cm soil depth 7.5	17.5	40	7.5	17.5	40
				cm H_2O					
No-Till	Bare	E	0.40	-168	-173	--	-50	-110	-19
		W	1.88	-4	-55	+12	-1	-1	+11
	Mulch	E	1.52	-16	-14	+31	-27	-25	-11
		W	1.28	-30	-5	-32	-2	-7	-15
Conven.	Normal	E	1.35	+9	+14	-30	--	+7	-64
		W	1.16	+8	-8	+28	+8	+8	--
	Mulch	E	4.96	+7	+12	+5	+8	+11	+6
		W	4.60*	-4	-3	+11	+2	-10	+19

*40 to 50 min only

Table 8. 1979-1987 Continuous corn tillage yield results, Lancaster, WI.

Tillage Treatment with normal residue	1979	1980	1981	1982	1983	1984	1985	1986	1987	79-83	79-87
	bu/A										
Ridge plant	162	157	157	147	100	---	---	---	---	145	---
No-Till (slot plant)	163	146	151	141	85	108	120	165	177	137	140
Chisel	160	150	167	154	95	115	125	159	168	145	144
Conventional	169	159	168	151	89	121	133	164	168	147	145
Paraplow*	---	---	---	---	---	106	125	162	---	---	---
Ro-Till	---	---	---	---	---	---	---	---	172	---	---

*Fall 1983 and Fall 1984

TILLAGE EFFECTS ON CORN PRODUCTION IN NORTH EASTERN MINNESOTA

J.F. Moncrief, J.J. Kuznia, and D.D. Breitbach

Plots have been established in Pine and Isanti counties to evaluate four different tillage systems at each site. Tillage ranges from moldboard plowing to a "strict no till" approach. Corn follows corn at the Pine county site and soybeans at the Isanti county site.

The **Pine County** data are shown in table 1 to 8. At this site corn followed corn on a well drained Cushing loam soil. The Chisel, Moldboard, and spring disc treatments had similar yields. The no till system resulted in a yield reduction of about an 18 bushel per acre. It does not appear to be the result of stand reduction. It is possible that there was competion for soil moisture by weeds (nutsedge).

PINE COUNTY

Table 1. Cultural practices at Pine County, MN. 1987.

Tillage

No Till

Disc-Plots were disced on May 4, 1987.

Chisel-Plot were chisled on May 4, 1987.

Moldboard-Plots were plowed on May 4, 1987

All plots except No Till had Rotary tillage with a Lilly Roterra on May 4 1987 to incorporated the hebicide applied prior to planting.

Preceding Crop

Corn

1987 Crop

Land O Lakes 1093

Single cross hybrid

(95 day)

Planting and Harvest Date

Planter used was a John Deere Maximerge with 2 inch fluted coulters and 36 inch rows.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 4, 1987	26,700 plants/ac	October 6, 1987

Fertilizer

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	---	lbs/ac	--	Date Applied
Corn	46-0-0	250 lbs/ac	115	0	0	May 2, 1987
	10-15-35[1]	280 lbs/ac	28	42	98	May 4, 1987

1. Planter applied 2" beside and 2" below seed.

Soil

The soil at this site is a Cushing (Glossic Eutroboralfs, fine-loamy, mixed) loam.

Herbicide Control

3 qt/ac (3.375 lbs/ac) Bicep was applied with a Lily roterra.

Soil Test

Table 2. Initial soil test on proposed tillage plots on soil test on April 7, 1987.

		Tillage							
		No Till		Disc		Chisel		Moldboard	
	Sig. of	mean	stdev	mean	stdev	mean	stdev	mean	stdev
Nutrient	Tillage	lb/ac							
NH_4-N	(.050)	5.0	1.2	5.1	0.6	4.3	0.7	3.6	0.4
NO_3-N	(.975)	35.9	5.8	32.5	11.9	32.8	15.3	33.4	10.6
NH_4+NO_3	(.954)	40.9	5.8	37.5	11.4	37.0	15.5	37.1	10.3
P	(.193)	124.0	60.1	107.0	55.8	60.6	44.5	83.9	45.9
K	(.711)	471.0	115.9	411.4	41.8	463.6	72.3	421.5	78.7

Table 3. The effect of tillage on soil cover by corn residue on May 28, 1987, n=24.

		Tillage							
		No Till		Disc		Chisel		Moldboard	
		mean	stdev	mean	stdev	mean	stdev	mean	stdev
Location	Tillage	%							
In Row	(.000)	56.0	23.1	41.5	15.2	26.0	10.1	1.33	2.54
Between Row	(.000)	77.5	18.9	58.6	15.9	34.8	10.7	3.66	7.07

Table 4. The effect of tillage on corn growth stages, n=40.

	Tillage							
	No Till		Disc		Chisel		Moldboard	
	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Date	%							
5/24[1]	1.69	.966	1.88	.782	2.00	.751	2.34	.878
6/17[2]	5.28	.818	5.45	.977	6.10	.702	6.34	.733

1. Significance of tillage was .007.
2. Significance of tillage was .000.

Table 5. The effect of tillage on corn stand, n=16.

	Tillage							
	No Till		Disc		Chisel		Moldboard	
	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Date	plants/ac x1000							
5/24[1]	23.2	3.3	22.1	2.8	26.5	2.5	27.2	3.7
6/17[2]	23.4	3.3	22.0	4.4	25.6	1.8	27.3	2.9

1. Significance of tillage was .000.
2. Significance of tillage was .000.

Table 6. The effect of tillage on the presence of weed species and density on May 28, 1987, n=32.

		Tillage							
		No Till		Disc		Chisel		Moldboard	
	Sig. of	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Weed	Tillage	plants/ac x1000							
Pigweed	(.059)	0.6	1.6	1.3	1.9	5.5	6.0	5.0	10.0
Foxtail	(.059)	0.0	0.0	0.7	2.0	3.8	7.2	8.0	9.6
Crabgrasss	(.187)	5.9	11.1	8.5	14.3	0.0	0.0	0.0	0.0
Nutsedge	(.552)	72.9	116.2	24.7	45.0	63.9	83.7	39.7	41.8
Ragweed	(.288)	1.2	2.2	2.9	3.7	6.9	7.1	11.1	19.4
Lambsquarter	(.099)	0.0	0.0	2.4	6.8	7.7	9.7	3.8	5.2
Smartweed	(.409)	0.0	0.0	2.4	6.8	0.0	0.0	0.0	0.0
Vol Corn	(.330)	0.0	0.0	5.5	9.9	4.2	8.6	0.9	2.3
Quackgrass	(.026)	0.0	0.0	0.9	1.3	0.0	0.0	0.0	0.0

1. Due to unequal variances, a natural log transformation was used for analysis of variance.

Table 7. The effect of tillage on the presence of weed species and density on June 17,1987, n=32.

		Tillage							
		No Till		Disc		Chisel		Moldboard	
	Sig. of	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Weed	Tillage	plants/ac x1000							
Crabgs	(.400)	1.8	3.9	0.0	0.0	12.1	34.2	0.0	0.0
Nutseg	(.320)	117.1	163.7	37.9	64.3	35.8	42.4	47.2	79.5
Ragwed	(.287)	0.3	0.8	1.2	3.4	4.9	10.0	0.3	0.7
Lambqr	(.343)	0.0	0.0	0.0	0.0	2.8	6.7	2.7	3.8
Smrtwd	(.025)	0.0	0.0	0.0	0.0	2.0	3.8	0.3	0.8
Volcrn	(.011)	0.1	0.3	15.9	15.9	11.8	13.8	5.2	9.4
Quacgr	(.373)	2.8	5.9	2.1	3.3	5.8	9.8	3.9	7.3

1. Due to unequal variances, a natural log transformation was used before analysis of variance.

Table 8. The effect of tillage on yields and grain moisture at harvest, October 6, 1987, n=4.

	Tillage							
	No Till		Disc		Chisel		Moldboard	
Sig. of	mean	stdev	mean	stdev	mean	stdev	mean	stdev
Tillage	bu/ac							
(.026)	141	6.6	158	5.8	166	7.0	155	14.1
	% moisture							
(.000)	26.7	.78	25.7	.39	25.5	.38	24.2	.73

Isanti County data is presented in tables 9 to 11. At this site corn followed soybeans on an Alstad fine sandy loam soil that is somewhat poorly drained. The performance of the tillage systems evaluated at this site were similar to the Pine county site. All were similar except the no till treatment. The yield reduction associated with this system was 11 bushels per acre. At this site differences in plant populations account for the yield reduction associated with the no till system. The planter used at both sites was equipped with 2" fluted coulters to cut through crop residue. It may be that the planter did not have the weight to penetrate dry soil under no till conditions at this site which resulted in the stand loss. The point is, if stand differences are accounted for in the statistical analysis there is no effect of tillage on yields.

ISANTI COUNTY

Table 9. Cultural practices at Isanti County, MN. 1987.

Tillage
- No Till
- Disc-Plots were disced on May 5, 1987
- Chisel-Plots were chiseled then disced on May 5, 1987
- Moldboard-Plots were plowed then disced on May 5, 1987

Preceding Crop
1986-Soybeans

1987 Crop
Corn-Pioneer 3790

Planting and Harvest Date

Planter was a John Deere 7000 equipped with ripple conservation coulters.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 6, 1987	27,200 plants/ac	October 6, 1987

Fertilizer

Crop	Material Analysis	Rate	N	P_2O_5	K_2O	S	Mg	Date Applied
			Actual					
			-------	lbs/ac	-------			
Corn	12-14-26-4-3	277 lbs/ac	33	38	73	11	9	May 6, 1987
	82-0-0	146 lbs/ac	120	0	0	0	0	June 5, 1987

Soil Test

Organic Matter	pH	Bray 1 Phosphorus	Potassium	Sulfur	Zinc
		---------- lbs/ac	----------	--- ppm	----
Medium	7.0	115	238	15	1.1

Soil

The soil at this site is a Alstad (Aquic Eutroboralfs, fine-loamy, mixed) fine sandy loam, 0 to 2 percent slope. Soil is somewhat poorly drained.

Weed Control

2 qt/ac (2 lbs/ac) Lasso + 1 qt/ac (1 lb/ac) Bladex + 1 qt/ac (1 lb/ac) Atrazine.

Table 10. The effect of tillage on plant populations on August 1, n=6.

Sig. of Tillage	No Till mean	No Till st dev	Disc mean	Disc st dev	Chisel mean	Chisel st dev	Moldboard mean	Moldboard st dev
	----------	----------	plants/ac x 1000	----------	----------	----------	----------	----------
(.014)	22.3	4.27	26.6	1.05	26.3	.55	26.6	.76

Table 11. The effect of tillage on corn yields and moisture harvested on October 6, 1987, n=6.

Sig. of Tillage	No Till mean	No Till st dev	Disc mean	Disc st dev	Chisel mean	Chisel st dev	Moldboard mean	Moldboard st dev
	----------	----------	----------	bu/ac	----------	----------	----------	----------
(.344)[1]	157	9.1	166	7.6	168	6.1	168	6.2
	----------	----------	----------	% moisture	----------	----------	----------	----------
(.006)	23.1	.77	22.3	.76	21.7	.79	22.0	.47

1. Plant population was used as a covariate in this analyis of varience. If population effects are accounted for there is no difference in yield due to tillage.

INVESTIGATIONS OF TILLAGE AND CORN HYBRID ON A PACHIC UDIC HAPLOBOROLL SOIL IN WESTERN MINNESOTA

J.F. Moncrief, S.D. Evans, and A.E. Olness

This study was initiated in the fall of 1983 to evaluate the interactions of tillage system, hybrid and nitrogen response of corn grown continuously. This paper focuses on the influence of tillage on corn hybrid performance. Four tillage systems were used to evaluate two single cross hybrids (Pioneer 3906 and DeKalb-Pfizer XL8). Tillage treatments are fall moldboard and chisel plowing (with the exception of 1986), ridge till, and no till. Ridge tilled corn was the only treatment that received cultivation. This site has been in continuous corn since 1982. The planter used was equipped with disc row cleaners which were only used in the ridge till treatment. All other treatments had "in row" tillage by a 2" fluted coulter. Nitrogen was spring applied as anhydrous ammonia. Nitrogen rates were pooled beyond the level of corn response to evaluate tillage and hybrid interactions. Phosphorus and potassium was applied with the planter.

The results of the analysis of variance is shown in table 1. There are significant main effects of year, tillage, and hybrid as well as several interactions. The Pioneer 3906 hybrid had grain yields an average of 20 bushels per acre higher than the DeKalb XL8 (table 2). There was a significant interaction between hybrid and year. In the last two years of the study the difference was greatest (table 2). There was also a significant tillage by hybrid interaction (table 3). The greatest difference between the two hybrids occurred with ridge tillage (29 bu/acre) followed by the no till, chisel, and moldboard treatments respectively. Tillage systems that eliminate primary tillage had larger differences between

Table 1. The effect of tillage, corn hybrid, and year on the significance of an F test for yield from analysis of variance.

Source of variation	Sig. of F
Year	<.000
Rep	.416
Till	.030
Till x Year	.042
Hybrid	<.000
Hybrid x Year	.003
Hybrid x Till	.015
Hybrid x Rep	.681
Till x Hybrid x Year	.265
Year x Hybrid x Rep	.340
Till x Year x Rep	.254
Hybrid x Till x Rep	.058

Table 2. The effect of hybrid and year on grain yields.

	Year				
	1984	1985	1986	1987	Avg.
	Bu/acre				
P 3906	130	89	130	150	125
DK XL8	119	74	100	128	105
Diff.	11	15	30	22	20

Table 3. The effect of tillage and hybrid on grain yields from 1984 to 1987.

	Tillage				
	Mld	Chsl	Rdg	NT	Avg.
	Bu/acre				
P 3906	120	127	133	118	125
DK XL8	109	111	104	96	105
Diff.	11	16	29	22	20

Table 4. The effect of tillage and hybrid on grain yields in 1984.

	Tillage				
	Mld	Chsl	Rdg	NT	Avg.
	Bu/acre				
P 3906	135	128	137	116	129
DK XL8	126	120	125	106	119
Diff.	9	8	12	10	10

Table 5. The effect of tillage and hybrid on grain yields in 1985.

	Tillage				
	Mld	Chsl	Rdg	NT	Avg.
	Bu/acre				
P 3906	88	96	87	84	89
DK XL8	72	82	69	70	73
Diff.	16	14	18	14	16

Table 6. The effect of tillage and hybrid on grain yields in 1986.

	Tillage				
	Mld	Chsl	Rdg	NT	Avg.
	Bu/acre				
P 3906	102	139	149	129	130
DK XL8	92	114	107	85	100
Diff.	10	25	42	44	30

Table 7. The effect of tillage and hybrid on grain yields in 1987.

	Tillage				
	Mld	Chsl	Rdg	NT	Avg.
	Bu/acre				
P 3906	157	145	156	141	150
DK XL8	142	128	117	123	128
Diff.	15	17	39	18	22

Table 8. The effect of tillage and year on grain yields.

	Year				
	1984	1985	1986	1987	Avg.
Tillage	Bu/acre				
Mldbrd	130	80	97[1]	149	114
Chisel	124	89	127[1]	137	119
Ridge	131	78	128	137	119
No Till	111	78	107	132	107

1. Due to wet fall conditions in 1985, primary tillage was done in the spring of 1986.

hybrids. Although the tillage x hybrid x year interaction was not statistically significant (.265), the biggest difference between hybrids grown with ridge tillage seemed to occur the last two years of the study (tables 4-7).

The growing season rainfall was highest in 1986 and lowest in 1987. Plant moisture stress data show that the DK XL8 hybrid consistently had higher levels of stress (not measured in 1986). In 1987 there was a significant tillage by hybrid interaction. There was a larger difference in stress between the two hybrids when grown with ridge till and no till systems. One plausible explanation may be that the DK XL8 hybrid is more sensitive to root pruning that is associated with the ridge till system. In 1987 there was very little rainfall following the ridging operation. This hybrid may have been more sensitive to the reduced soil temperatures and increased resistance to root penetration under no till conditions, which could have resulted in shallow rooting making it more sensitive to the dry season. At this point this is speculation until the total body of supporting data is interpreted.

Corn yields were low in 1985 due to an early frost. The four year averages show the ridge till and chisel plowing systems to result in the highest grain yield (table 8). Moldboard plowing was done in the spring of 1986 due to wet soil conditions in the fall of 1985, which resulted in a very low yield (table 6). The four year average yield was 5 bushels per acre less when moldboard plowing than corn grown with the ridge till or chisel plowing system. No till grown corn resulted in grain yields 12 bushels per acre less than the chisel or ridge till corn.

THE EFFECT OF TILLAGE ON SMALL GRAIN AND SOYBEAN PRODUCTION IN NORTHWESTERN MINNESOTA-1987

J.F. Moncrief, J.J. Kuznia, and D.D. Breitbach

Plots were established in the fall of 1985 to evaluate the effect of tillage on small grain and soybean production in northwestern Minnesota. The rotation at each site is wheat-soybeans-barley. In the wheat year the plots are split with winter and spring wheat. In 1987 soybeans were grown at the Becker County site and Winter and Spring wheat at the Douglas County site. The tillage systems being evaluated are fall moldboard or chisel plowing followed by secondary tillage in the spring and no tillage.

The Becker County data is presented in tables 1 to 6. The soil covered by wheat residue after planting was 75%, 26%, and 10% for the no till, chisel, and moldboard plow systems respectively (table 2). Plots were split with drill applied (with the seed) fertilizer (diammonium phosphate-DAP). The University of Minnesota does not recommend applying DAP with the soybean seed at the rates we used in this study. This is the dominant source of dry phosphate in Minnesota and was used to illustrate the effect of tillage on seed injury with this source of fertilizer.

The major weeds at this site are mustard and field bindweed. The weed density at harvest is shown in table 3. Tillage and starter fertilizer had an effect on the presence of weeds at harvest. There were much more weeds in the no till plots. There was also an increase in weeds when starter was used. This was due to the stand loss associated with the no till treatment and further reduction when starter was applied. This could have been due to more shallow planting, failure to close the seed furrow, or less soil mixing.

Grain yields and moisture are shown in table 4 and 5 respectively. Yields are similar for the chisel and moldboard plow treatments and there is no response to drill applied fertilizer. No till yields reflect the reduced stands that allowed better competition by broadleaf weeds.

BECKER COUNTY

Table 1. Cultural practices at Becker County, MN. 1987.

Tillage	Preceding Crops	1987 Crop
No Till	1985-Barley	Soybeans-McCalls
Chisel-Fall	1986-Winter and Spring wheat	
Moldboard-Fall		

Planting and Harvest Dates

Planter was a Haybuster No Till Disc Drill.

	Planting		
Crop	Date	Rate	Harvested
Soybeans	June 2, 1987	225,000 plants/ac	October 1, 1987

Fertilizer

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	---lbs/ac----			Date Applied
Soybeans	18-46-0[1]	110 lbs/ac	20	51	0	June 2, 1987

1. Drill applied with the seed.

Soil

Hamerly clay loam (Aeric Calciaquolls, fine-loamy, frigid)-Winger silty clay loam (Typic Calciaquolls, fine-silty, frigid) complex, 2 percent slope. Soil is somewhat poorly drained to moderately well drained soil.

Weed Control

1 qt/ac (3/4 lb/ac) Roundup was applied on May 18, 1987.
1 1/2pt/ac (3/4 lb/ac) Basagran + 1/2 pt/ac (.125 lb/ac) Blazer was applied on June 18, 1987.
3/4 pt/ac (.375 lb/ac) Basagran was applied on July 20.
1 pt/ac (.125 lb/ac) Fusilade 2000 was applied on August 1, 1987.

Table 2. The effect of tillage on soil cover by wheat residue on June 2, 1987, n=12.

		Tillage					
		No Till		Chisel		Moldboard	
	Sig. of Tillage	mean	st dev	mean	st dev	mean	st dev
		%					
Between	(0.0)	69.0	10.3	23.3	12.9	7.7	5.2
In Row	(0.0)	81.3	9.2	31.0	18.4	11.3	9.6

Table 3. The effect of tillage and starter on the presence of weed cover on October 1, 1987[1], n=3.

	Tillage (.000)						
	No Till		Chisel		Moldboard		
	mean	stdev	mean	stdev	mean	stdev	Avg
Fertilizer[2]							
Starter	4.33	0.57	0.67	0.57	0.33	0.57	1.78
No Starter	3.00	0.00	0.33	0.57	0.00	0.00	1.11
average	3.67	0.81	0.50	0.54	0.17	0.40	

1. The visual rating used is as follows; 1=None, 2=Slight, 3=Moderate, 4=Severe and 5=Very Severe.
2. The significance of tillage was .008; tillage x fertilizer interaction was .006.

Table 4. The effect of tillage and starter on soybean yields October 1, 1987, n=3.

	Tillage(.002)						
	No Till		Chisel		Moldboard		
	mean	stdev	mean	stdev	mean	stdev	Avg
Fertilizer[1]			bu/ac				
Starter	31.2	0.60	42.8	1.33	42.6	1.35	38.8
No Starter	36.9	2.01	41.9	2.18	42.7	0.57	40.5
average	34.1	3.43	42.3	1.69	42.7	0.93	

1. The significance of tillage was .073; tillage x fertilizer interaction was .061.

Table 5. The effect of tillage and starter on the moisture of soybeans at harvest, October 1, 1987, n=3.

	Tillage (.249)					
Sig. of Fert.[1]	No Till		Chisel		Moldboard	
	mean	stdev	mean	stdev	mean	stdev
Fertilizer(.722)			%			
Starter	8.6	0.12	8.5	0.20	8.4	0.48
No Starter	8.9	0.65	8.3	0.15	8.5	0.38
average	8.7	0.44	8.4	0.17	8.4	0.39

1. The significance of tillage x fertilizer interaction was .603.

The crops grown at the Douglas County site are winter and spring wheat. Tillage treatments are moldboard, chisel, and no till. Spring soil test values are shown in table 6. There was more mineral nitrogen in the top two feet of the winter wheat plots due the fall applied fertilizer with the drill (table 6). There were higher levels of mineral nitrogen in the no till winter wheat treatment than the plots that were chisel or moldboard plowed. This may be due to the slower rate of nitrification of the fall applied ammonium due to cooler soil temperatures that would have prevented losses. The soil P at this site is very variable. There were no discernable tillage trends. The soil K was affected by tillage and was higher under no till conditions in the winter wheat plots. A similar trend occurred in the spring wheat plots although not statistically significant. This has been observed at other sites and reflects the slower soil fixation of K when it is mixed with a smaller volume of soil.

The soil cover by crop residue is shown in table 8. Cover was about 10, 40, and 75% for the moldboard, chisel, and no till systems respectively and similar in and between the row. The stands were quite variable (table 9). Tillage effects on stand were not statistically significant. Early growth was affected by tillage but differences were small and would not be expected to affect grain yields (table 10).

Although tillage effects on the density and presence of various weed species were statistically significant in some cases, the levels were low and not expected to affect yields (tables 11, 12, and 13).

The main effect of tillage on winter wheat grain yields was not statistically significant (table 14). There was a tillage by variety interaction, however. The two varieties used at this site responded differently to chisel plowing. The authors don't have an explanation at this time. Tillage did not effect spring wheat yields. There was a winter wheat varietal effect on test weight (table 16) but not tillage. Tillage did effect spring wheat test weight. No till grain test weights were two lbs/bushel lower than the chisel and moldboard grain. Protein was not affected by tillage for either winter or spring wheat although there was a difference between varieties and winter and spring wheat.

DOUGLAS COUNTY

Table 6. Cultural practices at Douglas County, MN. 1987

Tillage

No Till
Chisel Plow-Plots were chiseled on September 11, 1986.
Moldboard Plow-Plots were plowed on August 29, 1986.
The chisel and moldboard plow treatments were followed by a spring field cultivation before seeding the spring wheat.

Preceding Crop

1985-Soybeans, 1986-Barley

1987 Crop

Spring Wheat-Pioneer 2369
Winter Wheat-Bighorn and Roughrider

Planting and Harvest Date

Planter was a Haybuster 107 drill, with 7" row spacing that had double disk openers and twin angled packing wheels.

Crop	Planting Date	Harvested
Winter Wheat	September 29, 1986	July 24, 1987
Spring Wheat	April 21, 1987	July 24, 1987

Fertilizer

Crop	Material Analysis	Rate	Actual N ---	Actual P_2O_5 lbs/ac	Actual K_2O ---	Date Applied
Winter Wheat	18-46-0[1]	100 lbs/ac	18	46	0	September 29, 1986
	46-0-0[2]	217 lbs/ac	100	0	0	May 29, 1987
Spring Wheat	18-46-0[1]	100 lbs/ac	18	46	0	April 21, 1987
	46-0-0[2]	217 lbs/ac	100	0	0	May 29, 1987

1. Drill applied with seed.
2. Urea was broadcast.

Soil

Complex of: Barnes (Udic Haploborolls, fine-loamy, mixed)-Langhei (Typic Udorthents, fine-loamy, mixed (calcareous) ,frigid) loams, 2 to 6 percent slopes, well-drained eroded. The Langhei occurs on eroded knobs and Barnes on uniform slopes and valleys.

Weed Control

No Till Plots:

1 qt/ac ($^3/_4$ lb/ac) Roundup + surfactant on September 5, 1987.

Winter Wheat:

1.5 pt./ac Bromoxynil(Buctril) + 1 pt/ac MCPA(ester) on May 28, 1987.

Spring Wheat:

1 pt/ac 2,4-D on June 1, 1987.

Soil Test

Table 7. Soil test results from Douglas County on April 9, 1987.

			WINTER WHEAT							SPRING WHEAT					
			Tillage							Tillage					
		Sig. of	No Till		Chisel		Moldboard		Sig. of	No Till		Chisel		Moldboard	
	Depth	Tillage	mean	stdev	mean	stdev	mean	stdev	Tillage	mean	stdev	mean	stdev	mean	stdev
Nutrient	Inches	WtWheat	lbs/ac						SpWheat	lbs/ac					
NO_3	0-6	(.162)	36.8	4.7	29.5	7.9	32.3	6.0	(.801)	20.7	3.5	24.0	6.9	21.1	10.5
	6-24	(.320)	41.4	4.7	33.2	6.1	34.2	12.9	(.965)	31.3	10.3	31.8	14.0	33.2	21.4
	0-24	(.150)	78.2	8.6	62.7	9.0	66.5	17.5	(.929)	52.0	13.4	55.8	20.2	54.3	14.4
NH_4	0-6	(.000)	7.9	0.6	5.8	0.5	6.1	0.8	(.181)	12.2	9.3	6.0	1.0	7.8	2.2
	6-24	(.070)	20.9	1.7	19.5	3.0	17.5	1.5	(.662)	20.4	4.4	18.5	4.4	18.8	4.1
	0-24	(.010)	28.8	2.1	25.3	2.9	23.6	2.1	(.223)	32.6	12.6	24.5	5.0	26.6	6.0
NO_3+NH_4	0-6	(.053)	44.7	4.7	35.3	8.2	38.4	5.8	(.765)	32.8	12.5	30.1	3.7	28.9	8.7
	6-24	(.189)	62.3	5.0	52.7	7.8	51.6	13.4	(.963)	51.7	14.3	50.3	16.9	52.0	25.0
	0-24	(.050)	107.0	8.7	88.0	8.9	90.0	17.8	(.899)	84.5	25.4	80.4	22.8	80.9	19.4
P	0-6	(.246)	20.4	18.1	10.8	11.9	8.2	10.3	(.569)	18.4	19.4	28.5	36.1	39.2	40.3
K	0-6	(.065)	350	67.8	278	36.7	273	53.8	(.347)	347	51.4	309	68.6	316	51.5

Table 8. The effect of tillage on barley residue on June 4, 1987.

			Tillage					
			No Till		Chisel		Moldboard	
			mean	st dev	mean	st dev	mean	st dev
Crop	Variety	Location	%					
Winter Wheat (n=12)	Bighorn	In Row	65.0	21.6	38.0	20.9	7.7	6.7
		Between Row	74.3	14.4	36.3	14.3	13.0	7.8
	Roughrider	In Row	71.7	16.4	41.7	19.7	10.0	6.7
		Between Row	78.7	13.3	41.7	26.8	7.3	6.9
Spring Wheat (n=24)	Pioneer	In Row	70.2	14.9	45.8	22.1	10.8	15.7
		Between Row	73.5	13.4	41.3	17.1	15.8	14.8

Table 9. The effect of tillage on plant population on June 4, 1987.

		Tillage					
		No Till		Chisel		Moldboard	
	Sig. of	mean	stdv	mean	stdv	mean	stdv
Crop-Variety	Tillage[1]	------ plants/ac x 1000 ------					
Winter Wheat	(.704)	n=12					
Bighorn		153	44.7	128	62.8	137	58.5
Roughrider		153	62.2	195	31.4	150	68.9
Spring Wheat		n=24					
Pioneer	(.491)	124	65.3	116	63.2	148	64.3

1. The significance of variety was .175, and the variety x tillage interaction was .328.

Table 10. The effect of tillage on crop growth stages on June 4, 1987.

		Tillage					
		No Till		Chisel		Moldboard	
	Sig. of	mean	stdv	mean	stdv	mean	stdv
Crop-Variety	Tillage[1]	---- Zadoks growth stage ----					
Winter Wheat	(.000)	n=60					
Bighorn		55.4	5.79	57.7	2.99	58.9	1.99
Roughrider		56.0	4.35	59.2	2.12	59.1	2.09
Spring Wheat		n=60 --- Haun growth stage ---					
Pioneer	(.000)	3.71	0.32	3.69	0.39	3.97	0.44

1. The significance of variety was .073, and the variety x tillage interaction was .510.

Table 11. The effect of tillage on weed species present in spring wheat (Pioneer 2369) and their density on June 4, 1987, n=18.

		Tillage					
		No Till		Chisel		Moldboard	
	Sig. of	mean	stdv	mean	stdv	mean	stdv
Weed	Tillage	---------- % of coverage ----------					
Foxtail	(.155)	1.18	1.30	7.41	10.5	1.22	1.65
Mustard	(.867)	0.37	0.22	0.43	0.36	0.43	0.17
Lambsqurter	(.682)	0.33	0.26	0.55	0.74	0.40	0.15
Buckwheat	(.878)	0.33	0.26	0.30	0.22	0.37	0.21
Ragweed	--	0.00	0.00	0.08	0.20	0.08	0.20
Quackgrass	--	0.00	0.00	0.00	0.00	0.33	0.41
Cockle	--	0.17	0.26	0.00	0.00	0.10	0.20
Wormweed	(.811)	0.25	0.27	0.17	0.26	0.17	0.26
Smartweed	(.879)	0.33	0.23	0.33	0.26	0.41	0.30
Pigweed	--	0.00	0.00	0.10	0.20	0.00	0.00
Pennycress	(.456)	0.28	0.25	0.80	1.57	0.20	0.21
Dandelion	--	0.25	0.27	0.00	0.00	0.00	0.00

Table 12. The effect of tillage on weed species present on Bighorn winter wheat and their density on June 4, 1987. Weed species which were significantly affected by tillage are in bold type, n=18.

		Tillage					
		No Till		Chisel		Moldboard	
	Sig. of	mean	stdv	mean	stdv	mean	stdv
Weed	Tillage	-------- % of coverage --------					
Foxtail	(.693)	0.87	0.60	0.77	0.67	0.53	0.40
Mustard	**(.065)**	**0.53**	**0.15**	**0.20**	**0.10**	**0.40**	**0.10**
Lambsquartr	(.207)	0.20	0.00	0.43	0.31	0.50	0.00
Buckwheat	**(.088)**	**0.20**	**0.10**	**0.36**	**0.23**	**0.70**	**0.30**
Ragweed	--	0.00	0.00	0.20	0.26	0.00	0.00
Quackgrass	--	0.03	0.06	0.00	0.00	0.00	0.00
Cockle	(.129)	0.03	0.06	0.30	0.26	0.33	0.29
Wormweed	--	0.20	0.26	0.20	0.26	0.00	0.00
Smartweed	(.444)	0.27	0.15	0.13	0.15	0.20	0.26
Pigweed	**(0)**	**0.17**	**0.29**	**0.17**	**0.29**	**0.17**	**0.29**
Pennycress	(.921)	0.37	0.23	0.30	0.10	0.30	0.36
Dandelion	--	0.33	0.29	0.00	0.00	0.00	0.00

Table 13. The effect of tillage on weed species present on Roughrider winter wheat and their density on June 4, 1987. Weed species which were significantly affected by tillage are in bold type, n=18.

		Tillage					
		No Till		Chisel		Moldboard	
	Sig. of	mean	stdv	mean	stdv	mean	stdv
Weed	Tillage	-------- % of coverage --------					
Foxtail	(.132)	0.50	0.10	0.33	0.06	0.37	0.15
Mustard	--	0.00	0.00	0.20	0.26	0.07	0.06
Lambsquartr	(.224)	0.23	0.23	0.33	0.21	0.50	0.10
Buckwheat	(.311)	0.07	0.16	0.37	0.23	0.23	0.25
Ragweed	--	0.00	0.00	0.33	0.29	0.33	0.29
Quackgrass	--	0.00	0.00	0.00	0.00	0.33	0.29
Cockle	--	0.03	0.06	0.17	0.29	0.00	0.00
Wormweed	--	0.40	0.17	0.17	0.29	0.00	0.00
Smartweed	**(.016)**	**0.50**	**0.00**	**0.03**	**0.06**	**0.27**	**0.21**
Pigweed	--	0.00	0.00	0.00	0.00	0.20	0.35
Pennycress	--	0.17	0.06	0.20	0.20	0.00	0.00
Dandelion	--	0.17	0.29	0.00	0.00	0.00	0.00

Table 14. The effect of tillage on wheat yields on July 24, 1987.

	Tillage						
	No Till		Chisel		Moldboard		
	mean	stdv	mean	stdv	mean	stdv	Avg
	bu/ac						
Winter Wheat[1]	n=12						
Bighorn	36.9	9.1	44.4	4.5	38.0	5.0	39.8
Roughrider	38.0	5.5	29.0	4.2	37.7	4.3	34.9
Spring Wheat[2]	n=8						
Pioneer	34.4	4.1	32.5	9.3	38.9	8.2	35.3

1. The significance of tillage was .832 and variety was .005, the significance of tillage x variety interaction was .000.
2. The significance of tillage was .149.

Table 15. The effect of tillage on harvest moisture on July 24, 1987.

	Tillage						
	No Till		Chisel		Moldboard		
	mean	stdv	mean	stdv	mean	stdv	Avg
	%						
Winter Wheat[1]	n=12						
Bighorn	9.6	2.4	12.0	0.5	11.5	1.4	11.0
Roughrider	15.0	10.0	10.8	3.1	11.1	0.8	12.3
Spring Wheat[2]	n=8						
Pioneer	15.5	3.2	13.6	1.3	13.1	1.4	13.9

1. The significance of tillage was .839 and variety was .421, the significance of tillage x variety interaction was .188.
2. The significance of tillage was .048.

Table 16. The effect of tillage on test weights on July 24, 1987.

	Tillage						
	No Till		Chisel		Moldboard		
	mean	stdv	mean	stdv	mean	stdv	Avg
	lb/bu						
Winter Wheat[1]	n=12						
Bighorn	55.8	0.68	55.9	0.92	56.9	1.20	56.2
Roughrider	58.2	0.26	58.2	0.82	58.3	0.87	58.2
Spring Wheat[2]	n=8						
Pioneer	58.6	2.16	60.1	1.48	59.8	1.53	59.5

1. The significance of tillage was .121 and variety was .000, the significance of tillage x variety interaction was .303.
2. The significance of tillage was .048.

Table 17. The effect of tillage on protein on July 24, 1987.

	Tillage						
	No Till		Chisel		Moldboard		
	mean	stdv	mean	stdv	mean	stdv	Avg
	%						
Winter Wheat[1]	n=12						
Bighorn	12.7	0.20	12.4	0.37	12.2	0.70	12.4
Roughrider	14.5	0.52	13.9	1.18	14.5	0.90	14.3
Spring Wheat[2]	n=8						
Pioneer	14.9	1.27	15.3	0.92	15.6	1.01	15.3

1. The significance of tillage was .302 and variety was .000, the significance of tillage x variety interaction was .353.
2. The significance of tillage was .259.

TILLAGE EFFECTS ON WINTER AND SPRING WHEAT, BARLEY, AND SOYBEAN PRODUCTION ON THE LACUSTRINE SOILS OF NORTHWESTERN MINNESOTA

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In an effort to evaluate the production of winter and spring wheat, barley, and soybeans on the poorly drained soils (Aquolls) of the Red River Valley in northwestern Minnesota plots were established in 1986 in Norman County, Minnesota. The soil at this site is a complex of Fargo-Hegne silty clay (table 1). The rotation followed is wheat (plots are split between winter and spring wheat), soybeans, and barley. Soil test results for barley following soybeans are shown in table 2. Tillage affected soil mineral nitrogen in the barley plots. There was less mineral N in the 6 to 24 inch depth increment without tillage. This suggests that there was more mineralization of soil nitrogen in the fall and spring following primary tillage or more losses without tillage. When wheat followed barley (table 3) similar trends were present but not statistically significant.

Soil cover by crop residue is shown in table 2. The soil cover left following planting when winter wheat followed barley was adequate for erosion control with the no till and chisel plowing systems. When spring secondary tillage was done on chisel plowed plots for spring wheat, the soil cover was less than desirable levels for adequate erosion control. Barley followed soybeans and had adequate cover on only the no till treatment. Soybeans followed wheat and again had less than adequate cover on all except the no till treatment.

Statistical analysis suggests that tillage only affected plant population of barley grown after soybeans. Winter wheat stands were quite variable and reduced within no tillage plots. This was most likely due to an open winter and shallow planting in no till plots. Winter wheat did not have the benefit of "snow catch" due to barley stubble to provide insulation. The growth of the Roughrider wheat was less variable than the Bighorn and influenced by tillage (table 4). The Marshall spring wheat advanced less quickly than the Stoa. Barley and soybeans tended to grow slower with conservation tillage but differences were not statistically significant.

The effect of tillage and crop on weed density by species is shown in tables 7 to 17. The major weeds in the soybeans following wheat were foxtail, mustard, and volunteer wheat. Chisel plowing resulted in higher levels of foxtail. Mustard was higher in the chisel and moldboard plowed plots. These data were collected before applying post emergence broadleaf and grass herbicides. There were very few weeds at harvest and did not affect soybean yields.

Barley following soybeans had higher levels of volunteer soybeans in chisel plowed plots. There were low levels of weeds in barley plots and they did not affect yields.

There were significant effects of tillage on weed densities in winter wheat (tables 9 and 10). Mustard and buckwheat were higher in moldboard plowed plots. No till plots had higher levels of curlydock. No till and chisel plowed plots had higher levels of foxtail.

Spring wheat showed higher levels of pigweed in chisel plowed plots. The effect of tillage on the appearance of foxtail was similar to the winter wheats. There were winter wheat varietal effects on buckwheat, mustard, dandelions, and pigweed (table 13). This was a result of less competition due to shorter straw, tillage effects on weed seed distribution, and less wheat stand depending on the weed species. Pigweed were present in higher numbers in chisel plowed plots with Stoa spring wheat but higher with Marshall spring wheat in moldboard plowed plots (table 14).

Winter and spring wheats are compared in table 15. Winter wheat had higher densities of foxtail, mustard, buckwheat, lambquarters, and cockle. There was also a significant tillage by crop (winter vs. spring wheat) interaction on mustard density. Higher densities were found with chisel and moldboard plowing for winter wheat production. Tall and short wheat varietal comparisons are shown in table 16. Buckwheat competed better in short wheat. Over all varieties of wheat foxtail densities were higher with less tillage (table 17). Mustard had higher densities with more tillage.

Wheat plots were split with a fungicide application. Ratings for leaf lesions are shown in tables 18 and 19. Significance values from the analysis of variance are shown in table 20. There were no significant effects of tillage on leaf diseases in either winter or spring wheat. Fungicide application reduced disease ratings at all times of observation. There was a greater response to fungicide application by the Stoa spring wheat over the Marshall at the June 27 observation. There was an interaction on the July 13 observation of spring wheat between tillage, variety, and fungicide application (table 18). There was generally more of a response by the Stoa wheat and varietal effects were reversed in the chisel plowed treatments.

Grain yields are shown in tables 21 to 23. Statistical significance of treatments are shown in table 24. Tillage affected winter wheat yields but not spring wheat yields (table 22). Winter wheat yields were five bushels per acre lower when grown without tillage. This yield reduction is due to reduced stand and the subsequent increase in weed pressure rather than disease problems. This is also the explanation for the tillage by winter wheat variety interaction.

There was more stand loss due to no tillage in the Bighorn plots and subsequent competition by buckwheat (table 13). There was a trend of a yield increase with less tillage with spring wheat. This is due to less mature wheat (as evidenced by harvest moisture-table 25) at the time of a severe hail storm that resulted in less loss due to broken stems (on July 21).

There was a significant response to fungicide application (7.4 bu/acre) by winter wheat but not spring wheat (table 21). The response was greater in the conservation tillage systems by the Roughrider but not affected by tillage in the Bighorn plots. The Bighorn also responded much more to fungicide application than the Roughrider.

Grain test weights are shown in tables 28 to 30. There were significant tillage, varietal and interactions on test weights in winter wheat. Unlike the Bighorn winter wheat, Roughrider had a higher test weight and was not affected by tillage.

Grain protein data is presented in tables 31 to 34 for wheat. Similar mirror images of treatment yield responses by protein occurred due to a dilution affect of increased yields.

Barley data are shown in table 35. Yields, moisture, protein, and test weight of barley grown after soybeans were not affected by tillage.

Soybean data are shown in table 36. Yields and moisture of soybeans following wheat were also not affected by tillage. This has been consistent in Minnesota research.

Table 1. Cultural practices at Norman County, MN. 1987.

Tillage

No Till-the soybean and barley plots were dragged in spring.
Chisel Plow-fall
Moldboard Plow-fall
The spring seeded chisel and moldboard plow treatments were field cultivated twice with a drag behind it before seeding.

Preceding Crop 1985-Spring Wheat, 1986-start of three year (wheat, barley, soybean) rotation.

1987 Crops

Winter wheat - Bighorn
- Roughrider
Spring wheat - Marshall
- Stoa
Barley - Robust
Soybeans - McCalls

Planting and Harvest Dates

A Haybuster No Till Disc Drill was used to plant all plots.

	Planting		
Crop	Date	Rate	Harvested
Winter wheat	Sept. 26, 1986	90 lbs/ac	July 29, 1987
Spring wheat	April 24, 1987	90 lbs/ac	July 29, 1987
Barley	April 24, 1987	96 lbs/ac	July 29, 1987
Soybeans	May 8, 1987	94 lbs/ac	Oct. 1, 1987

Soil

Fargo silty clay, 0 to 1 percent slopes (Vertic Haplaquolls, fine, montmorillonitic, frigid) on 50 percent of the plot and Hegne (Typic Calciaquolls, fine, frigid)-Fargo (Vertic Haplaquolls, fine, montmorillonitic, frigid) silty clays on the rest of the plot. Both soils are poorly drained.

Weed Control

Wheat	Chemical		Amount	Applied
Winter	Roundup		1.2 pt/ac	Sept. 9
	Hoelon	(tankmix)	3.0 pt/ac	June 3
	Buctril	"	1.0 pt/ac	"
	MCPA Ester	"	0.5 pt/ac	"
Spring	Hoelon	(tankmix)	3.0 pt/ac	June 3
	Buctril	"	1.0 pt/ac	"
	MCPA Ester	"	0.5 pt/ac	"
Soybeans	Brominal 3+3(no till)	(tankmix)	2.2 pt/ac	May 11
	Roundup "	"	1.4 pt/ac	"
	Poast	(tankmix)	1.5 pt/ac	June 6
	Herbimax Oil	"	2.0 pt/ac	"
	Basagran	(tankmix)	1.5 pt/ac	June 9
	Blazer	"	1.0 pt/ac	"
	Herbimax Oil	"	2.0 pt/ac	"
Barley	MCPA Ester		1.0 pt/ac	June 4

Fungicides

1st application: Diathane M45 at 2 lb/ac + 2 oz/ac sticker on June 16, 1987 with the Ada Co-op sprayer.

2nd application: Manzate 200 DF at 1.5 qt/ac with 7 gal/ac water on June 26, 1987 using a spray foil.

Fertilizer

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			----lb/ac----			
			No Till			
Winter wheat:	18-46-0[1]	137 lb/ac	25	63	0	Sept. 26, 1986
	46-0-0[2]	220 lb/ac	101	0	0	April 29, 1987
			Tilled			
	18-46-0[1]	137 lb/ac	25	63	0	Sept. 26, 1986
	46-0-0[2]	152 lb/ac	70	0	0	April 29, 1987
			No Till			
Spring wheat:	46-0-0[2]	220 lb/ac	101	0	0	April 24, 1987
	18-46-0[1]	100 lb/ac	18	46	0	April 29, 1987
			Tilled			
	46-0-0[2]	152 lb/ac	70	0	0	April 24, 1987
	18-46-0[1]	100 lb/ac	18	46	0	April 29, 1987
			No Till & Tilled			
Barley:	46-0-0[2]	175 lb/ac	81	0	0	April 24, 1987
	18-46-0[1]	100 lb/ac	18	46	0	April 29, 1987
			No Till & Tilled			
Soybeans:	18-46-0[1]	53 lb/ac	10	24	0	May 8, 1987

1. Drill applied.
2. Urea broadcast.

Soil Test

Table 2. Soil test results at Norman County barley sites on June 3, 1987.

Nutrient	Depth Inches	Sig. of Tillage	No Till mean	No Till stdev	Chisel mean	Chisel stdev	Moldboard mean	Moldboard stdev
			----	----	lb/ac	----	----	----
NO_3	0-6	(.963)	35.9	21.8	31.5	10.1	34.4	14.6
	6-24	(.117)	62.1	32.1	133.6	4.3	118.4	58.5
	0-24	(.157)	98.0	12.3	165.2	6.0	152.8	65.6
NH_4	0-6	(.366)	16.2	7.1	8.2	5.3	9.1	4.9
	6-24	(.525)	32.7	8.4	38.3	12.1	30.0	2.8
	0-24	(.710)	48.9	13.1	46.5	17.0	39.0	5.2
NO_3+NH_4	0-6	(.822)	52.1	25.2	39.8	15.2	43.5	18.2
	6-24	(.100)	94.8	39.5	171.9	8.3	148.4	61.2
	0-24	(.224)	146.9	24.3	211.6	22.9	191.9	67.5
K	0-6	(.400)	664.4	51.7	628.7	74.2	584.5	81.2

Table 3. Soil test results at Norman County wheat sites on June 3, 1987.

		WINTER WHEAT							SPRING WHEAT						
			Tillage							Tillage					
			No Till		Chisel		Moldboard			No Till		Chisel		Moldboard	
	Depth	Sig. of	mean	stdev	mean	stdev	mean	stdev	Sig. of	mean	stdev	mean	stdev	mean	stdev
Nutrient	Inch.	Tillage	lbs/ac						Tillage	lbs/ac					
NO_3	0-6	(.210)	24.9	2.5	50.2	3.8	38.5	25.5	(.489)	48.3	17.6	45.2	12.6	32.4	8.2
	6-24	(.843)	79.4	39.9	102.4	27.0	82.5	61.5	(.706)	103.3	16.2	89.2	56.0	78.6	24.1
	0-24	(.657)	104.3	38.4	152.6	27.4	120.9	86.9	(.636)	151.6	30.1	134.4	68.3	111.0	30.4
NH_4	0-6	(.324)	8.8	3.2	11.9	1.4	10.7	0.8	(.016)	11.8	0.3	11.9	0.7	10.2	0.9
	6-24	(.583)	21.3	7.7	28.3	4.1	25.2	6.8	(.874)	27.7	5.3	25.8	5.4	26.7	6.8
	0-24	(.314)	30.1	6.4	40.3	2.7	36.0	7.5	(.758)	39.5	5.1	37.6	5.0	37.0	6.0
NO_3+NH_4	0-6	(.190)	33.7	5.7	62.2	4.4	49.2	26.1	(.419)	60.1	17.9	57.1	11.8	42.6	7.4
	6-24	(.816)	100.7	47.5	130.7	30.9	107.7	68.2	(.711)	130.9	19.6	115.0	60.3	105.3	30.1
	0-24	(.617)	134.4	44.5	192.9	29.8	156.9	94.2	(.625)	191.0	31.1	172.1	71.7	148.0	36.1
K	0-6	(.048)	718.0	79.3	589.4	25.5	555.0	8.5	(.160)	616.2	56.5	594.3	17.0	540.3	45.0

Table 4. The effect of tillage on in-row an between-row soil cover on barley residue for wheat, soybean residue for barley and wheat residue for soybeans. For wheat and barley, data was collected on April 24, 1987; soybeans on May 8, 1987.

	IN-ROW RESIDUE						BETWEEN ROW RESIDUE					
	Tillage											
	No Till		Chisel		Moldboard		No Till		Chisel		Moldboard	
	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev
Crop-Variety	%						%					
Winter Wheat n=12												
Bighorn	76.3	10.8	32.3	7.5	15.7	11.3	69.3	8.7	22.0	11.3	9.0	9.3
Roughrider	82.6	7.3	26.0	11.5	16.7	4.7	71.7	18.0	16.0	5.1	12.0	6.3
Spring Wheat n=12												
Marshall	76.3	16.4	13.3	11.6	12.7	7.5	66.0	24.9	7.7	6.2	8.0	4.5
Stoa	66.3	15.8	10.3	4.9	14.7	11.4	62.3	12.2	9.0	5.1	9.7	7.9
Barley n=18												
Robust	62.0	17.1	11.6	4.9	5.6	3.9	46.2	13.8	6.7	3.6	2.0	2.4
Soybeans n=18												
McCalls	66.9	17.9	11.6	11.2	7.1	5.5	63.8	16.3	11.6	8.5	5.8	4.5

Table 5. The effect of tillage on plant population.

Crop-Variety	Sig. of Tillage	No Till mean	No Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
		------ plants/ac x 1000 -------					
Winter Wheat[1]	(.453)	n=6					
Bighorn		232	102	232	97	276	71
Roughrider		397	170	445	112	494	222
Spring Wheat[2]	(.312)	n=6					
Marshall		440	171	547	130	300	194
Stoa		281	124	368	190	436	197
Barley	(.058)	n=9					
Robust		716	132	807	157	891	164
Soybeans	(.864	n=18					
McCalls		180	83.6	168	51.0	178	54.7

1. The significance of variety was .000, and the variety x tillage interaction was .838.
2. The significance of variety was .240, and the variety x tillage interaction was .056.

Table 6. The effect of tillage on crop growth.

Crop-Variety	Sig. of Tillage	No Till mean	No Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
		----- Zadoks growth stage ----					
Winter Wheat[1]	(.000)	n=30					
Bighorn		45.0	5.3	46.6	3.0	45.1	5.1
Roughrider		44.0	2.3	46.1	2.3	49.7	3.4
Spring Wheat[2]	(.674)	n=30 --- Haun growth stage ---					
Marshall		3.49	.29	3.54	.53	3.40	.36
Stoa		3.74	.47	3.63	.62	3.85	.56
Barley	(.223)	n=45 --- Haun growth stage ---					
Robust		3.75	.69	3.80	.54	3.95	.48
Soybeans	(.214)	n=45 ------ Node number ------					
McCalls		1.73	.44	1.73	.44	1.87	.34

1. The significance of variety was .022, and the variety x tillage interaction was .000.
2. The significance of variety was .001, and the variety x tillage interaction was .072.

Table 7. The effect of tillage on weeds in soybeans on June 3, 1987, n=6.

Weed	Sig. of Tillage[1]	No Till mean	No Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
		----------- % cover -----------					
Foxtail	(.061)	18.3	6.8	24.5	8.8	15.5	10.0
VolWheat	(.624)	2.5	1.8	2.5	1.0	1.9	1.4
Pigweed	(.078)	0.6	0.2	2.0	2.1	0.9	0.6
Ragweed	(.758)	0.1	0.2	0.1	0.2	0.2	0.3
Mustard	(.001)	0.7	0.3	2.9	1.8	4.8	3.3
Buckwheat	(.126)	0.3	0.3	0.5	0.0	0.3	0.3
Lambsqurtr	--	0.0	0.0	0.1	0.2	0.1	0.2
Quackgrass	--	0.1	0.2	0.0	0.0	0.1	0.2

1. Due to unnatural variances, a natural log transformation was used for significance.

Table 8. The effect of tillage on weeds in barley on June 3, 1987, n=6.

Weed	Sig. of Tillage[1]	No Till mean	No Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
		----------- % cover -----------					
Foxtail	(.383)	2.7	1.4	1.9	1.0	2.2	0.8
VolSoybean	(.038)	1.2	1.9	2.7	1.2	1.5	0.8
Pigweed	--	0.4	0.2	0.3	0.3	0.0	0.0
Ragweed	(.475)	1.5	2.0	0.3	0.4	0.2	0.3
Mustard	(.211)	1.0	1.0	1.8	0.9	1.8	0.8
Buckwheat	(.223)	6.5	5.0	4.8	5.0	2.7	0.8
Lambsqurtr	(.320)	0.3	0.3	0.6	0.7	0.4	0.2
Quackgrass	--	0.4	0.4	0.0	0.0	0.0	0.0
Dandelion	--	0.3	0.3	0.0	0.0	0.0	0.0
Curlydock	--	0.1	0.2	0.0	0.0	0.0	0.0
CommonRgwd	--	0.2	0.3	0.0	0.0	0.0	0.0
Smartweed	--	0.1	0.2	0.0	0.0	0.0	0.0

1. Due to unnatural variances, a natural log transformation was used for significance.

Table 9. The effect of tillage on weeds in Bighorn wheat on June 3, 1987, n=6.

Weed	Sig. of Tillage[1]	No Till mean	No Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
		% cover					
Foxtail	(.114)	15.5	9.8	15.5	14.8	8.2	3.7
Pigweed	(.434)	0.5	0.5	1.4	1.1	1.0	0.5
Ragweed	--	0.0	0.0	0.0	0.0	0.1	0.2
Mustard	(.001)	0.7	0.7	2.0	2.5	6.3	4.2
Buckwheat	(.457)	22.0	21.7	11.7	2.9	15.7	4.1
Lambsqurtr	(.943)	1.8	2.2	1.4	1.3	1.3	1.9
Pennycress	(.639)	0.1	0.2	0.1	0.2	0.2	0.4
Quackgrass	--	0.3	0.5	0.0	0.0	0.0	0.0
Dandelion	--	0.6	0.2	0.0	0.0	0.1	0.2
Curlydock	(.213)	0.2	0.4	0.4	0.4	0.8	1.2
CommonRgwd	(.782)	0.3	0.3	0.3	0.3	0.3	0.3
Smartweed	--	0.0	0.0	0.2	0.4	0.2	0.4
Cockle	(.755)	1.0	2.0	3.5	6.6	1.2	0.9
Milkweed	(.234)	0.4	0.5	0.2	0.4	0.2	0.4

1. Due to unnatural variances, a natural log transformation was used for significance.

Table 10. The effect of tillage on weeds in Roughrider winter wheat on June 3, 1987 n=6.

Weed	Sig. of Tillage[1]	No Till mean	No Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
		% cover					
Foxtail	(.007)	17.3	12.3	8.0	3.7	3.8	1.8
Pigweed	(.306)	0.3	0.5	0.2	0.3	0.5	0.4
Ragweed	--	0.0	0.0	0.1	0.2	0.3	0.8
Mustard	(.149)	0.5	0.4	1.9	1.7	2.4	3.8
Buckwheat	(.092)	6.7	4.9	9.0	1.3	8.0	2.4
Lambsqurtr	(.136)	1.9	2.9	0.4	0.4	1.6	1.8
Pennycress	--	0.0	0.0	0.1	0.2	0.0	0.0
Quackgrass	--	0.1	0.2	0.0	0.0	0.0	0.0
Dandelion	--	0.3	0.3	0.0	0.0	0.0	0.0
Curlydock	(.087)	1.0	0.9	0.2	0.3	0.2	0.3
CommonRgwd	(.142)	0.3	0.3	0.2	0.4	0.1	0.2
Smartweed	--	0.2	0.3	0.0	0.0	0.0	0.0
Cockle	(.273)	0.9	0.9	2.8	1.5	1.5	2.7

1. Due to unnatural variances, a natural log transformation was used for significance.

Table 11. The effect of tillage on weeds in Marshall spring wheat on June 3, 1987, n=6.

Weed	Sig. of Tillage[1]	No Till mean	No Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
		% cover					
Foxtail	(.002)	12.7	8.7	4.8	1.9	3.8	1.0
Pigweed	(.403)	0.4	0.5	0.7	0.8	1.1	1.6
Mustard	(.674)	0.2	0.3	0.8	0.6	0.8	0.4
Buckwheat	(.145)	3.7	3.2	1.9	1.0	2.7	1.0
Lambsqurtr	(.138)	0.8	1.6	0.2	0.3	0.1	0.2
Quackgrass	--	0.2	0.3	0.1	0.2	0.0	0.0
Dandelion	--	0.3	0.4	0.0	0.0	0.0	0.0
Curlydock	--	0.2	0.4	0.0	0.0	0.0	0.0
CommonRgwd	--	0.2	0.3	0.0	0.0	0.0	0.0
Smartweed	--	0.1	0.2	0.0	0.0	0.1	0.2
Cockle	(.465)	0.3	0.3	0.3	0.4	0.2	0.3

1. Due to unnatural variances, a natural log transformation was used for significance.

Table 12. The effect of tillage on weeds in Stoa spring wheat on June 3, 1987, n=6.

Weed	Sig. of Tillage[1]	No Till mean	No Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
		% cover					
Foxtail	(.013)	14.3	10.2	8.3	3.0	4.7	2.3
Pigweed	(.084)	0.6	1.2	1.8	2.2	0.5	0.3
Ragweed	--	0.0	0.0	0.1	0.2	0.0	0.0
Mustard	(.578)	0.6	0.4	1.0	0.5	0.8	0.3
Buckwheat	(.694)	3.2	1.2	2.8	1.0	2.7	1.2
Lambsqurtr	--	0.3	0.3	0.0	0.0	0.0	0.0
Quackgrass	--	0.3	0.3	0.0	0.0	0.0	0.0
Dandelion	--	0.3	0.3	0.0	0.0	0.0	0.0
Curlydock	--	0.0	0.0	0.1	0.2	0.0	0.0
Smartweed	--	0.0	0.0	0.1	0.2	0.0	0.0
Cockle	--	0.2	0.3	0.4	0.2	0.0	0.0
Milkweed	--	0.3	0.4	0.0	0.0	0.0	0.0

1. Due to unnatural variances, a natural log transformation was used for significance.

Table 13. The effect of tillage, variety, and tillage by variety on weeds in winter wheat on June 3, 1987.

		Tillage										Tillage					
		No Till		Chisel		Moldboard			Variety			No Till		Chisel		Moldboard	
	Sig. of	mean	stdev	mean	stdev	mean	stdev	Sig. of	Bghn	Rrdr	Sig. of	Bghn	Rrdr	Bghn	Rrdr	Bghn	Rrdr
Weed	Tillage	n=12	-------	% cover	-----------			Variety	n=18	% ---	TillxVar	n=6	-------	% cover	-----------		
Foxtl	(.008)	16.4	10.6	11.8	11.0	6.0	3.6	(.189)	13.1	9.7	(.309)	15.5	17.3	15.5	8.0	8.2	3.8
Pigwd	(.339)	0.4	0.7	0.8	1.0	0.8	0.5	(.009)	1.0	0.3	(.150)	0.5	0.3	1.4	0.2	1.0	0.5
Ragwd	--	0.0	0.0	0.0	0.1	0.2	0.6	(.355)	0.0	0.1	--	0.0	0.0	0.0	0.1	0.1	0.3
Mustd	(.003)	0.6	0.3	2.0	2.1	4.4	4.3	(.097)	3.0	1.6	(.103)	0.7	0.5	2.0	1.9	6.3	2.4
Bclwt	(.550)	14.3	17.0	10.3	2.5	11.8	5.1	(.009)	16.4	7.9	(.239)	22.0	6.7	11.7	9.0	15.7	8.0
Lamqr	(.225)	1.8	2.5	0.9	1.0	1.5	1.8	(.649)	1.5	1.3	(.414)	1.8	1.9	1.4	0.4	1.3	1.6
Pnycs	(.878)	0.0	0.1	0.1	0.2	0.1	0.3	(.289)	0.1	0.0	--	0.1	0.0	0.1	0.1	0.2	0.0
Qukgs	--	0.2	0.4	0.0	0.0	0.0	0.0	(.177)	0.1	0.0	--	0.3	0.1	0.0	0.0	0.0	0.0
Dndln	--	0.5	0.3	0.0	0.0	0.0	0.1	(.043)	0.2	0.1	--	0.6	0.3	0.0	0.0	0.1	0.0
Crlyd	(.461)	0.6	0.8	0.3	0.3	0.5	0.7	(1.00)	0.4	0.4	(.015)	0.2	1.0	0.4	0.2	0.8	0.2
CRgwd	(.914)	0.3	0.3	0.2	0.3	0.2	0.3	(.242)	0.3	0.2	(.541)	0.3	0.3	0.3	0.2	0.3	0.1
Smtwd	(1.00)	0.1	0.2	0.1	0.3	0.1	0.3	(.522)	0.1	0.1	--	0.0	0.2	0.2	0.0	0.2	0.0
Cockl	(.268)	1.0	1.5	3.1	4.6	1.3	1.9	(.863)	1.9	1.7	(.924)	1.1	0.9	3.5	2.8	1.2	1.5
Mlkwd	(.734)	0.2	0.4	0.1	0.3	0.2	0.6	--	0.3	0.0	--	0.4	0.0	0.2	0.0	0.3	0.0

Table 14. The effect of tillage, variety, and tillage by variety on weeds in spring wheat on June 3, 1987.

		Tillage										Tillage					
		No Till		Chisel		Moldboard			Variety			No Till		Chisel		Moldboard	
	Sig. of	mean	stdev	mean	stdev	mean	stdev	Sig. of	Mars	Stoa	Sig. of	Mars	Stoa	Mars	Stoa	Mars	Stoa
Weed	Tillage	n=12	-------	% cover	-----------			Variety	n=18	% ---	TillxVar	n=6	-------	% cover	-----------		
Foxtl	(.001)	13.5	9.0	6.6	3.0	4.3	3.0	(.294)	7.1	9.1	(.837)	12.7	14.3	4.8	8.3	3.8	4.7
Pigwd	(.176)	0.5	0.9	1.2	1.6	0.8	1.2	(.466)	0.7	0.9	(.098)	0.4	0.6	0.7	1.8	1.1	0.5
Ragwd	--	0.0	0.0	0.0	0.1	0.0	0.0	--	0.0	0.0	--	0.0	0.0	0.0	0.1	0.0	0.0
Mustd	(.021)	0.4	0.4	0.9	0.6	0.8	0.3	(.206)	0.6	0.8	(.527)	0.2	0.6	0.8	1.0	0.8	0.8
Bclwt	(.193)	3.4	2.3	2.4	1.1	2.7	1.1	(.768)	2.8	2.9	(.465)	3.7	3.2	1.9	2.8	2.7	2.7
Lamqr	(.158)	0.5	1.1	0.1	0.2	0.0	0.1	(.232)	0.4	0.1	--	0.8	0.3	0.2	0.0	0.1	0.0
Qukgs	--	0.3	0.3	0.0	0.1	0.0	0.0	(.644)	0.1	0.1	--	0.2	0.3	0.1	0.0	0.0	0.0
Dndln	--	0.3	0.3	0.0	0.0	0.0	0.0	(.633)	0.1	0.1	--	0.3	0.3	0.0	0.0	0.0	0.0
Crlyd	--	0.1	0.3	0.0	0.1	0.0	0.0	(.653)	0.1	0.0	--	0.2	0.0	0.0	0.1	0.0	0.0
CRgwd	--	0.1	0.2	0.0	0.0	0.0	0.0	--	0.1	0.0	--	0.2	0.0	0.0	0.0	0.0	0.0
Smtwd	(1.00)	0.0	0.1	0.0	0.1	0.0	0.1	(.581)	0.1	0.0	--	0.1	0.0	0.0	0.1	0.1	0.0
Cockl	(.105)	0.2	0.3	0.3	0.3	0.1	0.2	(.764)	0.2	0.2	--	0.3	0.2	0.3	0.4	0.2	0.0
Mlkwd	--	0.1	0.3	0.0	0.0	0.0	0.0	--	0.0	0.1	--	0.0	0.3	0.0	0.0	0.0	0.0

Table 15. The effect of crop (winter wheat by spring wheat) and crop by tillage interaction on weeds on June 3, 1987.

		Crop			Tillage					
					No Till		Chisel		Moldboard	
	Sig. of	Wint	Sprg	Sig. of	Wint	Sprg	Wint	Sprg	Wint	Sprg
Weed	Crop	n=36- % cover -		Tillxcrop	n=12 --------- % cover ----------					
Foxtail	(.032)	11.4	8.1	(.637)	16.4	13.5	11.8	6.6	6.0	4.3
Pigweed	(.448)	0.7	0.8	(.738)	0.4	0.5	0.8	1.2	0.8	0.8
Ragweed	(.251)	0.1	0.0	--	0.0	0.0	0.0	0.0	0.2	0.0
Mustard	(.001)	2.3	0.7	(.008)	0.6	0.4	2.0	0.9	4.4	0.8
Buckwheat	(.000)	12.2	2.8	(.795)	14.3	3.4	10.3	2.4	11.8	2.7
Lambquarters	(.000)	1.4	0.2	(.624)	1.8	0.5	0.9	0.1	1.5	0.0
Penycress	--	0.1	0.0	--	0.0	0.0	0.1	0.0	0.1	0.0
Quackgrass	(.538)	0.1	0.1	--	0.2	0.3	0.0	0.0	0.0	0.0
Dandelion	(.112)	0.2	0.1	--	0.5	0.3	0.0	0.0	0.0	0.0
Curlydock	(.001)	0.4	0.0	--	0.6	0.1	0.3	0.0	0.5	0.0
CommonRagweed	(.000)	0.2	0.0	--	0.3	0.1	0.2	0.0	0.2	0.0
Smartweed	(.408)	0.1	0.0	(.598)	0.1	0.0	0.1	0.0	0.1	0.0
Cockle	(.002)	1.8	0.2	(.246)	1.0	0.2	3.1	0.3	1.3	0.1
Milkweed	(.154)	0.2	0.0	--	0.2	0.1	0.1	0.0	0.2	0.0

Table 16. The effect of tall wheat varieties (Roughrider and Stoa) by short wheat varieties (Bighorn and Marshall) and tall by short varieties by tillage on weeds on June 3, 1987.

		Height			Tillage					
					No Till		Chisel		Moldboard	
	Sig. of	Short	Tall	Sig. of	Short	Tall	Short	Tall	Short	Tall
Weed	Height	n=36 % cover -		TillxHigh	n=12------- % cover ------------					
Foxtail	(.676)	10.1	9.5	(.563)	14.1	15.0	10.2	8.2	6.0	4.3
Pigweed	(.362)	0.9	0.6	(.580)	0.5	0.5	1.0	1.0	1.0	0.5
Ragweed	(.246)	0.0	0.1	--	0.0	0.0	0.0	0.1	0.0	0.2
Mustard	(.256)	1.8	1.2	(.185)	0.4	0.6	1.4	1.5	3.5	1.6
Buckwheat	(.044)	9.6	5.4	(.374)	12.8	4.9	6.8	5.9	9.2	5.3
Lambquarters	(.449)	0.9	0.7	(.680)	1.3	1.1	0.8	0.2	0.7	0.8
Pennycress	(.270)	0.1	0.0	--	0.0	0.0	0.0	0.0	1.0	0.0
Quackgrass	(.521)	0.1	0.1	--	0.3	0.2	0.0	0.0	0.0	0.0
Dandelion	(.127)	0.2	0.1	--	0.5	0.3	0.0	0.0	0.0	0.0
Curlydock	(.910)	0.3	0.2	(.116)	0.2	0.5	0.2	0.1	0.4	0.1
CommonRagweed	(.147)	0.2	0.1	(.836)	0.2	0.1	0.1	0.1	0.2	0.0
Smartweed	(.396)	0.1	0.0	--	0.0	0.1	0.1	0.0	0.1	0.0
Cockle	(.845)	1.1	1.0	(.964)	0.7	0.5	1.9	1.6	0.7	0.8
Milkweed	(.407)	0.2	0.0	--	0.2	0.1	0.1	0.0	0.2	0.0

Table 17. The effect of tillage on weeds of wheats (overall), n=24.

Weed	Sig. of Tillage	No Till mean	No Till stdev	Chisel mean	Chisel stdev	Moldboard mean	Moldboard stdev
		% cover					
Foxtail	(.000)	15.0	9.8	9.2	8.3	5.1	2.9
Pigweed	(.180)	0.5	0.8	1.0	1.3	0.8	0.9
Ragweed	--	0.0	0.0	0.4	0.1	0.1	0.4
Mustard	(.002)	0.5	0.4	1.4	1.6	2.6	3.5
Buckwheat	(.511)	8.9	13.1	6.4	4.5	7.3	5.9
Lamquarters	(.096)	1.2	2.0	0.5	0.8	0.8	1.4
Pennycress	(.861)	0.2	0.1	0.0	0.1	0.0	0.2
Quackgrass	--	0.2	0.3	0.0	0.1	0.0	0.0
Dandelion	--	0.4	0.3	0.0	0.0	0.0	0.1
Curlydock	(.516)	0.3	0.6	0.2	0.3	0.2	0.6
CommonRagweed	(.510)	0.2	0.2	0.1	0.3	0.1	0.2
Smartweed	(1.00)	0.1	0.2	0.1	0.2	0.1	0.2
Cockle	(.142)	0.6	1.1	1.7	3.5	0.7	1.5
Milkweed	(.407)	0.2	0.4	0.0	0.2	0.1	0.4

Table 18. The effect of tillage on disease in wheat on June 27, 1987.

Crop-Variety n=3	No Till fung	No Till noFung	Chisel fung	Chisel noFung	Moldboard fung	Moldboard noFung	Variety Avg n=18	Fungicide n=9 fung	Fungicide n=9 noFung
	Hosford Scale								
Bighorn	5.33	7.33	6.00	6.67	6.33	7.67	6.56	5.89	7.22
Roughrider	6.87	8.00	6.33	7.00	6.67	7.33	7.00	6.56	7.44
average n=6	6.00	7.67	6.17	6.83	6.50	7.50			
Overall n=12	6.83		6.50		7.00		n=18	6.22	7.33
Marshall	2.33	4.33	2.33	2.67	2.33	4.67	3.11	2.33	3.89
Stoa	1.67	2.00	1.67	4.00	2.00	3.33	2.44	1.78	3.11
average	2.00	3.17	2.00	3.33	2.17	4.00			
Overall	2.58		2.67		3.08			2.06	3.50

Table 19. The effect of tillage on disease in spring wheat on July 13, 1987.

Crop-Variety n=3	No Till fung	No Till noFung	Chisel fung	Chisel noFung	Moldboard fung	Moldboard noFung	Variety Avg n=18	Fungicide n=9 fung	Fungicide n=9 noFung
	Hosford Scale								
Marshall	5.17	7.17	4.83	7.17	5.50	6.33	6.03	5.17	6.89
Stoa	5.33	7.67	6.00	7.83	5.33	6.83	6.50	5.56	7.44
average n=6	5.25	7.42	5.42	7.50	5.42	6.58			
Overall n=12	6.33		6.46		6.00		n=18	5.37	7.17

Table 20. The significance of tillage, fungicide, variety and the interactions on wheat yields.

Wheat	Date	Till.	Fung.	Var.	Till x Fung	Till x Var	Var x Fung	Till x Fung x Var
		significance						
Winter	6-27	.524	.021	.189	.438	.383	.431	.816
Spring	6-27	.514	.005	.021	.871	.150	.827	.075
Spring	7-13	.548	.005	.221	.455	.647	.811	.768

Table 21. The effect of fungicide on the yields of wheat. The effects of tillage are averaged over fungicide, n=9.

	Fungicide			
	fung		no fung	
	mean	stdev	mean	stdev
Crop-Variety	bu/ac			
Winter wheat				
Bighorn	41.1	10.1	29.8	11.7
Roughrider	40.5	6.0	37.0	7.3
average	40.8		33.4	
Spring wheat				
Marshall	43.1	5.8	40.4	7.3
Stoa	31.2	8.9	31.4	4.6
average	37.1		35.9	

Table 22. The effect of tillage on the yields of wheat. The effect of fungicide are averaged over tillage, n=6.

	Tillage						
	No Till		Chisel		Moldboard		
	mean	stdev	mean	stdev	mean	stdev	Avg
Crop-Variety	bu/ac						
Winter wheat							
Bighorn	23.4	11.1	38.6	7.0	44.4	6.5	35.5
Roughrider	32.5	7.0	40.6	5.0	43.1	3.1	38.7
average	27.9		39.6		43.7		
Spring wheat							
Marshall	43.6	6.9	40.7	9.3	41.0	1.8	41.8
Stoa	33.3	5.8	32.1	8.9	28.5	5.9	31.3
average	38.5		36.4		34.7		

Table 23. The effect of tillage and fungicide on the yields of wheat, n=3.

	Tillage					
	No Till		Chisel		Moldboard	
	fung	no fung	fung	no fung	fung	no fung
Crop-Variety	bu/ac					
Winter wheat						
Bighorn	29.7	17.0	44.2	33.0	49.4	39.4
Roughrider	34.8	30.1	44.3	36.8	42.2	43.9
Spring wheat						
Marshall	46.7	40.6	41.0	40.4	41.7	40.3
Stoa	33.4	33.1	34.2	30.0	25.9	31.1

Table 24. The significance of tillage, fungicide, variety and the interactions on wheat yields.

Wheat	Till.	Fung.	Var.	Till x Fung	Till x Var	Var x Fung	Till x Fung x Var
	significance						
Winter	.004	.013	.056	.206	.066	.064	.449
Spring	.292	.709	.004	.410	.512	.353	.450

Table 25. The effect of tillage on the moisture of wheat at harvest. The effect of fungicide are averaged over tillage, n=6.

	Tillage						
	No Till		Chisel		Moldboard		
	mean	stdv	mean	stdv	mean	stdv	Avg
Crop-Varty				%			
Winter wht							
Bighorn	12.0	4.25	7.7	1.28	9.1	1.80	9.6
Roughrider	8.8	2.20	7.1	1.66	6.4	2.25	7.4
average	10.4		7.4		7.8		
Spring wht							
Marshall	18.2	3.87	14.5	2.48	15.6	3.58	1.61
Stoa	13.6	7.96	12.7	2.69	11.5	1.48	1.26
average	15.9		13.6		13.6		

Table 26. The effect of tillage and fungicide on the moisture of wheat at harvest, n=3.

	Tillage					
	No Till		Chisel		Moldboard	
	fung	no fung	fung	no fung	fung	no fung
Crop-Varty				%		
Winter wht						
Bighorn	9.26	14.76	6.88	8.51	7.73	10.38
Roughrider	7.96	9.67	7.02	7.09	7.75	5.05
Spring wht						
Marshall	20.36	16.09	12.41	16.55	16.82	14.33
Stoa	17.13	10.11	12.63	12.67	11.43	11.63

Table 27. The significance of tillage, fungicide, variety and the interactions on wheat moisture at harvest.

Wheat	Till.	Fung.	Var.	Till x Fung	Till x Var	Var x Fung	Till x Fung x Var
				significance			
Winter	.099	.383	.057	.317	.506	.101	.434
Spring	.684	.376	.092	.288	.686	.684	.623

Table 28. The effect of fungicide on the test weight of wheat at harvest. The effects of tillage are averaged over fungicide, n=9.

	Fungicide			
	fung		no fung	
	mean	stdev	mean	stdev
Crop-Variety		lb/bu		
Winter wheat				
Bighorn	56.9	2.01	54.6	3.02
Roughrider	60.1	0.55	58.8	0.43
average	58.5		56.7	
Spring wheat				
Marshall	59.3	1.12	58.8	1.56
Stoa	58.0	1.27	56.9	2.35
average	59.1		54.4	

Table 29. The effect of tillage on the test weight of wheat at harvest. The effects of fungicide are averaged over tillage, n=6.

	Tillage						
	No Till		Chisel		Moldboard		
	mean	stdev	mean	stdev	mean	stdev	Avg
Crop-Variety				lb/bu			
Winter wheat							
Bighorn	53.2	2.99	56.8	1.57	57.3	1.64	55.8
Roughrider	59.7	0.98	59.1	0.74	59.7	0.68	59.5
average	56.4		58.0		58.5		
Spring wheat							
Marshall	58.3	1.41	59.8	1.41	59.2	0.98	59.1
Stoa	56.9	2.27	57.8	2.27	57.7	1.32	57.4
average	57.6		58.8		58.4		

Table 30. The significance of tillage, fungicide, variety and the interactions on wheat test weights at harvest.

Wheat	Till.	Fung.	Var.	Till x Fung	Till x Var
			significance		
Winter	.035	.013	.001	.501	.024
Spring	.195	.122	.021	.938	.830

Table 31. The effect of fungicide on the protein content of wheat at harvest. The effects of tillage are averaged over fungicide, n=9.

	Fungicide			
	fung		no fung	
	mean	stdev	mean	stdev
Crop-Variety		%		
Winter wheat				
Bighorn	12.0	1.14	12.3	1.58
Roughrider	12.9	0.69	12.8	0.72
Spring wheat				
Marshall	13.3	0.83	13.3	0.91
Stoa	14.3	0.87	14.5	0.89

Table 32. The effect of tillage on the protein content of wheat at harvest. The effect of fungicide are averaged over tillage, n=6.

	Tillage						
	No Till		Chisel		Moldboard		
	mean	stdev	mean	stdev	mean	stdev	Avg
Crop-Variety				%			
Winter wheat							
Bighorn	13.0	1.20	11.5	0.87	11.9	1.61	12.2
Roughrider	13.0	0.47	12.4	0.62	13.1	0.84	12.8
average	13.0		12.0		12.5		
Spring wheat							
Marshall	13.5	0.66	13.5	1.25	13.0	0.54	13.3
Stoa	14.6	1.09	14.0	0.80	14.5	0.71	14.4
average	14.4		13.8		13.8		

Table 33. The effect of tillage and fungicide on the protein content of wheat at harvest, n=3.

	Tillage					
	No Till		Chisel		Moldboard	
	fung	no fung	fung	no fung	fung	no fung
Crop-Variety			%			
Winter wheat						
Bighorn	12.4	13.6	11.4	11.7	12.3	11.6
Roughrider	13.0	13.1	12.8	12.1	13.0	13.2
average	12.7	13.4	12.1	11.9	12.6	12.4
Spring wheat						
Marshall	13.7	13.3	13.4	13.5	12.8	13.3
Stoa	14.1	15.0	14.3	13.8	14.4	14.7
average	13.9	14.2	13.9	13.7	13.6	14.0

Table 34. The significance of tillage, fungicide, variety and the interactions on wheat protein content at harvest.

Wheat	Till.	Fung.	Var.	Till x Fung	Till x Var	Var x Fung	Till x Fung x Var
				significance			
Winter	.003	.595	.002	.044	.020	.103	.022
Spring	.794	.730	.043	.791	.645	.766	.601

Table 35. The effect of tillage on barley yields, moisture, protein content, and test weight, n=3.

	yield		% moisture		% protein		test wt	
	mean	st dev	mean	st dev	mean	st dev	mean	st dev
Tillage	-- bu/ac --		---- % ----		---- % ----		-- lb/bu --	
No Till	54.6	3.38	5.26	0.59	10.8	0.34	46.2	0.76
Chisel	58.5	2.83	5.14	0.40	11.1	0.61	45.8	0.28
Moldboard	57.3	5.52	6.42	6.11	11.3	0.21	46.0	0.86
Sig. of Tillage	(.449)		(.899)		(.189)		(.826)	

Table 36. The effect of tillage on soybean yield and moisture, n=3.

	yield		% moisture	
	mean	st dev	mean	st dev
Tillage	----bu/A----		-----%------	
No Till	26.4	3.68	9.13	0.23
Chisel	25.3	1.35	9.38	0.32
Moldboard	24.8	1.39	9.65	1.01
Sig. of Tillage	(.540)		(.663)	

CONSERVATION TILLAGE CORN AND SOYBEAN RESEARCH IN SOUTHEASTERN MINNESOTA-1987

J.F. Moncrief, T.L. Wagar, D.D. Breitbach, and J.J. Kuznia

Plots have been established in southeastern Minnesota to evaluate various conservation tillage strategies on the well drained loess soils. Plots are large to accomodate growers equippment. At individual locations plots are sometimes split with treatments to investigate management problems if the opportunity presents itself.

Statistics

The statistical significance for main effects of treatments is usually shown in parenthesis next to the treatment heading in the table (for example-tillage (.100). This number can be interpreted as the probability that differences between averages is due to chance and not the particular treatment (in the example tillage). In the example tillage is significant at a .100 probability (on a scale from 0 to 1). There is 10% chance that this is due to random variability or chance and a 90% chance that it is due to the different tillage systems being evaluated. Most researchers accept probabilities of .100 or less as being due to treatments and not chance for field trials.

As an aid in interpreting the statistical probabilities reported here it is suggested that any probability value .100 or less be accepted as evidence that differences in averages are due to the treatments being considered and not to chance.

The significance of interactions between variables is usually reported in footnotes below the tables. If there is a significant interaction between variables it means that the effect of a particular variable is not constant over the range of a second variable.

At Carver county there was no effect of tillage system on corn grain yields. Plots were hand harvested to evaluate yield losses. During hand harvesting, in an effort to estimate potential harvest loss due to European Corn Borer, the dropped ears and stalks broken below the ear were tallied. There was also no effect of tillage on the number of dropped ears and stalks broken below the ear. The yield loss due to European Corn Borer losses were subtracted from the hand harvested yield estimate to give yield after this loss. The final yield estimate at this site was taken with a four row combine by taking the center eight rows out of each plot. The ridge till system was not combine harvested due to stand loss during cultivation. Yield differences of combine estimates were also not statistically significant. Our estimates suggest a European Corn Borer loss of 8 bu./ac. or about 4%. The difference between hand harvesting and combine yields was about 14%. This is about 10% after corn borer losses which is about what is expected.

CARVER COUNTY

Table 1. Cultural practices at Carver County, MN 1987.

Tillage
- Till Plant (No Till)
- Ridge Till-ridge formed on June 26, 1987.
- Disc Chisel-chiseled on April 29, 1987 and light disced on April 30, 1987.
- Moldboard Plow-plowed on April 29, 1987 and light disced on April 30, 1987.
- Ridge, moldboard and disc were cultivated on June 12, 1987.

Preceding Crop
1985-86 Corn

1987 Crop
Corn-Pioneer 3737

Planting and Harvest Date

	Planting		
Crop	Date	Rate	Harvested
Corn	May 8, 1987	28,000 plants/ac	Oct. 7, 1987

Fertilizer History

Crop	Material Analysis (rate)	N	P_2O_5 (lb/ac)	K_2O	Date Applied
Corn:	82-0-0 (220 lbs/ac)	180	0	0	May 21, 1986
	9-23-30[1] (150 lbs/ac)	14	35	45	May 22, 1986

1. Applied 2" beside and 2" below seed.

Fertilizer

Crop	Material Analysis (rate)	N	P_2O_5 (lb/ac)	K_2O	Date Applied
Corn:	9-23-30[1] (150 lbs/ac)	14	35	45	May 8, 1987
	82-0-0 (183 lbs/ac)	150	0	0	May 13,1987

1. Applied 2" beside and 2" below seed.

Insecticide-8 lb/ac (1.6 lb/ac) Thimet 20-G applied at planting.

Soil

Lester (Mollic Hapludalfs, fine-loamy, mixed, mesic) loam 2 to 6 percent slopes. Soil is well drained.

Weed Control

3 qt/ac (3 lb/ac) Lasso + $2^1/_4$ qt/ac Bladex ($2^1/_4$ lb/ac) applied on May 14, 1987.

Table 2. The effect of tillage on the corn population at harvest on October 7, 1987, n=6.

Sig. of Tillage	No Till mean	No Till stdev	Ridge Till mean	Ridge Till stdev	Chisel mean	Chisel stdev	Moldboard mean	Moldboard stdev
	plants/ac x 1000							
(.470)	24.9	1.53	23.9	1.88	24.4	1.04	23.5	1.71

Table 3. The effect of tillage on corn yield and moisture at harvest on October 7, 1987.

Harvest Method		Sig. of Tillage	No Till mean	No Till stdev	Ridge Till mean	Ridge Till stdev	Chisel mean	Chisel stdev	Moldboard mean	Moldboard stdev
			bu/ac							
Hand harvested (standing and dropped ears)	n=6	(.769)	181	14.4	184	15.1	187	10.2	188	7.6
Hand harvested (minus dropped ears)	n=6	(.685)	174	17.3	173	19.4	182	12.1	180	11.6
Combine harvested	n=3	(.320)	157	18.1	---	----	158	11.4	166	8.2
			% moisture							
Moisture (hand harvested samples)	n=6	(.050)	18.4	0.8	18.7	0.9	18.2	0.7	17.3	0.9

This is an establishment year at the Dodge County site. All plots were spring disced. Ridges were established at cultivation. In the fall, primary tillage was done for the moldboard and chisel plow systems. There is a suspected compaction problem at this site. For this reason, all plots were split with a subsoiling treatment also in the fall.

DODGE COUNTY

Table 4. Cultural practices at Dodge County, MN. 1987.

Tillage

In the 1987 crop year there are only two tillage systems:
Spring Disc - Disced 3 times on April 17, 1987.
Ridge Till - Disced 3 times on April 17, 1987 and ridged on June 10, 1987.
Both were cultivated on June 1, 1987.

No Till - To be established for 1988 crop year.
Chisel Plow - To be established for 1988 crop year.
Moldboard Plow - To be established for 1988 crop year.

1987 Crop	Preceding Crop
Corn - Pioneer 3732	1985-86 Corn

Planting and Harvest Date

A six row John Deere 7000 with 28 inch row spacing was used.

	Planting		
Crop	Date	Rate	Harvested
Corn	April 29, 1987	28,000 plants/ac	Oct. 6, 1987

Fertilizer

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	----	lb/ac	----	Date Applied
Corn:	46-0-0	370 lbs/ac	170	0	0	April 16, 1987
	7-21-7[1]	10 gal/ac	8	24	8	April 29, 1987

1. Applied with the seed.

Insecticide

8 lbs/ac (1.2 lbs/ac active ingredient) Counter applied at planting.

Soil

The soil at this site is a Skyberg (Udollic Ochraqualfs, fine-loamy, mixed mesic) silt loam, with 0 to 2 percent slope. This soil is somewhat poorly drained.

Weed Control

3 qt/ac (3 lbs/ac) Lasso + 2 lbs/ac Atrazine (1.6 lbs/ac) applied on May 6, 1987.

Table 5. The effect of tillage on the corn yield and moisture at harvest on October 6, 1987, n=3.

	Tillage			
Sig. of	Ridge Till		Spring Disc	
Tillage	mean	stdev	mean	stdev
	--------- bu/ac ---------			
(.957)	167	3.02	167	1.17
	------ % moisture -------			
(.893)	22.8	0.36	22.7	0.74

At Fillmore county there was a significant effect of tillage and cultivation. The chisel and moldboard plowed treatments yielded 5 and 13 bu./ac. more than the spring disc and no till treatments. It is interesting to note that the no till plots were not cultivated in 1987. The yield difference is due to the difference in weed pressure from cultivation in 1985 and 1986.

FILLMORE COUNTY

Table 6. Cultural practices at Fillmore County, MN. 1987.

Tillage

Till Plant (No Till)
Disc - Fall 1986
Chisel- Fall 1986 with Soil Saver disc chisel
Moldboard - Fall 1986

Cultivation

Each plot is split with one half cultivated and the other half not on May 29, 1987.

1987 Crop	Preceding Crop
Corn - Pioneer 3737	1985-86 Corn

Planting and Harvest Date

Planter was a John Deere Maxemerge 4 row (38") planter equipped with John Deere row cleaners.

	Planting		
Crop	Date	Rate	Harvested
Corn	April 29, 1987	28,100 plants/ac	Oct. 8, 1987

Fertilization History

1983-injected 5-6000 gal/ac of liquid dairy manure.

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	---	lbs/ac	---	Date Applied
Corn:	16-41-8[1]	125 lb/ac	20	51	10	May 6, 1985
	82-0-0	134 lb/ac	110	0	0	May 22, 1985
Corn:	9-23-30[1]	125 lb/ac	11	29	38	May 7, 1986
	82-0-0	244 lb/ac	200	0	0	May 22, 1986

1. Applied 2" beside and 2" below seed.

Fertilizer

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	---	lbs/ac	---	Date Applied
Corn:	9-23-30[1]	100 lb/ac	9	23	30	April 29, 1987
	82-0-0	232 lb/ac	190	0	0	May 12, 1987

1. Applied 2" beside and 2" below seed.

Soil

Tama (Typic Argiudolls, fine-silty, mixed, mesic) and Downs (Mollic Hapludalfs, fine-silty, mixed, mesic) silt loams, eroded, 2 to 6 percent slopes. Soil is well drained.

Weed Control

2 qt/ac (2 lbs/ac) Lasso + $2^1/_3$ ($2^1/_3$ lbs/ac) Bladex on May 4, 1987.

Insect Control

6.9 lbs/ac Counter at time of planting.

Table 7. The effect of tillage and cultivation on severity of velvet leaf at harvest, September 25, 1987, n=6.

	Tillage(.943)							
	No Till		Disc		Chisel		Moldboard	
Cultivat[1]	mean	stdv	mean	stdv	mean	stdv	mean	stdv
	severity[2]							
Cult.	3.00	1.00	2.00	0.00	2.00	0.00	1.33	1.15
Not Cult.	4.67	0.58	4.00	0.00	4.00	1.00	4.00	0.00
average	3.83	1.17	3.00	1.10	3.00	1.26	2.67	1.63

1. The significance of cultivation was .074 and the significance of tillage x cultivation was .596.
2. Severity rating:1-none, 2-slight, 3-moderate, 4-severe and 5-very severe.

Table 8. The effect of tillage and cultivation on severity of foxtail at harvest, September 25, 1987, n=6.

	Tillage(.030)							
	No Till		Disc		Chisel		Moldboard	
Cultivat[1]	mean	stdv	mean	stdv	mean	stdv	mean	stdv
	severity[2]							
Cult.	3.33	1.15	0.00	0.00	0.00	0.00	0.00	0.00
Not Cult.	4.33	1.15	0.00	0.00	1.00	1.73	0.00	0.00
average	3.83	1.17	0.00	0.00	0.50	1.22	0.00	0.00

1. The significance of cultivation was .043 and the significance of tillage x cultivation was .349.
2. Severity rating:1-none, 2-slight, 3-moderate, 4-severe and 5-very severe.

Table 9. The effect of tillage and cultivation on corn yields, September 25, 1987, n=6.

	Tillage(.094)							
	No Till		Disc		Chisel		Moldboard	
Cultivat[1]	mean	stdv	mean	stdv	mean	stdv	mean	stdv
	bu/ac							
Cult.	160	4.0	163	10.4	171	9.0	167	14.3
Not Cult.	144	11.6	156	0.9	160	8.0	162	8.0
average	152	11.5	160	7.6	166	9.5	165	10.6

1. The significance of cultivation was .030 and the significance of tillage x cultivation was .684.

Table 10. The effect of tillage and cultivation on corn moisture, September 25, 1987, n=6.

	Tillage(.010)							
	No Till		Disc		Chisel		Moldboard	
Cultivat[1]	mean	stdv	mean	stdv	mean	stdv	mean	stdv
	%							
Cult.	22.6	0.71	21.8	0.93	21.1	1.80	21.8	0.34
Not Cult.	22.2	0.60	21.8	0.87	20.5	0.55	21.6	0.27
average	22.5	0.62	21.8	0.81	20.8	1.23	21.8	0.29

1. The significance of cultivation was .222 and the significance of tillage x cultivation was .862.

The Steele county site also had a significant effect of tillage on grain yields. The till plant treatments were planted with a six row conservation planter in 1987. Consequently this is an establishment year for the ridge till treatment. Till plant ridge had the ridges established in 1986. The till plant flat resulted in the lowest yields. The ridge till and moldboard treatments were comparable. No till and chisel plowed corn yields were also comparable. Damage from residual Command applied on the soybeans in 1986 (see same publication 1987) was affected by tillage (table 12) but not correlated with yields (table 15). Tillage effects on plant population in the early season were not present at harvest (compare table 12 and 13).

STEELE COUNTY

Table 11. Cultural practices at Steele County, MN. 1987.

Tillage

Slot Plant (No Till)
Ridge Till - Ridges formed on May 28, 1987.
Chisel Plow - Chiseled on April 15, 1987 with a John Deere 8650 then field cultivated with a Wilrich 42' field cultivator on April 16, 1987.
Moldboard Plow - Plowed on April 15, 1987 with a John Deere 4240 then field cultivated with a Wilrich 42' field cultivator on April 16, 1987.
Slot Plant - (No Till) Old paraplow plots.
All plots were cultivated on May 7, 1987.

1987 Crop	Preceding Crop
Corn - Pioneer 3737	1985-Corn, 1986-Soybeans

Planting and Harvest Date

Planter used on the till plant and ridge till plots was a Hiniker Econotill planter. The remaining plots were seeded with a John Deere Maxemerge 7000 eight row (30") planter.

		Planting		
Planter	Crop	Date	Rate	Harvested
Hiniker	Corn	April 16, 1987	26,200 plants/ac	Oct. 9, 1987
John Deere	Corn	April 16, 1987	27,700 plants/ac	Oct. 9, 1987

Fertilization History

	Material		Actual			
			N	P_2O_5	K_2O	
Crop	Analysis	Rate	---	lbs/ac	---	Date Applied
	0-0-60	250 lb/ac	0	0	150	Fall 1984
Corn:	7-21-7[1]	10 gal/ac	8	24	8	April 29, 1985
	82-0-0	163 lb/ac	134	0	0	May 30, 1985
Soybeans	none					

1. Applied with the seed.

Fertilizer

	Material		Actual			
			N	P_2O_5	K_2O	
Crop	Analysis	Rate	---	lbs/ac	---	Date Applied
Corn:	0-0-60	250 lb/ac	0	0	150	pre-plant 1987
	82-0-0	159 lb/ac	130	0	0	June 5, 1987

Soil

Le Sueur (Aquic Argiudolls, fine-loamy, mixed, mesic) clay loam, 2 to 4 percent slopes. Soil is moderately well drained to somewhat poorly drained.

Weed Control

2 qt/ac (2 lbs/ac) Bladex + $1^1/_2$ pt/ac ($1^1/_2$ lbs/ac) Dual on April 23, 1987.

Table 12. The effect of tillage on plant population and population damaged by Command on May 22, 1987.

	Sig. of Tillage	Moldboard mean	Moldboard stdv	Chisel mean	Chisel stdv	RidgeTill mean	RidgeTill stdv	TillPlant mean	TillPlant stdv	SlotPlant mean	SlotPlant stdv
		plants/acx1000									
Population	(.111)	28.7	3.1	25.0	3.9	25.3	3.3	27.9	4.1	24.1	3.8
		%									
Damaged	(.000)	0.0	0.0	63.4	26.5	29.7	39.2	18.0	11.7	6.8	11.4

Table 13. The effect of tillage on plant populations at harvest on October 9, 1987, n=6.

TILLAGE (.697)

Moldboard mean	Moldboard stdv	Chisel mean	Chisel stdv	RidgeTill mean	RidgeTill stdv	TillPlant mean	TillPlant stdv	SlotPlant mean	SlotPlant stdv
plants/acx1000									
26.2	1.3	26.1	0.7	26.4	1.7	27.0	1.0	26.2	1.0

Table 14. The effect of tillage on ears lost due to dropping on October 9, 1987, n=6.

TILLAGE (.195)

Moldboard mean	Moldboard stdv	Chisel mean	Chisel stdv	Ridge Till mean	Ridge Till stdv	TillPlant mean	TillPlant stdv	SlotPlant mean	SlotPlant stdv
ears/ac									
435	275	217	364	580	355	726	449	580	355

Table 15. The effect of tillage on yield and moisture at harvest on October 9, 1987.

Sig. of Tillage	Moldboard mean	Moldboard stdev	Chisel mean	Chisel stdev	Ridge Till mean	Ridge Till stdev	Till Plant mean	Till Plant stdev	Slot Plant mean	Slot Plant stdev
	bushels/ac									
(.095)	184	7.2	173	10.4	179	2.2	166	11.9	171	5.9
	% moisture									
(.166)	12.8	.89	12.6	.51	11.8	.82	12.7	.12	12.9	.75

The Wabasha county site showed no effect of tillage on either corn or soybean yields. This has been consistent for four years.

WABASHA COUNTY

Table 1. Cultural practices for Wabasha County, MN in 1987.

Tillage
- No Till
- Ridge Till - corn ridge formed on June 8, 1987
  - soybeans cultivated June 8, 1987 and ridge formed on July 8, 1987
- Spring Disc - following corn disc twice on May 8, 1987
  - following soybeans disced once on April 30, 1987
- Field Cultivate - April 25,1986 - field cultivator May 8, 1987

Crops	Preceding Crops
Corn - Pioneer 3737	1983 - Sweet Clover
Soybeans - Pioneer 1677	1984-86 - Corn-Soybean rotation

Planting and Harvest Date

Planter used on all corn plots was a John Deere Maxemerge six row (30") planter equipped with 2" fluted coulters. Planter used on no till, spring disc and chisel plow soybean plots was a Kinze No Till Drill with 10" row spacing. Planter used on spring disc ridge was a John Deere Maxemerge six row (30") planter equipped with 2" fluted coulters.

	Planting		
Crop	Date	Rate	Harvested
Corn	April 30, 1987	28,000 plants/ac	September 29, 1987
Soybeans	May 13, 1987	225,000 plants/ac	September 29, 1987

Fertilization History

Crop	Material Analysis (Rate)	Actual N ---	P_2O_5 lbs/ac	K_2O ---	Date Applied
All plots except chisel plow.	28-0-0 (7 gal/ac)	75	0	0	May 14, 1984
Corn:	7-21-7 (12.5 gal/ac)	10	29	10	May 16&18, 1984
Corn:	7-21-7[1] (25 gal/ac)	20	60	20	May 13, 1985
Corn:	82-0-0 (170 lbs/ac)	140	0	0	June 19, 1985
Corn:	46-0-0 (337 lbs/ac)	155	0	0	April 24, 1986
Corn:	9-23-30 (170 lbs/ac)	15	39	51	May 5, 1986

1. Placement 2" beside and 2" below seed.

Fertilizer

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			---	lbs/ac	---	
Corn:	9-23-30[1]	130 lbs/ac	12	30	39	April 30, 1987
Corn:	82-0-0	159 lbs/ac	130	0	0	June 8, 1987

1. Placement 2" beside and 2" below seed.

Soil

Fayette (Typic Hapludalfs, fine-silty, mixed, mesic) silt loam.

Weed Control

Corn

$1^1/_2$ pt/ac ($1^1/_2$ lbs/ac) Dual + $2^1/_2$ qt/ac ($2^1/_2$ lbs/ac) Bladex broadcast with the planter on April 30, 1987.

Soybeans

1 pt/ac (.375 lbs/ac) Roundup + 1% surfactant on May 13, 1986.

1 pt/ac ($^1/_2$ lb/ac) Basagran + $^1/_2$ pt/ac ($^1/_8$ lb/ac) Blazer + 1 qt oil concentrate on June 11, 1987.

1 pt/ac ($^1/_2$ lb/ac) Basagran + 1 pt/ac ($^2/_{10}$ lb/ac) Poast + 1 qt/ac Dash oil concentrate + 1 gal 28% on June 19, 1987.

Soil Test

Table 16. Soil test results for corn to be planted following soybeans on April 16, 1987.

Nutrient	Sig. of Tillage	No Till	Disc	Ridge	Chisel	Avg
		---------	lbs/ac		------------	
NH4-N	(.579)	4	4	4	3	4
NO3-N	(.429)	29	29	36	28	30
Total-N	(.443)	33	33	40	31	34
P	(.256)	64	58	57	54	58
K	(.833)	220	209	204	201	208

Table 17. Soil test results for soybeans to be planted following corn on April 16, 1987.

Nutrient	Sig. of Tillage	No Till	Disc	Ridge	Chisel	Avg
		---------	lbs/ac		------------	
NH4-N	(.772)	4	4	4	4	4
NO3-N	(.499)	16	16	22	18	18
Total-N	(.571)	20	20	26	22	22
P	(.602)	62	66	67	60	64
K	(.075)	215	187	200	177	195

Table 18. The effect of tillage on soil cover by soybean residue on June 3, 1987, n=8.

Location[1]	No Till mean	No Till stdv	Spring Disc mean	Spring Disc stdv	Ridge Till mean	Ridge Till stdv	Chisel mean	Chisel stdv
				%				
In Row	43.0	16.9	14.5	10.8	22.5	12.8	7.5	6.5
Between	59.5	15.1	24.0	19.3	33.0	17.9	17.5	13.3

1. The significance of tillage in-row was .000; between-row was .001.

Table 19. The effect of tillage on soil cover by corn residue on June 3, 1987, n=8.

Location[1]	No Till mean	No Till stdv	Spring Disc mean	Spring Disc stdv	Ridge Till mean	Ridge Till stdv	Chisel mean	Chisel stdv
				%				
In Row	82.5	15.4	59.5	20.2	37.5	20.0	37.0	12.7
Between	80.5	7.5	63.5	15.1	68.0	10.9	32.5	11.6

1. The significance of tillage in-row was .001; between-row was .000.

Table 20. The effect of tillage on population of corn and soybeans on June 3, 1987, n=16.

		Tillage							
		No Till		Spring Disc		Ridge Till		Chisel	
	Sig. of	mean	st dev	mean	st dev	mean	st dev	mean	st dev
Crop	Tillage	----------------		plants/ac x 1000		---------------			
Corn	(.760)	26	4.3	27	2.1	27	2.4	27	2.8
Soybeans	(.000[1])	117	32.1	143	30.2	147	23.5	173	17.1

1. The significance of no till, spring disc, and chisel till.

Table 21. The effect of tillage on visual weed rating at harvest for corn on September 29, 1987, n=4.[1]

	Tillage							
	No Till		Spring Disc		Ridge Till		Chisel	
Sig. of	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Tillage	----------------		%		---------------			
(1.000)	1.00	.00	1.00	.00	1.00	.00	1.00	.00

1. The visual rating used is as follows; 1=None, 2=Slight, 3=Moderate, 4=Severe and 5=Very Severe.

Table 22. The effect of tillage on visual weed rating at harvest for soybeans on September 29, 1987, n=4.[1]

	Tillage							
	No Till		Spring Disc		Ridge Till		Chisel	
Sig. of	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Tillage	----------------		%		---------------			
(1.000)	1.75	.96	1.75	.50	1.75	.50	1.75	.50

1. The visual rating used is as follows; 1=None, 2=Slight, 3=Moderate, 4=Severe and 5=Very Severe.

Table 23. The effect of tillage on corn yields and moisture at harvest on September 29, 1987, n=4.

	Tillage							
	No Till		Spring Disc		Ridge Till		Chisel	
Sig. of	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Tillage	----------------		bu/ac		---------------			
(.267)	181	4.1	180	7.5	184	4.2	178	2.8
	----------------		%		---------------			
(.080)	21.5	.5	20.5	1.0	20.8	.9	19.8	.7

Table 24. The effect of tillage on soybean yields and moisture at harvest on September 29, 1987, n=4.

	Tillage							
	No Till		Spring Disc		Ridge Till		Chisel	
Sig. of	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Tillage	----------------		bu/ac		---------------			
(.472)	60.9	2.8	58.4	2.5	56.9	5.9	59.4	3.3
	----------------		%		---------------			
(.156)	11.1	.4	11.5	.4	10.9	.7	11.6	.3

TILLAGE EFFECTS ON CORN AND SOYBEAN PRODUCTION IN THE CLEARWATER RIVER WATERSHED MEEKER, STEARNS, AND WRIGHT COUNTIES, 1987

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Following is a summary of the results of tillage demonstrations in the Clearwater River Watershed in 1987. This is a joint effort by the following organizations: Clearwater River Watershed District, Soil and Water Conservation Districts, Soil Conservation Service, Minnesota Pollution Control Agency, and the Minnesota Extension Service. Technical expertise has been provided from academic departments of the College of Agriculture, University of Minnesota. Cooperation from Richard and Ken Kuechle, Richard Eckman, and Lyndon and Earl Johnson in Meeker, Stearns, and Wright County respectively, is greatly appreciated.

The purpose of this demonstration is to evaluate various conservation tillage systems under the soil and climatic conditions of the Clearwater River Watershed. It is hoped that by providing objective scientific data to growers, they can consider tillage systems that fit their situation and provide erosion control that will maintain water quality in the watershed. The 1987 growing season was very dry (about 6 inches below normal). Two of the three tillage demonstration sites are on droughty soils and yields were low.

The **Meeker** county site is located on a complex of Delft clay loam, Koronis fine sandy loam, and Marcellon loam. The plots are located on a side slope and probably receive moisture which flows along the glacial till contact below the soil. For this reason this site showed the least effect of the dry weather conditions. A corn-soybean rotation is demonstrated at this site.

Soil test values are shown in tables 2 and 3 for the corn and soybeans respectively. There was about 30 lbs NO_3 + NH_4-N/acre in the top 8 inches in April following both corn and soybeans. Soil test P and K is in the medium range. These are Bray 1 analysis for phosphorus. Because this is a high pH soil (greater than 7.4), the Olsen test would be more reliable for fertilizer recommendations. Following corn the soil test is lower when moldboard plowing is done. This has been observed at other sites. Two thirds of the K taken up in corn is left behind in the stover. When it is not incorporated with tillage it is concentrated at the soil surface and results in a higher soil test. Tillage did not have a significant effect on soil test K following soybeans due to one third less crop residue. Phosphorus did not result in significant tillage effects. Three fourths of the P that is taken up by the corn is removed with the grain.

The soil covered by residue is shown in tables 4 and 5 for corn and soybean residue respectively. There is more soil cover following corn than soybeans. The in row soil cover (4 inches centered on the row) is related to early corn growth due to changes in soil temperature. The between row soil cover is more related to control of sediment and phosphorus losses. In row soil cover that is less than 20% will likely not affect corn growth due to reduced soil temperatures. All the tillage systems demonstrated except the no till have in row cover that is 20% or less. Although cover by corn residue (planted to soybeans) is greater than 20%, soybeans are not sensitive to its effects. The early soybean and corn growth and population is shown in tables 6 and 8 respectively.

The ridge till corn has over one half more leaf growth than the other systems. The no till and ridge till corn germinated sooner and is much less variable than the systems that had fall primary tillage (chisel and moldboard plow). This is due to more moist soil conditions at planting and better seed to soil contact. The detrimental effects of cloddy conditions with the chisel and moldboard plowing was more important to early corn growth than the presence of crop residues over the row area in 1987. About one month later there was no difference in corn growth due to tillage (table 10). Soybean growth was not affected by tillage. Soybeans are much less sensitive to changes in soil temperature due to the presence of crop residue than corn due to the location of the growing point (above the soil surface) and later planting date. There was a slight reduction in soybean population with the chisel and no till systems but would not be expected to affect yields.

There were very few weeds at this site (tables 7 and 9) and were unaffected by tillage. At these levels weeds would not be expected to affect corn or soybean growth or yields.

There was a measurable effect of tillage on K uptake on the June 26 date (table 11). Systems that eliminate primary tillage result in lower K uptake. This can be minimized by the application of row fertilizer at planting. One month later differences due to tillage had disappeared (table 12). There was an effect of tillage on ear leaf N concentrations.

Moisture stress was measured on June 26 and July 24 (tables 13 and 14). There was no measurable effect of tillage at this site on moisture stress and levels were relatively low. There was a significant effect on stress by position on the landscape. The corn that was down slope showed lower levels of stress. Moisture stress levels at this site were low. Apparently corn is fed from moisture moving from upslope at this site.

Grain yields are shown in tables 15 and 17 for corn and soybeans respectively. There was no difference in yield due to tillage for either crop. Landscape position effects are shown in table 16. The early differences in corn growth did not effect yields. There was adequate growing degree days to mature all treatments and small differences in early growth due to tillage did result in grain yield differences.

There was no effect of tillage on soybean yields at this site. This is consistent with data from other sites. There is an average 5 bu/acre response to row applied phosphorus with the drill. Research that supports banded P applications for soybeans is scarce. This is an ideal method of application to minimize entry into surface waters. Since the soil at this site tends to be wet in most years it was decided to evaluate crop residue effects on fungicide response for control of phytophthora root rot. There was no advantage to a planter/drill applied fungicide at planting.

MEEKER COUNTY

Table 1. Cultural practices at Meeker County MN. 1987.

Tillage

- No Till
- Ridge Till-Corn ridges were formed on June 27, 1987 and soybean were formed on July 7, 1987.
- Chisel-All plots were chiseled on October 29, 1986.
- Moldboard-All plots were moldboard plowed on October 28, 1986.

Preceding Crop

- Corn-soybean rotation since 1978.

1987 Crop

- Corn-Pioneer 3737
- Soybeans-Pioneer 1677

Planting and Harvest Dates

	Planting		
Crop	Date	Rate	Harvested
Corn	April 28, 1987	28,100 plants/ac	September 30, 1987
Soybeans	May 5, 1987	242,200 plants/ac	September 30, 1987

Fertilizer History-Prior to 1987[1]

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			---	lbs/ac	---	
Corn:	82-0-0	183 lbs/ac	150	0	0	Spring
	4-15-40[2]	250 lbs/ac	10	38	100	Planting

1. This is based on an interview with the cooperating farmer.
2. Planter placement 2" beside and 2" below row.

Fertilizer-1987

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			---	lbs/ac	---	
Corn	4-15-40	300 lbs/ac	12	45	120	October 27, 1986
	7-21-7[1]	17 gal/ac	13	40	13	April 28, 1987
	82-0-0	159 lbs/ac	130	0	0	May 15, 1987
Soybeans	4-15-40	300 lbs/ac	12	45	120	October 27, 1986
	0-46-0[2]	45 lbs/ac	0	21	0	May 5, 1987

1. Planter placement 2" beside and 2" below row.
2. Drill soybeans were split with row fertilizer which was surface banded ahead of and incorporated by the fluted coulters.

Fungicide Seed Treatment

Drill soybeans were split with Ridomil 5G at a rate of 6.1 lbs/ac ($^1/_3$ lb ai/ac).

Soil

The soils present at this site are as follows: 29% of plot area is Delft (Cumulic Haplaquolls, fine-loamy,mixed, mesic) clay loam, 43% is Koronis (Mollic Haplaudalfs, fine-loamy, mixed, mesic) fine sandy loam, and the remaining 28% is Marcellon (Aquic Argiudolls, fine-loamy, mixed, mesic) loam.

Weed Control

Corn

3 qt/ac (3 lbs/ac) Lasso + $2^1/_2$ qt/ac ($2^1/_2$ lbs/ac) Bladex on May 2, 1987.
2 qt/ac ($1^1/_2$ lbs/ac) Roundup spot sprayed on no till plots on May 2, 1987.

Soybeans

$1^1/_2$ pt/ac ($^3/_4$ lb/ac) Bassagran + 1 pt/ac ($^1/_5$ lb/ac) Poast + 1 qt/ac crop oil + 1 gal 28% on June 8, 1987.

Table 2. Soil test results for corn following soybeans on April 7, 1987.

Nutrient	Sig. of Tillage	No Till	Ridge	Chisel	Moldboard	Avg
		---------	lbs/ac	----------	----------	----------
NH_4-N[1]	(.327)	9.0	7.5	8.8	9.1	8.7
NO_3-N[1]	(.896)	21.0	22.3	20.2	25.9	22.4
Total-N	(.845)	30.0	29.8	29.1	35.1	31.0
P[2]	(.862)	21.2	25.2	27.9	22.8	24.4
K	(.258)	182.7	177.6	173.1	146.2	169.9

1. These values are for 8 inch samples.
2. Bray 1 phosphorus (this soil has a pH of 7.5).

Table 3. Soil test results for soybeans following corn on April 7, 1987.

Nutrient	Sig. of Tillage	No Till	Ridge	Chisel	Moldboard	Avg
		---------	lbs/ac	----------	----------	----------
NH_4-N[1]	(.740)	9.9	10.5	10.6	11.0	10.5
NO_3-N[1]	(.433)	12.0	20.6	16.1	18.9	16.9
Total-N	(.436)	21.9	31.2	26.8	29.9	27.4
P[2]	(.262)	26.0	20.6	32.7	23.7	25.5
K	(.016)	208.7	234.9	200.1	173.1	204.2

1. Thes values are for 8 inch samples.
2. Bray 1 phophorus (this soil has a pH of 7.5).

Table 4. The effect of tillage on soil covered by corn residue on May 27, 1987, n=16.
May 27, 1987, n=16.

	Tillage[1]							
	No Till		Ridge Till		Chisel		Moldboard	
	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Corn Residue	% cover							
In row	45	16	35	24	35	11	8	5
Between row	43	22	39	17	29	11	7	5

1. Significance of tillage for all positions relative to the row was .000.

Table 5. The effect of tillage on soil covered by soybean residue on May 27, 1987, n=16.

	Tillage[1]							
	No Till		Ridge Till		Chisel		Moldboard	
	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Soybean Residue	% cover							
In row	29	17	20	14	10	8	3	3
Between row	24	11	22	16	10	8	2	3

1. Significance of tillage for all positions relative to the row was .000.

Table 6. The effect of tillage on soybean growth stage and population on May 27, 1987.

	Tillage							
	No Till		Ridge Till		Chisel		Moldboard	
Sig. of Tillage	mean	stdv	mean	stdv	mean	stdv	mean	stdv
	growth stage[1]							
(.396)	2.3	.6	2.4	.7	2.2	.7	2.4	.6
	plants/ac x 1000							
(<.000)	225	48	163	8	223	61	240	51

1. Soybean growth stages are as follows: 1=emergence (Ve), cotyledons above soil surface; 2=cotyledon (Vc) unifoliolate leaves unrolled sufficiently so the leaf edges are not touching; 3=first node, fully developed leaves at unifoliolate nodes and 4=second node; fully developed trifoliolate leaf at node above the unifoliolate node

Table 7. The effect of tillage on weed severity in soybeans on May 27, 1987.

		Tillage							
		No Till		Ridge Till		Chisel		Moldboard	
	Sig. of	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Weed	Tillage	% cover							
Foxtail	--	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Horsetal	(.473)	1.5	7.1	6.8	12.2	5.0	4.2	1.0	1.2
Quackgrs	--	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Lambqurt	--	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0
VolCorn	(.436)	0.3	0.5	0.8	1.5	0.0	0.0	0.0	0.0
Ragweed	(.436)	0.0	0.0	0.3	0.5	0.0	0.0	0.0	0.0

1. Due to uneven variances, a natural log transformation was used for significance.

Table 8. The effect of tillage on corn growth stage and population on May 27, 1987.

	Tillage							
	No Till		Ridge Till		Chisel		Moldboard	
Sig. of Tillage	mean	stdv	mean	stdv	mean	stdv	mean	stdv
	leaves/plant[1]							
(.001)	3.3	.5	3.8	.4	3.2	1.0	3.0	1.3
	plants/ac x 1000							
(.092)	37.4	4.3	37.7	2.7	36.6	2.9	34.3	6.3

1. Corn leaves are tallied as full leaves when leaf collars are visible.

Table 9. The effect of tillage on weed severity in corn on May 27, 1987.

		Tillage							
		No Till		Ridge Till		Chisel		Moldboard	
	Sig. of	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Weed	Tillage	% cover							
Horsetal	(.436)	0.3	0.5	1.5	1.7	0.0	0.0	0.3	0.5
Quackgrs	(.685)	1.3	0.5	3.8	4.5	2.0	2.7	1.5	1.3
VolSoyb	(1.00)	0.3	0.5	0.3	0.5	0.3	0.5	0.3	0.5
Milkweed	--	0.0	0.0	0.0	0.0	0.3	0.5	0.0	0.0
CandThis	--	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5

1. Due to uneven variances, a natural log transformation was used for significance.

Table 10. The effect of tillage on corn plant weights, June 26, 1987.

Tillage (.400)							
No Till		Ridge Till		Chisel		Moldboard	
mean	stdv	mean	stdv	mean	stdv	mean	stdv
grams/plant							
28.3	6.6	24.5	3.1	29.5	2.9	31.5	8.4

Table 11. The effect of tillage on whole plant N and K on June 26, 1987.

		Tillage			
	Sig. of	No Till	Ridge	Chisel	Moldboard
Concentration	Tillage	% per plant			
N	(.344)	2.73	2.75	2.78	2.92
K	(.050)	1.83	1.96	2.66	2.63
Uptake		milligrams/plant			
N	(.226)	768	676	817	903
K	(.008)	524	465	785	818

Table 12. The effect of tillage on ear leaf concentration of N and K on July 24, 1987.

		Tillage			
	Sig. of	No Till	Ridge	Chisel	Moldboard
Nutrient	Tillage	%			
N	(.091)	2.86	2.73	2.81	3.00
K	(.736)	1.52	1.48	1.72	1.60

Table 13. The effect of tillage on corn leaf water potential on June 26, n=4 and July 24, 1987 n=8.

		Tillage							
		No Till		Ridge Till		Chisel		Moldboard	
	Sig. of	mean	stdev	mean	stdev	mean	stdev	mean	stdev
Date	Tillage	(-bars)							
June 26	(.829)	8.2	2.7	8.4	2.0	8.8	1.8	7.9	2.4
July 24	(.404)	6.0	1.8	7.5	1.7	7.0	1.8	7.3	2.2

Table 14. The effect of aspect on corn leaf water potential on June 26, and July 24, 1987.

		Direction	
		South	North
Date	Sig.	(-bars)	
June 26	<.000	9.9	6.7
July 24	.139	7.4	6.4

Table 15. The effect of tillage on corn yields, September 30, 1987.[1]

	Tillage							
	No Till		Ridge Till		Chisel		Moldboard	
Sig. of	mean	stdev	mean	stdev	mean	stdev	mean	stdev
Tillage	bu/ac							
(.176)	189	12.0	179	7.0	187	9.1	189	20.7
	% moisture							
(.311)	19.9	.9	20.6	.8	21.5	1.9	21.2	1.8

1. The soils at the Meeker County site for the corn area are, 60% Koronis fine sandy loam, 25% Marcellon loam and 15% Delft clay loam.

Table 16. The effect of aspect on corn yield on September 30, 1987.

	Direction	
	South	North
Date	bu/ac	
September 30	184	190
	% moisture	
	.21	.21

Table 17. The effect of tillage, starter and fungicide on soybean grain yields for 1987, n=4.[1]

Treatment[6]		Tillage							
		No Till		Ridge Till		Chisel		Moldboard	
Starter[4]	Fungicide[5]	mean	stdev	mean	stdev	mean	stdev	mean	stdev
		bu/ac							
no	no	51	3.9	50[3]	4.1	51	3.5	52	4.3
no	yes			46	3.9				
yes	no	54	8.1			57	4.9	58	1.8
yes	yes	54	2.9			58	4.0	57	10.7

1. The soils at the Meeker County site for the soybean area are, 20% Koronis fine sandy loam, 20% Marcellon loam and 60% Delft clay loam.
2. The significance of tillage without starter or fungicide is .896.
3. The significance of fungicide is .178 for Ridge Till.
4. The significance of tillage and starter without fungicide and with or without starter is .408 and .011 respectively. The significance of the tillage x starter interaction is .550.
5. The significance of tillage and fungicide with starter and with or without fungicide is .360 and .977 respectively. The significance of the tillage x fungicide interaction is .886.
6. The application rate of starter was 21 lbs/ac P_2O_5, fungicide rate was 6.1 lbs/ac Ridomil.

The Stearns County site is located on a complex of Fairhaven silt loam, Estherville sandy loam, and Hawick sandy loam soil. The soil at this site is very droughty. Data collected from this site are shown in tables 18 to 32. Corn was grown after soybeans in 1987. The soil covered by soybean residue was lower in the row for all tillage systems (planter equipped with sweeps) although it is high enough to effect early growth and stand establishment in the no till system (table 19). The variability of the stand in the no till treatment was much higher than the other tillage systems (table 20) and affected grain yields. This was the result of slippage of the coulter-gauge wheel on the planter that drives the planter units and in row crop residue.

Residue and starter fertilizer effects on early growth are shown in table 21 and 24. Most of the benefit to row fertilizer is achieved with a low rate and the response is larger for the conservation tillage systems. On May 29 it was noticed that the lower leaves were fired on the plots that did not receive row fertilizer at planting (table 22). The plants did not show these symptoms on the June 26 sampling date. Lower leaf necrosis was also affected by tillage. The authors don't have an explanation for these observations.

The dominant weeds at this site are lambsquarter and giant foxtail. Chisel and moldboard plowing resulted in the highest density of foxtail and the lowest density of lambsquarter (table 23). These observations were made before cultivation (May 29). All plots except the no till were cultivated. A banded application of Lasso was used for weed control. Weeds probably affected corn yields in the no till plots only.

Tissue levels and uptake of N, P, and K on June 26 are shown in tables 25 and 26, respectively. Ear leaf concentrations are shown in table 27. Nitrogen and potassium were lower with the conservation tillage systems on the June 26 date. There were higher levels of phosphorus with conservation tillage. Starter fertilizer reduced nitrogen content due to dilution. Table 26 shows large increases in uptake of all three nutrients due to starter fertilizer addition. A tillage by starter interaction occured with potassium uptake that illustrates the importance of row applied K on this soil when using conservation tillage. Ear leaf concentrations of K suggest that even at the higher rate of starter fertilizer there wasn't enough available for the conservation tillage options. This illustrates the value of dry starter fertilizer on these soils that allows higher analysis of K and probably would overcome this tillage induced K deficiency. This factor probably influenced grain yields.

Plant moisture stress is shown in tables 28 and 29. There is a significant benefit of residue in reducing moisture stress. Starter fertilizer increased moisture stress. Moisture stress is correlated with dry matter production on June 26. This reflects moisture depletion by the larger plants. The July 24 moisture stress measurements still show a tillage and starter fertilizer effect.

Ridging effects on grain yields in a dry year were evaluated (tables 30 and 31). Ridge till plots were split with a cultivation split. There was no apparent effect in ridging on grain yields. Grain yields and moisture for all tillage treatments are shown in table 32. The greatest response to row fertilizer occurred with the no till corn. Yields were lower with this system due to stand variability, in row cover by crop residue, and nitrogen losses. Plant tissue analysis (data not shown) shows a reduction in available nitrogen with no till corn. Nitrogen was applied as urea-ammonium nitrate solution at cultivation. All treatments were cultivated except the no till which had the nitrogen solution surface banded between the rows. The decrease in yield with starter fertilizer application when corn was grown with moldboard plowing is probably due to the increased moisture stress with this treatment combination. Due to the lack of residue and the hastened development, corn was probably subjected to higher levels of moisture stress at silk emergence . Corn showed higher moisture stress earlier in the season and it persisted longer with this treatment. Starter fertilizer may also have encouraged shallow rooting which had lower soil moisture levels in the absence of crop residues.

STEARNS COUNTY

Table 18. Cultural practices at Stearns County, MN. 1987.

Tillage

No Till
Ridge Till
Chisel-Plots were chisel plowed, and then disced on April 28th.
Moldboard-Plots were moldboard plowed, and then disced on April 28th.

Preceding Crops

The cropping history at this site is as follows: 1981-red clover and oats, 1982-corn, 1983-soybeans, 1984-corn, 1985-corn, 1986-soybeans.

1987 Crop

Corn - Johnson SX 490 a single cross 100 day hybrid.

Planting and Harvest Dates

Ridge till plots were planted with a four row Buffalo Till planter equipped with 12" sweeps at a 38" row spacing. All other plots were planted with the sweeps raised.

	Planting		
Crop	Date	Rate	Harvested
Corn	April 29, 1987	22,100 plants/ac	September 22, 1987

Fertilization History-Prior to 1987[1]

The fertilization history at this site is as follows: 1981-none, 1982-low rate of dry starter, 1983-low rate of starter and 0-0-60, 1984-4 gal/ac of 9-18-9 only, 1985-60 lbs/ac of N and 4 gal/ac of 9-18-9, 1986-all plots were split with and without a row fertilizer treatment at planting as in the table that follows.

Crop	Material Analysis	Rate	Tillage	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
				-- lbs/ac --			
Soybeans	9-18-9[2]	4 gal/ac	Ridge Till	4	8	4	May 16, 1986
	0-0-60[3]	90 lbs/ac	All Others	0	0	54	May 16, 1986

1. This information is based on an interview with the cooperating farmer.
2. Planter placement 1" below the seed.
3. Potash was surface banded ahead of and incorporated by the fluted coulters.

Fertilizer

All plots were split with three fertilizer treatments at planting.

Crop	Material Analysis (Rate)	Actual N	Actual P_2O_5	Actual K_2O
		--- lbs/ac --		
Corn	9-18-9[1] (0 gal/ac)	0	0	0
	9-18-9[1] (4.9 gal/ac)	4.7	10	4.7
	9-18-9[1] (9.7 gal/ac)	9.3	18.5	9.3

1. Planter placement 1" below the seed.

Nitrogen was applied as a split application of liquid 28% at the rate of 11 gal/ac (33 lbs/ac actual N) on all plots by the method listed below.

Date	Tillage	Method of Application
June 1	No Till	Surface dribble
	Ch/Mb/RT	Incorporated while cultivating
June 25	No Till	Surface dribble
	Ch/Mb	Incorporated while cultivating
	Ridge	Incorporated while ridging

Soil

The soils at the Stearns County site are Fairhaven (Typic Hapludolls) loam which is well drained on 54 percent of the plot. On 36 percent of the plot Estherville (Typic Hapludolls) sandy loam which is somewhat excessively drained is present. On the remaining 10 percent of the plot Hawick (Entic Hapludolls) loamy sand is present, this soil is excessively drained. The slope average for all three soils is 2.5 percent with the the highest being 4 percent.

Weed Control

$4^1/_2$ lbs/ac (.675 lb ai/ac) Lasso II applied in a 10 inch band at planting.
$^1/_2$ pt/ac ($^1/_4$ lb ai/ac) 2,4-D Amine on May 19, 1987.

Table 19. The effect of tillage on percent of the soil surface covered by soybean residue on May 29, 1987, n=16.

	TILLAGE[1]							
	No Till		Ridge Till		Chisel		Moldboard	
	mean	stdev	mean	stdev	mean	stdev	mean	stdev
Location	----------			%			----------	
In Row	30.0	18.9	16.7	9.7	22.5	14.0	5.0	3.7
Between	77.5	17.9	61.7	13.5	32.5	17.2	5.5	3.5

1. Significance of tillage for both positions relative to the row was less than .000.

Table 20. The effect of tillage on population of corn on May 29, 1987, n=16.

TILLAGE(.417)							
No Till		Ridge Till		Chisel		Moldboard	
mean	stdev	mean	stdev	mean	stdev	mean	stdev
----------			plants/ac x1000			----------	
19.1	4.98	20.7	1.97	20.1	1.49	20.6	1.81

Table 21. The effect of tillage and starter on growth stages of corn, May 29, 1987, n=40.

Table 22. The effect of tillage on the number of damaged leaves on plants, May 29, 1987, n=8.

lbs/ac starter[1] Fertilizer N P_2O_5 K_2O	TILLAGE(<.000) No Till mean	stdv	Ridge Till mean	stdv	Chisel mean	stdv	Moldboard mean	stdv	Avg	TILLAGE(.079) No Till mean	stdv	Ridge Till mean	stdv	Chisel mean	stdv	Moldboard mean	stdv	Avg
	leaves/plant									percent damage								
0 0 0	3.62	.38	4.22	.16	4.23	.25	4.30	.29	4.09	25.3	21.6	22.9	21.4	19.9	12.2	9.8	12.9	19.5
5 10 5	3.97	.47	4.17	.41	4.33	.26	4.40	.42	4.22	10.5	25.7	0.0	0.0	0.0	0.0	0.5	1.5	2.8
10 20 10	4.04	.45	4.22	.51	4.33	.40	4.35	.30	4.23	4.8	9.9	2.2	4.5	0.6	1.6	0.6	1.7	2.0
average	3.88	.46	4.20	.38	4.30	.31	4.35	.34		13.5	21.3	8.4	16.0	6.8	12.3	3.7	8.5	

1. The significance of starter was .001 and the interaction of tillage x starter was .002. (Table 21)

1. The significance of starter was .000 and the interaction of tillage x starter was .542. (Table 22)

Table 23. The effect of tillage on weed growth, by visual cover on May 29, 1987.

Weed	Sig. of Tillage	TILLAGE No Till mean	st dev	Ridge Till mean	st dev	Chisel mean	st dev	Moldboard mean	st dev
		percent cover							
Quackgrass		4.2	0.9	2.2	0.9	0.8	0.9	0.0	0.0
Milkweed		0.0	0.0	0.2	0.5	0.0	0.0	0.0	0.0
Foxtail	(.000)	1.2	0.5	1.5	0.6	10.0	4.1	8.0	8.1
Lambquarter	(.002)	4.7	2.9	4.7	2.6	1.2	0.9	0.2	0.5
Russian Thistle		0.7	1.5	0.5	0.6	0.0	0.0	0.2	0.5

Table 24. The effect of tillage on dry matter production, June 26, 1987, n=4.

lbs/ac starter[1] Fertilizer N P_2O_5 K_2O	TILLAGE(.000) No Till mean	st dev	Ridge Till mean	st dev	Chisel mean	st dev	Moldboard mean	st dev	Avg
	grams/plant								
0 0 0	11.5	3.45	16.2	4.72	22.6	5.51	31.5	5.15	20.5
5 10 5	20.8	1.20	24.2	.799	26.5	4.65	34.2	3.94	26.4
10 20 10	22.2	2.04	26.9	2.98	30.1	3.80	36.8	8.86	29.0
average	18.2	5.40	22.4	5.58	26.4	5.31	34.2	6.16	

1. The significance of starter was .000, the interaction of tillage x starter was .024.

Table 25. The effect of tillage on whole plant concentration of N, P, and K on June 26, 1987.

lbs/ac Starter Fertilizer N P_2O_5 K_2O	TILLAGE No Till mean	stdv	Ridge Till mean	stdv	Chisel mean	stdv	Moldboard mean	stdv	Avg
	% Nitrogen								
0 0 0	2.47	.49	2.60	.48	2.31	.43	2.29	.15	2.42
5 10 5	2.03	.23	2.67	.51	2.04	.16	1.99	.35	2.18
10 20 10	1.77	.16	2.51	.21	2.06	.24	1.88	.11	2.06
Sig.[1](.002)									
average	2.09	.42	2.60	.39	2.14	.30	2.05	.28	
	% Phosphorus								
0 0 0	.43	.09	.39	.04	.36	.01	.37	.05	.39
5 10 5	.36	.04	.38	.04	.37	.02	.32	.08	.35
10 20 10	.39	.09	.35	.10	.39	.07	.33	.02	.37
Sig.[1](.050)									
average	.39	.07	.38	.06	.37	.04	.34	.05	
	% Potassium								
0 0 0	.98	.10	1.08	.24	1.15	.18	1.90	.70	1.28
5 10 5	1.15	.21	1.07	.09	1.17	.18	2.10	.29	1.37
10 20 10	1.15	.35	1.20	.14	1.13	.20	1.57	.29	1.26
Sig.[1](.000)									
average	1.09	.23	1.12	.17	1.15	.17	1.85	.48	

1. The significance of tillage; the significance of starter for N was .011, P was .140 and K was .281. The tillage x starter interaction on N was .435, P was .391 and K was .111.

Table 26. The effect of tillage on plant uptake of N, P and K, June 26, 1987.

lbs/ac Starter Fertilizer N P_2O_5 K_2O	TILLAGE No Till mean	stdv	Ridge Till mean	stdv	Chisel mean	stdv	Moldboard mean	stdv	Avg
	milligrams Nitrogen/plant								
0 0 0	288	99	420	143	518	124	720	96	486
5 10 5	420	25	650	143	543	107	666	92	570
10 20 10	394	51	674	84	624	117	691	160	596
Sig.[1](.002)									
average	367	84	582	165	561	115	692	111	
	milligrams Phosphorus/plant								
0 0 0	50	18	63	14	81	20	114	12	77
5 10 5	74	5	92	9	97	16	107	19	92
10 20 10	86	14	94	21	119	25	120	25	105
Sig.[1](.014)									
average	70	20	83	20	99	25	114	19	
	milligrams Potassium/plant								
0 0 0	114	34	181	87	265	97	622	337	296
5 10 5	240	49	258	27	312	81	721	152	383
10 20 10	257	87	323	51	336	27	571	155	372
Sig.[1](.000)									
average	204	87	254	81	304	74	637	219	

1. The significance of tillage; the significance of starter for N was .015, P was .002 and K was .003. The tillage x starter interaction on N was .103, P was .419 and K was .045.

Table 27. The effect of tillage on earleaf concentration of N, P and K on July 24, 1987.[1]

lbs/ac Starter Fertilizer N P_2O_5 K_2O	Sig. of Tillage	TILLAGE No Till mean	stdev	Ridge Till mean	stdev	Chisel mean	stdev	Moldboard mean	stdev	Avg
	(<.000)	% Nitrogen								
0 0 0		2.22	.15	2.42	.06	2.37	.13	2.42	.03	2.36
5 10 5		2.02	.21	2.44	.14	2.15	.17	2.17	.09	2.20
10 20 10		1.94	.18	2.38	.09	2.39	.06	2.50	.35	2.30
average		2.06	.20	2.41	.10	2.31	.16	2.36	.24	
	(.017)	% Phosphorus								
0 0 0		.28	.05	.35	.07	.23	.12	.24	.07	.27
5 10 5		.27	.05	.32	.04	.27	.02	.20	.08	.26
10 20 10		.26	.09	.32	.06	.26	.03	.25	.08	.27
average		.93	.10	1.10	.07	1.00	.07	1.01	.13	
	(<.000)	% Potassium								
0 0 0		.48	.18	.47	.19	.65	.17	.95	.34	.64
5 10 5		.47	.12	.53	.09	.67	.19	1.08	.21	.69
10 20 10		.50	.12	.72	.33	.75	.14	.98	.24	.74
average		.48	.13	.57	.24	.69	.16	1.01	.25	

1. The significance of starter for concentration of N,P and K was .014, .933 and .292 respectively. The signiifcance of the tillage x starter interaction for N, P, and K was .158, .741 and .694 respectively.

Table 28. The effect of tillage on plant leaf water potential on June 26, 1987.[1]

lbs/ac Starter Fertilizer N P_2O_5 K_2O			TILLAGE (.003) No Till mean	stdv	Ridge Till mean	stdv	Chisel mean	stdv	Moldboard mean	stdv	Avg
			(-bars)								
0	0	0	3.0	2.1	3.1	1.2	4.5	3.0	5.8	1.3	4.4
10	20	10	5.5	2.2	4.1	.6	5.9	3.0	7.8	2.9	5.8
average			4.2	2.4	3.6	1.1	5.2	3.0	6.8	2.4	

1. The significance of starter was .001 and the significance of tillage x starter interaction was .370.

Table 29. The effect of tillage on plant leaf water potential on July 24, 1987.[1]

lbs/ac Starter Fertilizer N P_2O_5 K_2O			TILLAGE (.046) No Till mean	stdv	Ridge Till mean	stdv	Chisel mean	stdv	Moldboard mean	stdv	Avg
			(-bars)								
0	0	0	6.3	1.6	7.1	1.8	6.9	1.8	7.9	2.3	7.0
10	20	10	8.0	1.2	9.3	2.3	7.5	1.8	9.2	1.4	8.5
average			7.1	1.6	8.2	2.3	7.2	1.8	8.6	2.0	

1. The significance of starter was .000 and the significance of tillage x starter interaction was .632.

Table 30. The effect of cultivation and ridging on corn yield on September 22, 1987, n=2.

lbs/ac Starter Fertilizer N P_2O_5 K_2O			Sig. of Cultivation (.852)	Ridged mean	st dev	Not Ridged mean	st dev
				bu/ac[1]			
0	0	0		81.6	12.8	93.3	9.6
5	10	5		90.1	16.9	87.3	1.9
10	20	10		90.5	22.2	91.9	8.5

1. The significance of starter fertilizer was .521; the significance of the interaction of cultivation x starter fertilizer was .497.

Table 31. The effect of cultivation and ridging on corn harvest moisture on September 22, 1987, n=2.

lbs/ac Starter Fertilizer N P_2O_5 K_2O			Sig. of Cultivation (.399)	Ridged mean	st dev	Not Ridged mean	st dev
				% mosture[1]			
0	0	0		22.5	0.6	21.0	1.0
5	10	5		20.6	2.2	20.8	2.0
10	20	10		20.1	1.6	21.0	0.3

1. The significance of starter fertilizer was .383; the significance of the interaction of tillage x starter fertilizer was .692.

Table 32. The effect of tillage and starter fertilizer on corn yield and harvest moisture on September 22, 1987, n=4.

lbs/ac Starter Fertilizer N P_2O_5 K_2O			Sig. of Tillage	TILLAGE No Till mean	stdev	Ridge Till mean	stdev	Chisel mean	stdev	Moldboard mean	stdev	Avg
N P_2O_5 K_2O			(.000)	bu/ac[1]								
0	0	0		49.5	8.4	81.5	12.7	88.4	12.8	104.8	10.2	81.3
5	10	5		74.3	12.0	90.1	16.9	94.0	10.0	92.4	7.7	87.8
10	20	10		80.4	7.5	90.5	22.1	100.9	8.4	92.4	11.9	91.1
average				68.1	16.4	87.4	16.6	94.5	11.0	96.6	11.0	
N P_2O_5 K_2O			(.012)	% moisture[2]								
0	0	0		23.3	1.3	22.5	0.6	21.8	0.9	20.9	1.1	22.1
5	10	5		20.6	0.8	20.5	2.1	18.6	2.1	19.4	0.0	19.8
10	20	10		19.7	1.3	20.1	1.5	19.0	1.6	18.9	1.2	19.4
average				21.3	1.9	21.1	1.8	19.9	2.1	19.7	1.3	

1. The significance of starter fertilizer was .010; the significance of the interaction of tillage x starter fertilizer was .002.
2. The significance of starter fertilizer was .000; the significance of the interaction of tillage x starter fertilizer was .780.

Data collected at the Wright County site are shown in tables 33 to 43. Soil cover by crop residue is shown in tables 34 and 35. There is generally more residue after corn than soybeans. In row cover by soybean residue is less than 20% for all but the no till system. Crop residue would have a minimal influence on corn growth. In row cover by soybean residue is less than 20% for all but the no till system (table 38). Similar to the Meeker site, higher in row cover by corn residue would also not effect soybean growth (table 36). Erosion control would be marginal with chisel plowing after soybeans and not adequate with moldboard plowing after either crop. Corn stands were higher with the ridge till system. This is due to more moist soil at planting and better seed to soil contact than the moldboard and chisel plowing options (table 38). Stand reduction with the no till treatment is due to in row crop residue (50%, table 35). The effect of tillage on early growth was similar to the Meeker county site. Ridge till corn was ahead of the other treatments and less variable in growth.

There were no significant weed problems in the soybeans (table 37). Tillage did effect the weeds in the corn. Lambsquarter was the dominant weed and there were higher densities in the no till and ridge till systems. These observations were made before ridging. There was also an application of 2,4-D on May 30 (table 33). The lambsquarter probably affected yields at this site.

Grain yields are shown in table 41 and 42 for soybeans and corn respectively. There is no difference in soybean yields due to tillage if the row spacing is the same. Ridge till soybeans were 8 bu/acre less than the narrow row soybeans (30 and 8 inches). Other research shows that the row spacing response by soybeans is greater in dry years. It is interesting that there was no row spacing response by the soybeans at the Meeker site. Last year there was no row width response at the Wright county site.

In two years at this site the average row width response was 3.6 bu/acre (about $18.00/acre at $5.00/bu). This cost would offset the cost of a conservation tillage drill. The cost of incorporating a preplant incorporated herbicide would be roughly equivalent to two cultivations with a ridge till cultivator. If primary tillage was also used costs would be higher than a ridge till system. Herbicide cost also would have roughly the same (banded preemerge for ridge till compared to preplant incorporated with spring discing). So a spring disc system with narrow rows would be roughly the same profitability as a ridge till system. Systems with primary tillage or no tillage would be less profitable for soybean production based on tillage and herbicide costs, and yields. It must be remembered that the specific circumstance of the individual's enterprise is the determining factor as to the profitability of any system.

Corn yields were higher with the moldboard and chisel plowing systems. Nitrogen was applied sidedress as anhydrous ammonia. Starter fertilizer was applied as 8-23-30 at 150 lbs/acre. Ear leaf tissue samples taken at silk emergence did not show any nutrient concentration differences that would explain these yield differences (table 40). There was early lambsquarter competition in the no till and ridge till treatments which likely explains part of the reduction in yield with these systems. It is probable that the early growth by corn grown with the ridge till system (table 38) resulted in a longer period of moisture stress and possibly at silk emergence which may explain the yield reduction with this system.

WRIGHT COUNTY

Table 33. Cultural practices at Wright County, MN. 1987.

Tillage

No Till

Ridge-Corn was ridged on June 17, 1987 and soybeans were ridged on June 23, 1987.

Chisel-All plots were chiseled on November 6, 1986.

Moldboard-Corn plots were light disced then all plots plowed on October 16, 1986.

Both the chisel and moldboard were split by cultivation. The corn was cultivated on May 29, 1987 and June 17, 1987 and the soybeans on June 6 and 23, 1987. During the first cultivation ridge plots were done also.

Preceding Crops

Corn-soybean rotation since 1982.

1987 Crops

Corn - Pioneer 3737 Soybeans - Pioneer 1677

Planting and Harvest Dates

Soybeans-Ridge till plots were planted with a John Deere Maxemerge planter equipped with Buffalo Till ridge cleaners with 10" sweeps. All other plots were planted with a Tye No Till drill with 8" row spacing equipped with 2" fluted coulters.

Corn-Ridge till plots were planted with a John Deere Maxemerge planter equipped with Buffalo Till ridge cleaners with 10" sweeps. All other plots were planted with the John Deere Maxemerge planter but the sweeps were raised.

Crop	Planting Date	Planting Rate	Harvested
Corn	May 4, 1987	29,700 plants/ac	October 8, 1987
Soybeans	May 4, 1987	225,000 plants/ac	October 8, 1987

Fertilization History-Prior to 1987[1]

Since 1983 both corn and soybeans received 100 to 150 lbs/ac of a 5-12-36 fertilizer applied with the planter. Prior to that only the corn received fertilizer with the planter. 1986-corn was fertilized as follows:

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			---	lbs/ac	---	
Corn:	8-23-30[2]	140 lbs/ac	11	32	42	May 2, 1986
	28-0-0[3] UAN	37 gal/ac	110	0	0	June 13, 1986

1. This information is based on an interview with the cooperating farmer.
2. Planter placement 2" beside and 2" below row.
3. Surface banded between rows.

Fertilizer-1987

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			---	lbs/ac	---	
Corn:	8-20-32[1]	140 lbs/ac	11	28	45	May 4, 1987
	82-0-0	183 lbs/ac	150	0	0	June 15, 1987

1. Planter placement 2" beside and 2" below row.

Soil

Fairhaven (Typic Hapludolls, fine-loamy over sandy or sandy-skeletal, mixed, mesic) silt loam, 2 to 6 percent slopes, moderately eroded. Soil is well-drained.

Weed Control

Corn

2 qt/ac (2 lbs ai/ac) Lasso + $1^1/_2$ qt/ac ($1^1/_2$ lbs ai/ac) Bladex on May 4, 1987 with planter.
$^1/_2$ pt/ac ($^1/_4$ lb ai/ac) 2,4-D on May 30, 1987.

Soybeans

1 pt/ac ($^1/_2$ lb ai/ac) Basagran + $^1/_2$ pt/ac ($^1/_8$ lb ai/ac) Blazer + 1 pt/ac crop oil on May 25, 1987.
1 pt/ac ($^1/_2$ lb ai/ac) Basagran + $^1/_4$ pt/ac ($^1/_{16}$ lb ai/ac) Blazer + 1 pt/ac ($^2/_{10}$ lb ai/ac) Poast + 1 qt/ac Dash crop oil + 1 gal 28% on June 8, 1987.

Table 34. The effect of tillage on percent of the soil surface covered by corn residue on June 1, 1987, n=16.

	TILLAGE (<.000)-							
	No Till		Ridge Till		Chisel		Moldboard	
	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Location	% cover							
In Row	61.0	33.3	20.0	21.5	44.0	29.4	5.7	9.5
Between	60.0	29.3	47.7	22.4	46.7	27.0	5.5	9.2

Table 35. The effect of tillage on percent of the soil surface covered by soybean residue on June 1, 1987, n=16.

	TILLAGE (<.000)							
	No Till		Ridge Till		Chisel		Moldboard	
	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Location	% cover							
In Row	49.5	23.3	7.2	9.8	14.5	9.6	1.7	3.2
Between	78.2	19.0	31.2	20.4	19.7	10.5	2.5	5.2

Table 36. The effect of tillage on soybean population and growth stage, June 1, 1987, n=8.

	TILLAGE							
	No Till		Ridge Till		Chisel		Moldboard	
Sig. of	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Tillage	1000 plants/ac							
(.000)	229	49	161	21	247	38	257	23
	stage[1]							
(.174)	2.4	.7	2.4	.5	3.0	.7	2.9	.7

1. Soybean growth stages are as follows: 1=emergence(Ve), cotyledons above soil surface; 2=cotyledon(Vc) unifoliolate leaves unrolled sufficiently so the leaf edges are not touching; 3=first node, fully developed leaves at unifoliolate nodes and 4=second node; fully developed trifoliolate lead at node above the unifoliolate nodes.

Table 37. The effect of tillage on weed population in soybean on June 1, 1987.

		TILLAGE							
		No Till		Ridge Till		Chisel		Moldboard	
	Sig. of	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Weed	Tillage	% cover							
Purslne	(.132)	0.1	0.3	0.4	0.5	0.0	0.0	0.0	0.0
Lambqurt	(.436)	0.3	0.5	0.5	0.6	0.1	0.3	0.0	0.0
Foxtail	(.124)	3.8	0.9	7.0	3.6	4.5	2.1	8.0	3.4
Milkweed	(.583)	2.8	3.2	1.1	1.9	1.8	1.7	1.3	0.9
Ragweed	(.034)	0.1	0.3	0.4	0.3	0.0	0.0	0.0	0.0
VolCorn	(.264)	0.0	0.0	0.6	0.9	0.4	0.3	0.1	0.3
Quackgrs	(.461)	1.8	2.0	2.8	2.2	3.3	1.9	4.5	4.0
PenyCres	(.021)	2.5	2.4	3.5	1.3	0.4	0.5	0.4	0.5
ShepPurs	(.001)	1.5	1.9	4.0	1.2	0.0	0.0	0.0	0.0
Buckwhet	(.436)	0.8	1.5	1.3	2.5	1.0	2.0	0.5	1.0

Table 38. The effect of tillage on corn population and growth stages on June 1, 1987, n=8.

	TILLAGE							
	No Till		Ridge Till		Chisel		Moldboard	
Sig. of	mean	st dev	mean	st dev	mean	st dev	mean	st dev
Tillage	1000's plants/ac							
(.046)	27.1	3.9	30.7	2.1	28.3	2.0	27.4	1.4
	leaves/plant							
(.252)	3.8	.3	4.3	.4	3.6	.9	3.6	1.0

Table 39. The effect of tillage on weed population in corn on June 1, 1987.

Weed	Sig. of Tillage	No Till mean	No Till stdv	Ridge Till mean	Ridge Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
		% cover							
Purslne	(.088)	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0
Lambqurt	(.006)	23.0	17.1	25.0	12.9	4.3	0.9	6.6	6.5
Foxtail	(.49)	03	03	04	03	10	14	08	05
Milkweed	(.308)	0.4	0.5	0.3	0.3	0.5	1.0	0.1	0.3
Pigweed	(.436)	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.3
Ragweed	(.327)	0.0	0.0	0.1	0.3	0.3	0.3	0.0	0.0
VolSoyb	(.436)	0.5	0.0	0.6	0.3	0.8	0.3	0.4	0.3
Quackgrs	(.308)	0.3	0.5	1.3	1.9	0.0	0.0	0.1	0.3
PenyCres	(.522)	0.8	0.9	0.1	0.3	0.4	0.5	0.6	0.9

Table 40. The effect of tillage on earleaf tissue concentration of nitrogen and potassium on July 24, 1987.

Nutrient	Sig. of Tillage	NoTill	Ridge	Chisel	Mboard	Avg
		%				
N	(.447)	2.50	2.37	2.53	2.53	2.48
K	(.986)	2.24	2.36	2.35	2.36	2.33

Table 41. The effect of tillage on soybean yields and moisture at harvest, October 8, 1987, n=4.

Sig. of Tillage	No Till mean	No Till stdv	Ridge Till mean	Ridge Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
	bu/ac							
(.004)	40.2	6.1	31.1	2.0	38.1	4.1	39.1	5.2
	% moisture							
(.561)	7.2	.4	7.0	.5	7.0	.4	7.4	.3

Table 42. The effect of tillage on corn yields and moisture at harvest, October 8, 1987, n=8.

Sig. of Tillage	No Till mean	No Till stdv	Ridge Till mean	Ridge Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
	bu/ac							
(.034)	106	10.4	110	25.3	123	16.3	121	21.7
	% moisture							
(.136)	16.1	2.7	15.3	1.5	14.3	.8	14.2	1.4

Table 43. The effect of cultivation with chisel and moldboard plow on corn yields and moisture at harvest, October 8, 1987, n=4.

Sig. of Tillage	Chisel Plow cultivated mean	Chisel Plow cultivated st dev	Chisel Plow not cult mean	Chisel Plow not cult st dev	Moldboard Plow cultivated mean	Moldboard Plow cultivated st dev	Moldboard Plow not cult mean	Moldboard Plow not cult st dev
	bu/ac[1]							
(.798)	127	9.7	119	21.9	125	26.3	119	19.8
	% moisture[2]							
(.511)	14.2	0.8	14.5	0.8	14.0	1.8	14.6	1.3

1. The significance of cultivation was .366; the significance of the interaction of tillage x cultivation was .719.
2. The significance of cultivation was .040; the significance of the interaction of tillage x cultivation was .349.

TILLAGE, NITROGEN, CORN HYBRID, SOYBEAN VARIETY, AND SOYBEAN SEED TREATMENT EFFECTS ON YIELDS AT MORRIS, LAMBERTON, AND WASECA MN.-1986 AND 1987

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This is summary of a study initiated in 1986 to evaluate: the effect of tillage on nitrogen response by corn following soybeans and soybeans responding to residual soil nitrogen following corn; the effect of tillage on the performance of corn hybrids and soybean varieties; and the effect of tillage and soybean variety on the response to seed treatment with fungicides. This study is being conducted at the Morris, Lamberton, and Waseca Agricultural Experiment Stations. A corn-soybean rotation is being followed.

Tillage ranges from fall plowing with a moldboard, chisel, or paraplow or elimination of primary tillage (ridge till or no till systems). The paraplow is a unique type of subsoiler that leaves the surface relatively undisturbed but lifts the soil more than a conventional subsoiling operation. The tillage is reduced following soybeans in two treatments since less crop residue is being managed. The moldboard/chisel plow system is moldboard plowed following corn and chisel plowed following soybeans. The chisel/no till system is chisel plowed following corn and no tilled following soybeans. Only the ridge till plots were cultivated. Nitrogen was spring applied as anhydrous ammonia. Nitrogen rates at Lamberton and Waseca range from 0 to 200 lbs/acre in 40 lbs/acre increments. Rates were from 0 to 120 lbs/acre in 40 lbs/acre increments at the Morris location. In the second year of the study residual N from the previous corn year were evaluated. There were no discernable influence of residual N on soybean yields (data not presented). The corn and soybean hybrid or varieties are the same at the Lamberton and Waseca locations. Different hybrid or varieties were used at the Morris location due to the shorter season.

RESULTS-1986

Corn

There was one out of six studies that resulted in significant tillage effects on grain yields (tillage and hybrid study at Morris, table 1). The chisel plowing treatment was an average of 7 bu/acre less than the other systems at this site. At the other two sites there were no significant differences in corn yields due to tillage. There were also significant hybrid effects at all locations (table 2). Nitrogen response by corn is shown in table 3. Responses were to 40, 120 and 120 for the Lamberton, Waseca and Morris sites respectively. The Lamberton site showed a significant tillage by N rate interaction. The paraplow treatment was "yield limited" by some other factor at about 80 lbs N/acre.

Soybeans

There was a tillage effect on soybean yields at the Morris and Waseca sites. The ridge till system resulted in a yield reduction of 3 and 5 bu/acre for the Morris and Waseca sites respectively. There was also a tillage by variety interaction at two sites (.130 and .009 at Lamberton and Waseca respectively). These interactions are shown in Figure 1. Yield reductions with this system were much greater with the Elgin variety (especially at Waseca). There was a wide range in soybean yield due to variety. There was a 10 bu/acre reduction between the high and low yielding variety at the waseca site.

Soybean seed treatments resulted in a slight yield reduction at the Morris site, a slight yield increase at the Waseca site with one source of seed treatment and no response at the Lamberton site (table 7). There was a significant variety by seed treatment at the Lamberton site however. Some varieties responded positively and some negatively (table 8) to seed treatments resulting in a non significant main effect of seed treatment. These interactions are shown in Figure 2.

Table 1. The effect of tillage on corn yields following soybeans 1986.

Crop[1]		Morris TxH[2]	Morris TxN[3]	Morris Avg.	Lamberton TxH	Lamberton TxN	Lamberton Avg.	Waseca TxH	Waseca TxN	Waseca Avg.	Avg.
Cn	Sb	Bu/acre									
NT	NT	140ab	142	141	123	155	139	135	137	136	139
RT	RT	141a	140	141	122	161	142	137	139	138	140
CH	NT	140ab	141	140	117	158	138	141	138	140	139
MB	CH	130b	136	133	117	160	139	134	135	135	136
PP	PP	141a	139	140	117	146	132	136	133	135	136
Sig.		.091	.915		.643	.217		.422	.494		

1. Tillage is different following corn and soybeans in some cases. Tillage follows the crop listed in the heading and are:NT-no till, RT-ridge till, CH-chisel, MB-moldboard, and PP-paraplow.
2. This is the tillage by hybrid study, yields are averaged over hybrid, n=20.
3. This is the tillage by nitrogen study, yields are averaged over nitrogen rates, n=16 and 20 for Morris and the other two sites respectively.

Table 2. The effect of corn hybrid on grain yields, n=20.

Morris Hybrid	Morris Bu/acre	Hybrid	Lmbrtn[1] -Bu/acre--	Wsca
P3906	137b	P3737	124a	157a
DK XL8	122c	P3732	131a	138c
DK 461	146a	DK 524	111b	146b
F 4211	135b	SC2410	120ab	130d
P 3790	149a	F 4327	112b	112e
Signif.	<.000		.010	<.000

1. The tillage by hybrid study did not receive nitrogen at this site.

Table 3. Nitrogen response by corn following soybeans, 1986.

Location	0	40	80	120	160	200
	Bu/acre					
Morris[1](<.000)	114	139	149	156		
Lmbrtn[2](<.000)	131	155	157	161	165	167
Waseca[2](<.000)	82	123	147	153	154	157

Nitrogen Rate (lb/acre) in column heads.

1. The hybrid at the Morris location was P 3970, n=16. The number in parenthesis is the p value.
2. The hybrid at the Lamberton and Waseca locations was P 3737, n=20.

Table 4. The effect of tillage and N rate on yields-Lamberton, 1986[1].

Tillage[2]	0	40	80	120	160	200
	Bu/acre					
NT/NT	127	159	157	163	158	170
RT/RT	127	163	162	182	159	177
NT/CH	136	155	159	167	169	161
MD/CH	127	162	156	173	169	170
PP/PP	137	138	154	142	151	156

N rate (lbs/acre) in column heads.

1. The significance of tillage, N rate, and the tillage by N rate interaction is .217, <.000, and .098 respectively.
2. The letter before the slash is following corn and the second following soybeans: NT-no till, RT-ridge till, CH-chisel, MD-moldboard, and PP-paraplow.

Table 5. The effect of tillage on soybean yields following corn, 1986, n=96.

Crop[1]		Morris	Lbrtn.	Waseca
Cn	Sb	Bu/acre		
NT	NT	45.2a	47.3	44.5a
RT	RT	42.0b	47.1	39.5b
CH	NT	44.3ab	46.5	45.6a
MB	CH	45.5a	47.7	45.9a
PP	PP	45.3a	48.8	43.6a
Sig.		.055	.205	.011

1. Tillage is differenct following corn and soybeans in some cases.

Table 6. The effect of variety on soybean yields following corn, 1986, n=60.

Variety	Morris Bu/acre	Variety	Lmbrtn. ----Bu/acre----	Waseca
P 0877	45.8a	Corsoy79	47.5bc	42.9d
Simpson	45.9a	BSR 101	46.1c	46.6ab
Evans	44.9a	A 1937	47.7bc	47.3a
AP 120	40.7c	Sibley	47.8bc	43.0d
Swift	42.3b	Elgin	42.3d	37.4e
Dassel	45.2a	Hardin	49.7ab	45.0bc
Dawson	46.0a	P 1677	51.5a	44.3cd
Hodg.78	45.0a	Hodg.78	47.0c	43.9cd
Signif.	<.000		<.000	<.000

Table 7. The effect of seed treatment on soybean yields, 1986, n=160.

Fung.	Morris	Lmbrt	Wsca
	Bu/acre		
none	44.9a	47.1	43.2b
Captan	44.4ab	48.1	44.8a
Apron	44.1b	47.2	43.4b
Sig.	.088	.390	.029

Table 8. The interaction between variety and seed treatment at Lamberton and Waseca, 1986.

	Location					
	Lmbrtn (<.000)[1]			Waseca (<.000)[1]		
	none	cptn	apm	none	cptn	apm
Variety	------------Bu/acre------------					
Corsoy79	47.9	47.6	47.0	42.7	43.0	42.9
BSR 101	45.7	47.2	45.6	47.3	45.5	47.0
A 1937	48.7	47.7	46.8	48.3	47.5	46.0
Sibley	48.0	47.6	47.8	43.2	42.4	43.5
Elgin	38.8	45.8	42.4	32.2	43.9	36.1
Hardin	49.9	49.6	49.7	45.7	45.8	43.5
P 1677	51.7	51.8	51.1	41.8	45.8	45.2
Hodg.78	46.3	47.5	47.4	44.7	44.2	42.9

1. The number in parenthesis is the significance of the variety by seed treatment interaction, n=20. See table 7 for main effects of seed treatment.

RESULTS-1987

Corn

Tillage affected grain yields at all but the tillage by hybrid study at Morris and are summarized in table 9. There was a yield decline with the no till and paraplow treatments at the Morris and Waseca locations. The fall chisel plowing treatment resulted in the highest grain yield at the Lamberton location. There were also significant main effects of corn hybrid at the Morris and Waseca location but not at Lamberton (table 10). The nitrogen response is shown in table 11. There was no response to nitrogen at the Morris site. Corn responded to the 40 and 80 lbs/acre rate at the Lamberton and Waseca sites respectively. There was no interaction at any site between tillage and N response. Tillage did interact with corn hybrid at the Morris site (table 12). The ridge till response to the P 3906 and DK XL8 was similar in another study at this location with corn grown after corn (sister study reported in this publication).

Soybeans

Tillage effects were not consistent in their effect on soybean yields but the trend was for the ridge till system to result in a small yield advantage and the paraplow treatment a small yield reduction (table 13). There were significant variety effects at all locations (table 14). The Swift, Dawson, and Hodgson 78 were the highest yielding varieties at the Morris location. Asgrow 1937 and Hardin were the high yielding varieties at the Lamberton and Waseca sites. Evans and Sibley were the lowest yielding varieties at the Morris and Lamberton and Waseca sites respectively.

There was a significant tillage by soybean variety interaction in the tillage-soybean-nitrogen study at the Lamberton and Morris sites (p value of <.000 and .042 respectively for the tillage by variety interaction). These interactions are shown in figure 3. At the Lamberton site the BSR 101 and Hodgson varieties were consistently lower yielding across the tillage systems evaluated. The Hardin and Asgrow 1937 reversed ranking depending on tillage system. Hardin was higher yielding when grown with chisel or paraplowing, about the same with ridge tillage or moldboard plowing and lower yielding than the Asgrow when grown with the no till system. At the Morris location the Hodgson 78 was higher yielding when grown with ridge tillage or moldboard plowing and about the same as the other varieties with the other tillage systems. The consistent trend at both locations is the similarity between ridge till and moldboard plowing in the variety response. There was no advantage with seed treated with fungicide at any site (table 14) regardless of tillage.

Table 9. The effect of tillage on corn yields following soybeans, 1987.

Crop[1]		Morris			Lamberton			Waseca			
Cn	Sb	TxH[2]	TxN[3]	Avg.	TxH	TxN	Avg.	TxH	TxN	Avg.	Avg.
		Bu/acre									
NT	NT	122	114b	118	133b	131a	132	148d	132b	140	130
RT	RT	131	133a	132	130bc	121b	126	158ab	140ab	149	136
CH	NT	135	128a	132	132b	119b	126	151cd	147a	149	136
MB	CH	128	132ab	130	142a	132a	137	161a	150a	156	141
PP	PP	129	115b	122	126c	114b	120	154bc	140ab	147	130
Sig.		.158	.017		.001	.003		.005	.022		

1. Tillage is different following corn and soybeans in some cases. Tillage follows the crop listed in the heading and are:NT-no till, RT-ridge till, CH-chisel, MB-moldboard, and PP-paraplow.
2. This is the tillage by hybrid study, yields are averaged over hybrid, n=20.
3. This is the tillage by nitrogen study, yields are averaged over nitrogen rates, n=16 and 20 for Morris and the other two sites respectively.

Table 11. Nitrogen response by corn following soybeans, 1987.

Location	Nitrogen Rate (lb/acre) 0	40	80	120	160	200
	Bu/acre					
Morris[1](.456)	120	123	127	121		
Lmbrtn[2](.068)	112	125	128	127	121	127
Waseca[2](<.000)	101	132	153	150	159	153

1. The hybrid at the Morris location was P 3970, n=16. The number in parenthesis is the p value.
2. The hybrid at the Lamberton and Waseca locations was P 3737, n=20.

Table 10. The effect of corn hybrid on grain yields, 1987, n=20.

Hybrid	Morris	Hybrid	Lmbtn	Wsca
			-Bu/acre--	
P3906	137a	P3737	127	159a
DK XL8	123c	P3732	131	158a
DK 461	136a	DK 524	133	147b
F 4211	122c	SC2410	135	162a
P 3790	127b	F 4327	138	146b
Signif.	<.000		.396	<.000

Table 12. The effect of tillage and hybrid on yields at Morris, 1987.

Hybrid<.000	Tillage[1](.158) N/N	R/R	C/N	M/C	P/P	Avg.
	Bu/acre					
P 3906	128	142	132	142	141	137
DK XL8	122	115	132	111	134	123
DK 461	121	141	147	134	135	136
F 4211	126	122	130	117	116	122
P 3790	115	135	134	134	119	127
Average	122	131	135	128	129	

1.Tillage is different following corn and soybeans in some cases. The letter before the slash is following corn and the second following soybeans: N-no till, R-ridge till, C-chisel, M-moldboard, and P-paraplow.
2. The tillage by hybrid interaction was significant at .068.

Table 13. The effect of tillage on soybean yields following corn in 1987.

Crop[1]	Morris TxVxS[2]	Morris TxVxN[3]	Morris Avg.	Lamberton TxVxS	Lamberton TxVxN	Lamberton Avg.	Waseca TxVxS	Waseca TxVxN	Waseca Avg.	Avg.
Cn Sb	Bu/acre									
NT NT	42.3	39.5ab	40.9	39.3	42.3	40.8	42.0	43.6ab	42.8	41.5
RT RT	42.7	40.9a	41.8	38.7	44.4	41.6	42.4	44.2a	43.3	42.2
CH NT	42.2	38.1ab	40.2	39.5	43.6	41.6	42.3	41.5b	41.9	41.2
MB CH	41.2	39.0ab	40.1	38.8	44.6	41.7	42.0	43.0ab	42.5	41.4
PP PP	39.0	36.9b	38.0	37.0	42.4	39.7	42.6	41.4b	42.0	39.9
Sig.	.417	.100		.338	.623		.956	.056		

1. Tillage is different following corn and soybeans in some cases. Tillage follows the crop listed in the heading and are:NT-no till, RT-ridge till, CH-chisel, MB-moldboard, and PP-paraplow.
2. This is the tillage by variety by seed treatment study, yields are averaged over varieties and seed treatment, n=64 for the Morris site and 96 for the other two sites.
3. This is the tillage by variety by nitrogen study, yields are averaged over varieties and nitrogen rates, n=16 and 20 for Morris and the other two sites.

Table 14. The effect of seed treatment on soybean yields.

Fung.	Location Mors	Lmbt	Wsca
	Bu/acre		
none	41.3	37.8	42.2
Captan	41.4	38.8	42.5
Apron	41.7	39.4	42.1
Sig.	.443	.189	.704

Table 14. The effect of variety on soybean yields following corn, 1987.

Variety	Morris TxVxS[1]	Morris TxVxN[2]	Morris Avg.	Variety	Lamberton TxVxS	Lamberton TxVxN	Lamberton Avg.	Waseca TxVxS	Waseca TxVxN	Waseca Avg.	Avg.
	Bu/acre				Bu/acre						
P 0877	41.7ab	38.4c	40.1	Corsoy79	38.7c	---	38.7	41.7bc		41.7	40.2
Simpson	41.7ab	39.3b	40.5	BSR 101	37.1d	41.0b	39.1	43.5ab	42.4b	43.0	41.1
Evans	38.4b	36.8d	37.6	A 1937	43.6a	45.9a	44.8	44.7a	43.6ab	44.2	44.5
AP 120	39.7b	---	39.7	Sibley	34.0f	---	34.0	39.2c	---	39.2	36.6
Swift	43.7a	---	43.7	Elgin	37.2d	---	37.2	41.3bc	---	41.3	39.3
Dassel	39.1b	---	39.1	Hardin	42.8a	46.8	44.8	43.5ab	45.1a	44.3	44.6
Dawson	43.5a	---	43.5	P 1677	40.3b	---	40.3	44.9a	---	44.9	42.6
Hodg.78	43.9a	41.1a	42.5	Hodg.78	35.7e	40.1b	37.9	39.0c	39.8c	39.4	39.9
Signif.	.008	<.000			<.000	<.000		<.000	<.000		

1. This is the tillage by variety by seed treatment study, yields are averaged over tillage and seed treatment, n=60.
2. This is the tillage by variety by nitrogen study, yields are averaged over tillage and nitrogen rates, n=80 and 120 for Morris and the other two sites respectively.

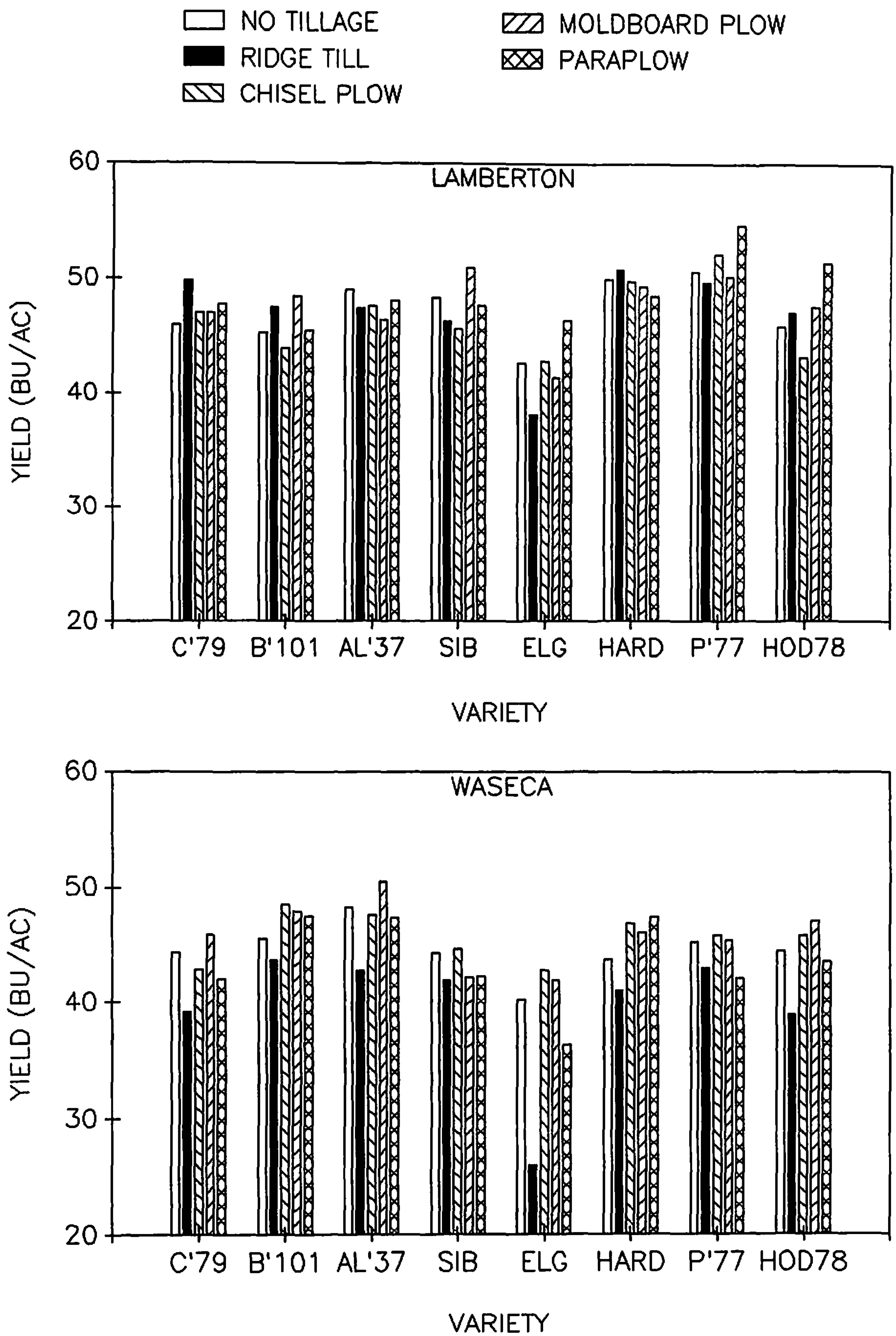

Figure 1. The interaction of soybean variety and tillage system, 1986.

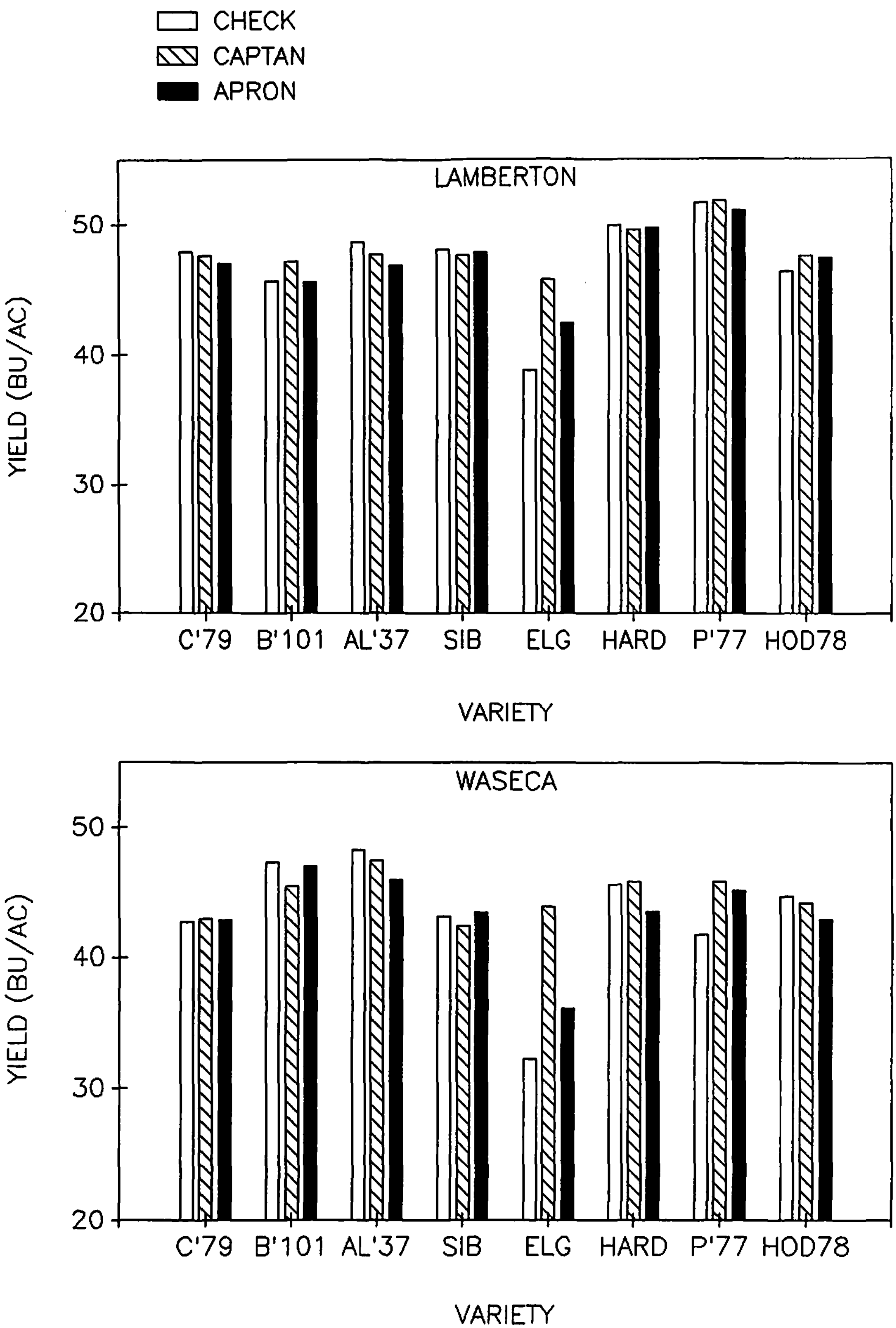

Figure 2. The interaction of soybean variety and seed treatment, 1986.

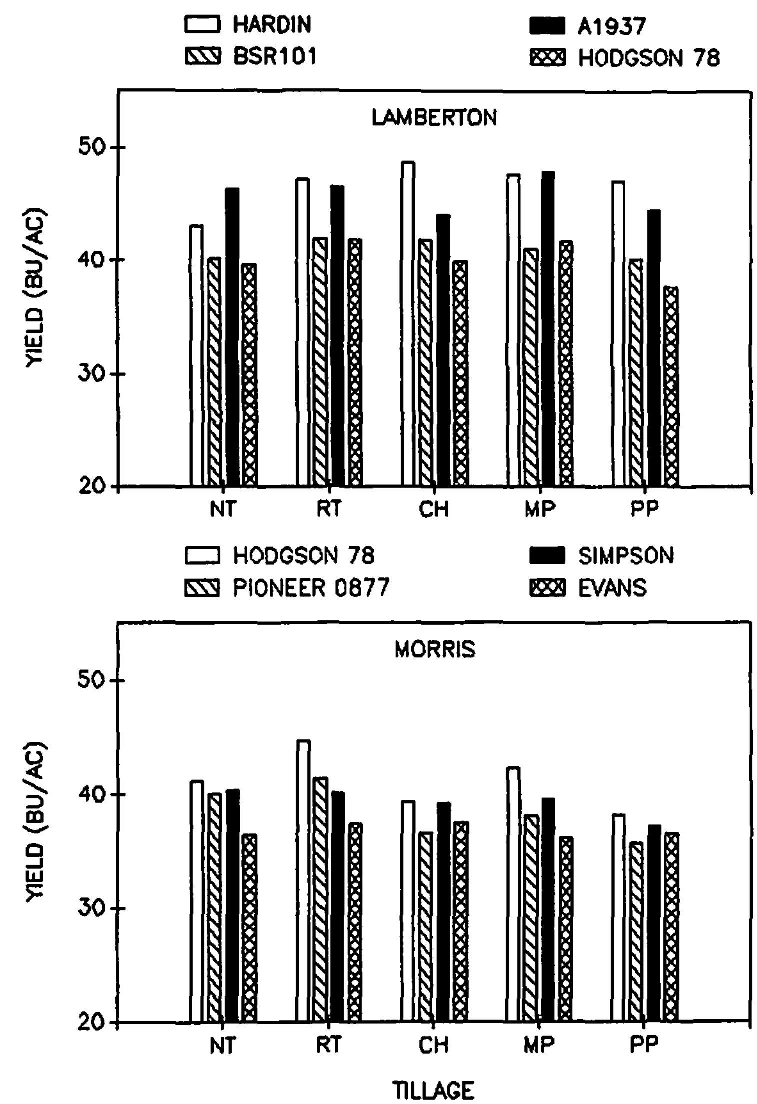

Figure 3. The effect of tillage and soybean variety on yields, 1987.

THE EFFECT OF TILLAGE ON THE NITROGEN RESPONSE BY CORN FOLLOWING ALFALFA

J.F. Moncrief, M. Wiens, D.D. Breitbach, and J.J. Kuznia

A study was initiated in 1987 to evaluate the effect of tillage on the nitrogen response by corn following alfalfa. When crop residue is left on the soil surface temperatures are reduced that can affect the rate of mineralization of organic nitrogen in alfalfa residues. The purpose of this study is to help refine the nitrogen recommendations following alfalfa to address tillage effects. Tillage ranged from moldboard plowing to no till. Nitrogen was applied on June 16 as broadcast urea and irrigated in.

Crown counts were made in the spring to determine the variability of alfalfa stand (table 2). Tillage treatments have not been established at this time. There was no correlation between the proposed randomized tillage and nitrogen plots and alfalfa crown density. Soil cover by crop residue after planting is shown in table 5. Soil cover by crop residue ranged from about 10% with moldboard plowing to over 90% with no tillage. Although emergence was affected by tillage, final stands were quite good and not effected by tillage (tables 3 and 14). The difference in emergence due to tillage resulted in about one day difference in silk emergence (table 4) and one half to one percent difference in grain moisture at harvest (table 12). The effect of tillage on crop phenology during early growth is shown in table 15. Generally in row soil cover by crop residue retarded early growth. During the May 27 to June 1 period there was emergence of additional plants in the moldboard plow treatment that brought its average leaf number down temporarily. On June 16 nitrogen was applied as broadcast urea and irrigated in. Between June 8 and June 16 apparently the no till system was limited by less nitrogen released from the alfalfa. After nitrogen application no till corn grew faster than the other systems. During the last week of observation the no till corn appears to be limited by nitrogen (these values are averaged over all rates of nitrogen, including the check plots). For a fair evaluation of crop residue effects on temperature only the plots that received nitrogen should be used in the analysis after this date.

Weeds were present in low numbers and affected by tillage in some cases (table 6). Foxtail tended to be higher in the no till and disc treatments and lambsquarters higher with moldboard plowing. At these levels they would not be expected to affect grain yields. On July 9 weeds were wiped with a Roundup wick applicator. There were no weeds present at harvest.

Row fertilizer was applied with the planter (table 1) and included 16 lbs N/acre. Additional nitrogen was applied as broadcast urea and irrigated in at the eight leaf stage of corn growth. Nitrogen was less available with conservation tillage options. Color ratings which qualitatively evaluate tillage are shown in tables 7 and 8. There were main effects of tillage and nitrogen rate on plant color and also plant height (tables 7,8,9, and 10). An interaction between tillage and nitrogen rate on plant color was found on the July 3 date. These data support the yield differences shown in table 11. At the 102 lb N/acre rate of nitrogen there was no affect of tillage on grain yields. At lower rates differences become much greater. Similar trends are shown with the stover data (table 13).

Table 1. Cultural practices at Staples Irrigation Center, Wadena County, MN. 1987.

Tillage	Previous Crop	1987 Crop
No Till	Alfalfa	Corn - Pioneer 3790
Spring Disc - Plots disced twice on May 8, 1987.		
Moldboard Plow - Plots plowed on May 8, 1987.		

Planting and Harvest Date

Planter for this site was a John Deere Maximerge planter equipped with 2" fluted coulters.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 11, 1987	32,000 plants/ac	October 1, 1987

Fertilizer

Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Actual S	Date Applied
		----	lbs/ac	----		
17-7-23-6[1]	93 lbs/ac	16	6	21	6	May 11, 1987
46-0-0[2]	0 lbs/ac	0	0	0	0	June 16, 1987
46-0-0[2]	75 lbs/ac	35	0	0	0	June 16, 1987
46-0-0[2]	146 lbs/ac	67	0	0	0	June 16, 1987
46-0-0[2]	221 lbs/ac	102	0	0	0	June 16, 1987

1. Planter applied 2" below and 2" beside row.
2. Broadcast as urea and irrigated in.

Soil

The soil at this site is a Verndale (Udic Argiborolls, coarse-loamy, mixed) with a slope of 0 to 2 percent. The soil is well drained.

Weed Control

1 qt/ac (3/4 lb/ac) Roundup + 1/2 pt/ac (.125 lb/ac) Banvel on May 2, 1987.
1 qt/ac (2 lb/ac) Dual + 1 1/2 qt/ac (1 1/2 lbs/ac) Bladex on May 14, 1987.
Weeds between the rows were wiped with a Roundup wick applicator at 4 inches high on July 9.

Table 2. The viability on alfalfa crown counts with proposed tillage on April 28, 1987.

	Tillage: No Till mean	No Till stdev	Disc mean	Disc stdev	Moldboard mean	Moldboard stdev
Viable	------------		crowns/m²		------------	
16 lbs/ac	18.3	7.92	21.1	7.80	22.3	3.52
50 lbs/ac	20.5	8.25	22.7	7.05	23.2	7.28
83 lbs/ac	16.3	5.85	22.1	9.17	17.5	6.79
117 lbs/ac	17.1	4.46	18.6	11.2	17.1	6.34
NonViable	------------		crowns/m²		------------	
16 lbs/ac	11.5	2.35	10.9	1.32	10.0	2.57
50 lbs/ac	10.6	4.64	9.3	1.13	11.9	6.61
83 lbs/ac	11.4	4.05	12.0	4.33	13.0	4.86
117 lbs/ac	8.6	2.74	11.9	4.76	11.6	3.13
Total	------------		crowns/m²		------------	
16 lbs/ac	29.8	6.88	32.0	6.23	32.3	3.08
50 lbs/ac	31.1	7.69	32.0	6.07	35.1	4.85
83 lbs/ac	27.8	3.84	34.1	10.2	30.5	5.99
117 lbs/ac	25.6	3.29	30.6	13.9	28.8	6.67

Table 3. The effect of tillage on emergence of corn from May 9, to June 1, 1987. n=16.

Date	Sig. of Tillage	Tillage: No Till mean	No Till stdev	Disc mean	Disc stdev	Moldboard mean	Moldboard stdev
		---------		plants/ac x 1000		---------	
May 19	(.000)	0.0	0.00	1.2	1.88	6.1	5.28
May 20	(.000)	2.9	2.97	12.1	7.51	15.7	6.61
May 21	(.030)	17.1	8.00	24.0	6.93	22.5	6.75
May 22	(.194)	21.5	9.13	26.2	5.03	23.2	7.05
May 26	(.311)	29.3	4.60	29.2	5.11	26.5	7.45
May 27	(.576)	29.7	4.24	29.6	4.63	28.2	4.98
May 28	(.209)	30.6	4.02	30.6	4.59	28.2	4.77
May 29	(.358)	30.7	4.02	30.5	4.68	28.7	4.32
June 1	(.355)	30.7	4.21	30.5	4.54	28.7	4.41

Table 4. The effect of tillage on silk emergence by date, n=16.

		Tillage(.014)					
		No Till		Disc		Moldboard	
	Sig. of	mean	stdev	mean	stdev	mean	stdev
Date[1]	Tillage	%					
July 20	(.120)	2.7	4.5	7.5	9.5	9.4	11.3
July 22	(.007)	47.4	18.0	64.7	26.8	72.6	15.1
July 23	(.237)	78.4	15.0	82.2	19.1	86.3	9.2
July 24	(.304)	87.4	12.2	92.8	11.6	91.8	5.6
July 27	(.384)	96.3	6.5	97.4	3.7	98.9	2.5

1. Date of 50% silk emergence was July 21 for the moldboard plow treatment and July 22 for the disc and no till treatments.

Table 5. The effect of tillage on soil cover by corn residue on May 14, 1987, n=16.

	Tillage					
	No Till		Disc		Moldboard	
	mean	stdev	mean	stdev	mean	stdev
Location[1]	%					
In Row	91.7	6.4	47.7	24.5	12.7	19.7
Between	96.5	5.0	40.5	24.6	10.5	19.2

1. The significance of tillage with respect to both rows was <.000.

Table 6. The effect of tillage on the presence of weed species and density on July 2, 1987. n=12.

		Tillage					
		No Till		Disc		Moldboard	
	Sig. of	mean	stdev	mean	stdev	mean	stdev
Weed	Tillage	severity[2]					
Pigweed	(.227)	2.25	0.50	2.75	0.96	1.75	0.50
Foxtail	(.003)	6.00	1.15	4.00	2.30	1.75	0.50
VolAlfl	--	2.25	0.50	1.25	0.50	0.00	0.00
Dandeln	--	0.75	0.50	0.75	0.50	0.00	0.00
Lambqur	(0)	0.75	0.50	0.75	0.50	1.00	0.00
Quackgr	(.422)	1.00	0.82	0.50	0.58	0.25	0.50
Buckwht	(0)	0.75	0.50	1.00	0.00	1.00	0.00
CanThis	(.422)	0.25	0.50	0.50	1.00	0.25	0.50
Alyssum	--	1.30	0.50	0.25	0.50	0.00	0.00
Nightsh	--	0.75	0.50	0.50	0.58	0.50	0.58
Milkwed	--	0.25	0.50	0.00	0.00	0.00	0.00
Crabgrs	--	0.00	0.00	0.25	0.50	0.25	0.50
Ragweed	--	0.00	0.00	0.00	0.00	0.50	0.58
Hwkberd	--	0.50	0.58	0.00	0.00	0.00	0.00
Ydsorrl	--	0.25	0.50	0.00	0.00	0.00	0.00
Whtcokl	--	0.25	0.50	0.25	0.50	0.00	0.00
SmPigwd	--	0.00	0.00	0.00	0.00	0.25	0.50
RusThis	--	0.25	0.50	0.00	0.00	0.00	0.00
Purslne	(.422)	0.50	0.58	0.50	0.58	0.50	1.00

1. Due to unequal variances, a natural log transformation was used before analysis of variance.
2. Severity scale used is as follows; 1-none, 5-moderate and 10-severe.

Table 7. The effect of tillage on color by nitrogen July 3, 1987, n=4. (Color index ranges from 1=yellow to 10=dark green).

	Tillage(.000)						
	No Till		Disc		Moldboard		
	mean	stdev	mean	stdev	mean	stdev	Avg
Nitrogen[1]	color rating						
16 lbs/ac	6.25	0.50	7.00	0.82	8.00	0.00	7.08
50 lbs/ac	7.00	0.00	7.25	0.50	8.00	0.00	7.42
83 lbs/ac	7.25	0.50	7.50	0.58	8.00	0.00	7.58
117 lbs/ac	7.25	0.50	8.00	0.00	8.00	0.00	7.75
average	6.94	0.57	7.44	0.63	8.00	0.00	

1. The significance of nitrogen was .000, the significance of tillage x nitrogen was .019.

Table 8. The effect of tillage on color by nitrogen August 8, 1987, n=4. (Color index ranges from 1=yellow to 10=dark green).

	Tillage(.000)						
	No Till		Disc		Moldboard		
	mean	stdev	mean	stdev	mean	stdev	Avg
Nitrogen[1]	color rating						
16 lbs/ac	5.5	1.0	6.0	0.8	7.3	0.5	6.3
50 lbs/ac	6.3	0.5	6.3	1.5	7.5	1.0	6.7
83 lbs/ac	7.0	1.4	6.8	0.5	8.0	0.0	7.3
117 lbs/ac	7.8	0.5	7.8	1.0	8.0	0.0	7.8
average	6.6	1.2	6.7	1.1	7.7	0.6	

1. The significance of nitrogen was .000, the significance of tillage x nitrogen was .324.

Table 9. The effect of tillage and nitrogen on plant height July 3, 1987, n=4.

	Tillage(<.000)						
	No Till		Disc		Moldboard		
Nitrogen[1]	mean	stdev	mean	stdev	mean	stdev	Avg
	feet						
16 lbs/ac	3.2	0.1	3.8	0.2	4.0	0.1	3.67
50 lbs/ac	3.4	0.1	3.8	0.2	4.0	0.1	3.71
83 lbs/ac	3.4	0.1	3.8	0.1	4.0	0.1	3.78
117 lbs/ac	3.4	0.1	3.8	0.1	4.0	0.2	3.72
average	3.4	0.1	3.8	0.2	4.0	0.1	

1. The significance of nitrogen was .014, the significance of tillage x nitrogen was .219.

Table 10. The effect of tillage and nitrogen on plant height August 9, 1987, n=4.

	Tillage(<.000)						
	No Till		Disc		Moldboard		
Nitrogen[1]	mean	stdev	mean	stdev	mean	stdev	Avg
	feet						
16 lbs/ac	7.7	0.2	8.2	0.2	8.2	0.1	8.02
50 lbs/ac	7.9	0.1	8.1	0.3	8.2	0.2	8.06
83 lbs/ac	7.9	0.3	8.2	0.2	8.3	0.3	8.15
117 lbs/ac	8.0	0.4	8.2	0.2	8.4	0.3	8.19
average	7.9	0.3	8.2	0.2	8.3	0.2	

1. The significance of nitrogen was .069, the significance of tillage x nitrogen was .542.

Table 11. The effect of tillage and nitrogen on yields of corn on October 1, 1987, n=4.

	Tillage(.000)						
	No Till		Disc		Moldboard		
Nitrogen[1]	mean	stdev	mean	stdev	mean	stdev	Avg
	bu/ac						
16 lbs/ac	146	8.4	170	16.6	190	12.0	168.8
50 lbs/ac	171	19.6	190	11.4	196	5.3	186.3
83 lbs/ac	189	13.7	188	10.7	207	8.5	195.1
117 lbs/ac	199	12.4	189	13.8	201	8.5	196.7
average	177	24.4	185	14.7	199	10.4	

1. The significance of nitrogen was .000, the significance of tillage x nitrogen was .009.

Table 12. The effect of tillage and nitrogen on harvest moisture on October 1, 1987, n=4.

	Tillage(.085)					
	No Till		Disc		Moldboard	
Nitrogen[1]	mean	stdev	mean	stdev	mean	stdev
	%					
16 lbs/ac	32.6	0.7	32.0	1.2	31.4	1.6
50 lbs/ac	33.1	1.4	32.0	0.6	31.9	1.0
83 lbs/ac	32.6	0.2	31.9	0.5	31.9	0.6
117 lbs/ac	32.5	0.3	33.1	2.1	31.9	0.6
average	32.8	0.8	32.3	1.3	31.8	1.0

1. The significance of nitrogen was .655, the significance of tillage x nitrogen was .770.

Table 13. The effect of tillage and nitrogen on stover harvest on October 1, 1987, n=4.

	Tillage(.000)						
	No Till		Disc		Moldboard		
Nitrogen[1]	mean	stdev	mean	stdev	mean	stdev	Avg
	ton/ac						
16 lbs/ac	3.3	0.3	3.8	0.2	4.0	0.6	3.72
50 lbs/ac	3.6	0.2	4.2	0.3	4.4	0.4	4.08
83 lbs/ac	3.9	0.2	4.1	0.3	4.7	0.3	4.25
117 lbs/ac	4.1	0.2	4.0	0.2	4.6	0.2	4.24
average	3.7	0.4	4.0	0.3	4.5	0.4	

1. The significance of nitrogen was .000, the significance of tillage x nitrogen was .147.

Table 14. The effect of tillage and nitrogen on final stand on October 1, 1987, n=4.

	Tillage(.254)					
	No Till		Disc		Moldboard	
Nitrogen[1]	mean	stdev	mean	stdev	mean	stdev
	plants/ac x 1000					
16 lbs/ac	28.4	0.88	28.2	1.27	28.2	0.49
50 lbs/ac	28.7	2.45	28.5	1.30	27.7	0.67
83 lbs/ac	29.0	0.92	27.7	2.02	29.3	0.96
117 lbs/ac	29.8	2.53	28.2	0.75	28.4	0.77
average	29.0	1.77	28.2	1.30	28.4	0.91

1. The significance of nitrogen was .705, the significance of tillage x nitrogen was .617.

Table 15. The effect of tillage on early corn growth, n=16.

Date	Sig. of Tillage	No Till mean	No Till st dev	Disc mean	Disc st dev	Moldboard mean	Moldboard st dev
		leaves/plant					
May 19	(.000)	0.00	0.00	0.16	0.24	0.41	0.20
May 20	(.065)	0.34	0.24	0.41	0.20	0.50	0.00
May 21	(.069)	0.44	0.17	0.50	0.01	0.51	0.05
May 22	(.036)	0.50	0.00	0.51	0.03	0.54	0.07
May 26	(.036)	1.31	0.09	1.39	0.14	1.42	0.11
May 27	(.284)	1.85	0.17	1.99	0.19	1.94	0.38
May 28	(.190)	2.39	0.07	2.41	0.12	2.28	0.34
May 29	(.087)	2.46	0.06	2.47	0.05	2.39	0.17
June 1	(.059)	3.40	0.12	3.48	0.05	3.37	0.17
June 2	(.091)	3.85	0.26	4.01	0.24	3.93	0.28
June 3	(.018)	4.23	0.16	4.38	0.11	4.26	0.19
June 4	(.053)	4.66	0.19	4.82	0.18	4.67	0.25
June 5	(.241)	4.80	0.23	4.92	0.20	4.80	0.23
June 8	(.201)	5.93	0.20	6.02	0.24	6.08	0.30
June 9	(.191)	5.93	0.20	6.03	0.24	6.08	0.30
June 10	(.000)	6.22	0.26	6.60	0.26	6.63	0.32
June 11	(.003)	6.60	0.24	6.86	0.20	6.88	0.28
June 12	(.003)	6.60	0.24	6.86	0.20	6.88	0.28
June 15	(.000)	7.84	0.25	8.14	0.37	8.31	0.35
June 16	(.000)	7.91	0.28	8.31	0.30	8.31	0.35
June 17	(.402)	8.95	0.39	8.89	0.48	9.13	0.58
June 18	(.440)	8.94	0.39	8.94	0.42	9.13	0.57
June 19	(.000)	9.46	0.41	10.06	0.44	10.14	0.48
June 22	(.000)	10.28	0.23	10.75	0.45	10.91	0.39
June 24	(.000)	11.09	0.35	11.76	0.58	11.98	0.51

EFFECT OF TILLAGE AND APPLICATION OF SWINE MANURE ON CORN YIELD

J.R.Joshi,J.F.Moncrief,J.J.Kuznia,and J.B.Swan

Cooperator: D.Nord

A study was initiated in 1987 to determine the effects of tillage and frequency of manure application on corn yield and nitrogen uptake. A second purpose was to determine the amount of N taken up from manure applied prior to the current cropping year.

Procedure. Liquid swine manure was injected annually, every alternate year (even and odd year) at two rates(5,775 and 11,550 gal/ac) on ridge till and chisel till treatments. Two additional treatments with one receiving 170 lb. N/ac of anhydrous ammonia and the other receiving none were established in both tillage treatments for comparison.

Since 1987 was the year of establishment for this experiment, the treatments for an odd year were in effect for this year. The different cultural practices and the amount of N in the form of liquid swine manure and anhydrous ammonia are described in Table 1 below. Table 2 summarizes the effects of the various treatments on grain yield and grain moisture. The chisel tilled treatments resulted in generally lower grain yields and lower grain moisture, although the difference is not all significant. This is an establishment year, all the plots were spring chiseled and ridges were formed on ridge till plots. The effects of tillage were thus less likely to be evident for this year.

GOODHUE COUNTY

Table 1. Cultural practices at Nords Farm, Goodhue County, Mn. 1987

Tillage

Ridge Till

Chisel Plow

This was the establishment year for this site and the plots were all disced then sub-soiled and disced again prior to planting.

Preceding Crop: Corn since 1974.

1987 Crop: Corn - Pioneer 3906

Fertilizer History

Crop	Material Analysis (Rate)	Actual N	Actual P_2O_5	Actual K_2O
		--	lbs/ac	---
Corn	7-21-7[1] (10 gal/ac)	8	25	8
	82-0-0 (146 lbs/ac)	120	0	0

1. Planter applied.

Planting and Harvest Date

Planter was Allis Chalmers 385 six row (30").

Crop	Date	Rate	Harvested
Corn	May 11,1987	28,000 plants/ac	Sept. 24, 1987

Soil

Soils at this site are Seaton (Typic Haplaudalfs, fine-silty, mixed, mesic) silt loam, Mt. Carroll (Mollic Hapludalfs, fine-silty, mixed, mesic) silt loam and a Port Bryon (Typic Haplaudolls, fine-silty, mixed, mesic) silt loam.

Fertilizer

Crop	Material	Rate	Actual Total N	Actual NH_4-N	Date Applied
			--- lbs/ac	---	
Corn	pig manure[1]	5,775 gal/ac	55	39	May 7, 1987
	pig manure[1]	11,550 gal/ac	111	77	May 7, 1987
	82-0-0[1]	207 lbs/ac	170	170	May 18, 1987

1. Materials applied to appropiate plots.

Weed Control 3 pts/ac Prowl + 2 lbs/ac Bladex 90 DF. Insect Control 6.9 lbs/ac Counter.

Table 2. Effects of tillage and amount of manure application on grain yield and moisture of corn at harvest.

		YIELD			MOISTURE		
		Tillage[1]					
Year		Ridge mean	Chisel mean	Average	Ridge mean	Chisel mean	Average
1987	Source and rate of N[2]	-------- bu/ac ---------			----------- % -----------		
	None	138.4	130.3	134.4	35.4	35.2	35.3
	anhydrous 170 lbs N/ac	171.8	163.4	167.6	36.2	36.6	36.4
	manure 55 lbs N/ac	151.9	151.0	150.5	35.0	34.6	34.8
	manure 110 lbs N/ac	163.2	152.2	157.7	34.3	34.0	35.2

1. Significance value due to tillage was 0.303 and .085 for grain yield and grain moisture, respectively.
2. Yields were highly significant due to N application for both grain yield and grain moisture.

Table 3. Effects of tillage and amount of manure application on silage dry matter yield and dry matter content of corn.

		YIELD			DRY MATTER		
		Tillage[1]					
Year		Ridge mean	Chisel mean	Average	Ridge mean	Chisel mean	Average
1987	Source and rate of N[2]	-------- ton/ac ----------			----------- % -----------		
	None	2.33	2.65	2.49	29.3	33.3	31.3
	anhydrous 170 lbs N/ac	3.02	3.02	3.02	29.3	28.6	29.0
	manure 55 lbs N/ac	2.57	2.50	2.54	29.7	29.1	29.4
	manure 110 lbs N/ac	2.65	2.78	2.72	29.9	32.1	31.0

1. Significance due to tillage was 0.242 for silage dry matter yield and .004 for dry matter, respectively.
2. Differences due to N source and rate highly significant (.00).

EFFECT OF TILLAGE AND FREQUENCY OF MANURE APPLICATION ON N UPTAKE AND CORN YIELD - 1985-87 SUMMARY

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A study was initiated in 1983 to determine the effects of tillage and frequency of manure application on corn yields and on N uptake. A second purpose of this study was to determine the amount and effect of nitrogen taken up from manure applied one or two years prior to the current cropping year.

<u>Procedure.</u> Liquid dairy manure is injected either annually, biennially or triennially on chisel plowed treatments and annually or biennially on no-till treatments. Yields are compared with check treatments which receive broadcast potassium but no nitrogen fertilizer. The results of this experiment for 1983-84 period are summarized in "Effect of Tillage and Frequency of Manure Application on N-uptake and Corn Yield - 1983-84 Summary" in the 1985 bluebook. Nitrogen and potassium uptake are measured and reference nitrogen measurements are made annually on selected plots.

This paper summarizes the results of the experiment for 1985-87 period. Table 1 provides the information on various cultural practices, soil type and cropping history of the research site for 1987. Most of these practices follow the same operations that were in effect in the earlier years.The results of soil analyses in terms of N in the form of NO3-N, NH4-N, and total N at 0-2 ft and 0-5 ft depths for various treatments in 1986 are summarized and analyzed in Tables 2-4 and those for 0-5 ft depth are presented in Tables 5-6. There are highly significant differences in soil NO3-N levels due to the frequency of manure application and by depth. Tillage differences in soil test values are expressed in generally lower values of NO3-N, NH4-N and total N for the no-till plots for each depth but do not appear to be significant statistically.

Tables 7-9 summarize the grain yield response for 1985, 1986 and 1987. The differences in the grain yields are highly significant due to tillage and N source and frequency of manure application for 1986 and 1987. This trend is also evident in the 1985 data. The grain moisture content appears to vary significantly with tillage and treatment in 1986 and by N source and frequency of manure application in 1987. Similarly, Tables 10-12 illustrate the differences in stover yield, stover dry matter and their significance for the three years. There are highly significant differences both in stover dry matter yield and content for the years 1986-87 due to N source and frequency. The 1985 data show similar trends.

Tables 13-14 summarize the amounts of the primary nutrients applied in the experiment as liquid dairy manure and the effects of various treatments in corn yields (for all the years the experiment has been set up). The amount of total nutrients, especially the different forms of N, varied from year to year. This may account for inconsistent results with some treatments for some years. In general, all the manure treatments resulted in significantly higher grain yields than the control. The yields were either comparable to or sometimes higher than those for the fertilized treatments. The average yields for the seven year experiment show that there is not much difference in yields obtained from manure applied annually or in the year of application to that of fertilized treatment. The yields in the year after the year of application were generally lower than the other manure treatments but certainly higher than the controls indicating considerable carry over from the previous years.

GOODHUE COUNTY

Table 1. Cultural practices at Fluegers Farm Goodhue County, Mn. 1987

Tillage
No Till
Chisel Plow - Chiseled on April 30,1987 and then with a soil finisher on May 6, 1987.

Preceding Crop
Corn since 1981.

1987 Crop
Corn - Pioneer 3906

Planting and Harvest Date
Planter was a Hinicker Econotill two row (38") equipped with 2 inch fluted coulters.

Crop	Date	Rate	Harvested
Corn	May 7,1987	30,000 plants/ac	Sept. 14, 1987

Manure Application
Injected 9200 gal/ac liquid dairy manure with the following analysis in 1987.

Crop	NH4-N	Total-N	P	K
	---------	lbs/ac	-------------	
Corn	152	341	91	315

Fertilizer

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			--	lbs/ac	--	
Corn	0-0-60[1]	330 lbs/ac	0	0	198	April 16, 1987
	7-21-7[2]	15 gal/ac	12	37	12	May 7, 1987

1. Surface applied to specified plots.
2. Applied 2" beside and 2" below seed.

Insect Control 6.9 lbs/ac Lorsban 15G.

Soil
Timula (Typic Eutrochrepts, coarse-silty, mixed, mesic) silt loam, 2 to 6 percent slope. Soil is well drained.

Weed Control
3 qts/ac Lasso + 2lbs/ac Atrazine + + 1 1/2 qts/ac Roundup on May 12, 1987.

Table 2. The effect of tillage, frequency of manure application on NO_3^--N (lbs/ac) NH_4^+-N (lbs/ac) and total mineral nitrogen (lbs/ac) in April 1986.

N Source & Frequency	Depth (ft)	Nitrate-Nitrogen (NO_3) No Till mean	st dev	Chisel mean	st dev	Ammonium-Nitrogen(NO_3^-+NH_4) No Till mean	st dev	Chisel mean	st dev	Total-Nitrogen (NO_3+NH_4) No Till mean	st dev	Chisel mean	st dev
		----------	----------	----------	----------	----------	lbs/ac	----------	----------	----------	----------	----------	----------
Ammonium	0-2	96.2	59.0	83.1	33.2	31.4	23.3	36.2	17.1	128	58.5	119	37.5
Nitrate	2-5	183	45.3	197	61.3	27.0	27.0	21.9	16.3	210	47.1	218	58.0
Check	0-2	16.1	4.5	27.7	9.8	42.6	26.7	36.4	37.1	58.7	25.5	64.1	36.2
	2-5	4.7	4.2	16.5	17.9	15.2	14.8	17.8	10.0	19.4	9.7	34.2	8.9
Annual	0-2	39.3	15.1	35.8	10.8	22.5	12.8	44.5	23.2	61.8	6.7	80.3	33.9
	2-5	23.8	16.5	38.8	10.2	22.1	11.1	23.8	22.6	45.9	9.5	62.7	23.8
Biennual-82	0-2	19.6	4.6	26.7	4.3	22.3	6.4	26.2	7.0	42.3	5.2	52.9	5.1
	2-5	5.5	0.4	11.4	1.6	21.9	8.8	15.5	7.3	27.4	8.6	27.0	6.6
Biennual-83	0-2	28.1	8.5	44.2	26.2	38.6	25.2	18.7	6.4	66.6	26.3	62.9	20.5
	2-5	18.4	10.6	21.9	7.7	28.2	28.2	18.5	6.7	46.7	20.3	40.3	14.0
Triennual-82	0-2			26.0	10.6			22.1	4.3			48.1	6.3
	2-5			20.8	9.1			19.1	7.8			39.8	10.7
Triennual-83	0-2			18.2	2.7			24.0	6.2			42.2	6.5
	2-5			8.8	3.3			17.8	11.0			26.6	8.7
Triennual-84	0-2			23.6	8.3			44.2	35.5			67.9	42.1
	2-5			6.0	4.1			39.6	34.3			45.6	38.4

1. Manure treatments are defined as follows: Annual, Biennual and Triennual refer to the frequency of manure application, and the year refers to date of initiation.

Table 3. The significance of an F-test for treatment effects on NO_3^--N, NH_4^+-4 and total mineral nitrogen for no till and chisel plow, excluding triennual treatments from analysis for April 1986.

N Source & Frequency	Till.	Trt.	Depth	TilxTrt	TilxDep	Trtxdep	TilxTrtxDep
NO_3^--N	.497	.000	.014	.193	.178	.000	.554
NH_4^+-N	.906	.999	.038	.810	.688	.820	.758
Tot-N	.490	.000	.026	.384	.669	.000	.564

Table 4. The significance of an F-test for treatment effects on NO_3^--N, NH_4^+-4 and total mineral nitrogen for chisel plow in April 1986.

N Source & Frequency	Trt.	Depth	Trt x depth
NO_3^--N	.000	.016	.003
NH_4^+-N	.760	.019	.921
Tot-N	.000	.017	.004

Table 5. The effect of tillage, chemical and frequency of manure application on NO_3^--N, NH_4^+-4 and total mineral nitrogen from 0-5 feet (lbs/ac) in April 1986.

N Source & Frequency	Source of Nitrogen	Tillage: No Till mean	No Till st dev	Chisel mean	Chisel st dev
Chemical	NO_3^--N	280	87.4	280	83.3
	NH_4^+-N	58.4	49.9	58.1	30.4
	Tot-N	338	90.2	338	81.1
Check	NO_3^--N	20.9	8.5	44.2	27.6
	NH_4^+-N	57.8	29.2	54.1	38.4
	Tot-N	78.1	24.5	98.3	33.7
Annual	NO_3^--N	63.1	26.1	74.6	2.5
	NH_4^+-N	44.6	15.8	68.4	27.5
	Tot-N	108	15.9	143	26.7
Biennual-82	NO_3^--N	25.1	4.8	38.1	4.5
	NH_4^+-N	44.6	3.0	41.8	14.2
	Tot-N	69.7	5.1	79.9	10.1
Biennual-83	NO_3^--N	46.5	19.1	66.1	29.3
	NH_4^+-N	66.8	28.8	37.2	7.8
	Tot-N	113	13.1	103	30.7
Triennual-82	NO_3^--N			46.8	12.7
	NH_4^+-N			41.2	12.0
	Tot-N			88.0	5.9
Triennual-83	NO_3^--N			27.0	2.6
	NH_4^+-N			41.8	11.1
	Tot-N			68.8	12.7
Triennual-84	NO_3^--N			29.7	11.2
	NH_4^+-N			83.8	69.8
	Tot-N			113	80.2

1. Manure treatments are defined as follows: Annual, Biennual and Triennual refer to the frequency of manure application, and the year refers to date of initiation.

Table 6. The significance of tillage, treatment and applicable interactions on NO_3^--N, NH_4^+-4 and total mineral nitrogen from 0-5 feet (lbs/ac) in April 1986.

N Source & Frequency	Analysis of No Till & Chisel: Till.	Trt.	Till. x Trt.	Analysis of Chisel Treatment
NO_3^--N	.584	.000	.273	.000
NH_4^+-N	.899	.978	.451	.678
Tot-N	.573	.000	.552	.000

Table 7. The effect of tillage, frequency of manure application and potassium application on grain yields.

		Tillage					
		No Till			Chisel		
N Source &	K_2O	1985	1986	1987	1985	1986	1987
Frequency	lbs/ac			bu/ac			
Check	200	128.3	55.3	62.3	77.5	89.4	102.7
Annual	0	146.8	154.0	166.1	149.5	150.0	155.0
	200	140.6	140.0	162.3	152.4	150.0	168.5
Biennual-82	0	115.4	146.0	150.3	120.2	154.0	144.7
	200	102.3	147.0	116.5	113.1	148.0	134.6
Biennual-83	0	131.1	104.0	168.2	146.4	134.0	158.8
	200	145.7	107.0	169.4	152.9	109.0	168.1
Triennual-82	0				138.6	120.0	108.9
	200				137.0	107.0	90.4
Triennual-83	0				101.8	147.0	136.7
	200				80.2	145.0	122.2
Triennual-84	0				108.3	113.0	157.9
	200				124.8	92.3	170.7

Table 8. The effect of tillage, frequency of manure application and potassium application on grain moisture.

		Tillage			
		No Till		Chisel	
N Source &	K_2O	1986	1987	1986	1987
Frequency	lbs/ac		%		
Check	200	34.1	30.2	32.2	27.9
Annual	0	31.6	30.5	32.0	30.3
	200	32.0	31.0	32.4	32.3
Biennual-82	0	32.6	30.4	31.8	30.7
	200	32.6	31.8	32.0	30.6
Biennual-83	0	33.5	27.5	30.6	29.9
	200	32.3	29.4	31.4	29.6
Triennual-82	0			33.8	31.5
	200			32.7	30.7
Triennual-83	0			31.7	29.7
	200			31.4	29.3
Triennual-84	0			32.0	29.1
	200			32.7	29.2

1. Manure treatments are defined as follows: Annual, Biannual and Triannual refer to the frequency of manure application, and the year refers to date of initiation.

Table 9. The significance of tillage, treatment and applicable interactions on grain yield and grain moisture for 1986 and 1987.

		Analysis of No Till & Chisel			Analysis of Chisel
Variable	Crop Year	Till.	N Rate and Frequency	Till. x N Rate and Frequency	Treatment
grain yield	1986	.002	.000	.001	.000
	1987	.015	.000	.000	.000
moisture	1986	.006	.036	.014	.013
	1987	.512	.000	.026	.000

Table 10. The effect of tillage, frequency of manure application and potassium application on stover yield.

		Tillage					
		No Till			Chisel		
N Source &	K_2O	1985	1986	1987	1985	1986	1987
Frequency	lbs/ac	ton/ac					
Check	200	2.25	1.27	1.52	2.17	1.88	2.02
Annual	0	2.37	2.48	2.59	2.28	2.56	2.63
	200	2.42	2.69	2.75	2.53	2.59	2.80
Biennual-82	0	1.90	2.21	2.25	1.94	2.17	2.58
	200	1.89	2.51	2.15	2.14	2.09	2.40
Biennual-83	0	2.19	1.59	2.45	2.14	2.45	2.47
	200	2.40	1.88	2.60	2.38	2.25	2.56
Triennual-82	0				2.22	1.75	2.00
	200				2.17	2.07	1.98
Triennual-83	0				1.63	2.18	2.20
	200				1.62	1.93	1.89
Triennual-84	0				1.64	1.81	2.47
	200				1.97	1.83	2.64

Table 11. The effect of tillage, frequency of manure application and potassium application on % dry matter of stover.

		Tillage			
		No Till		Chisel	
N Source &	K_2O	1986	1987	1986	1987
Frequency	lbs/ac	%			
Check	200	40.4	35.6	40.0	37.5
Annual	0	38.1	34.8	37.0	34.7
	200	36.3	32.5	34.4	31.4
Biennual-82	0	31.4	37.9	37.2	40.1
	200	33.6	33.9	32.8	31.6
Biennual-83	0	44.5	39.7	42.7	36.1
	200	39.6	34.2	38.6	33.7
Triennual-82	0			39.2	39.1
	200			39.2	34.9
Triennual-83	0			39.4	39.8
	200			36.4	36.6
Triennual-84	0			49.3	40.6
	200			42.2	35.1

1. Manure treatments are defined as follows: Annual, Biennual and Triennual refer to the frequency of manure application, and the year refers to date of initiation.

Table 12. The significance of tillage, treatment and applicable interactions on stover yield and dry matter for 1986 and 1987.

		Analysis of No Till & Chisel			Analysis of Chisel
Variable	Crop Year	Till.	N Rate and Frequency	Till. x N Rate and Frequency	Treatment
stover yield	1986	.183	.001	.107	.492
	1987	.257	.000	.001	.001
dry matter	1986	.813	.004	.479	.001
	1987	.097	.000	.001	.002

Table 13. The amount of N, P_2O_5, and K_2O applied as liquid dairy manure from an anaerobic pit.

	1983	1984	1985	1986	1987	Average
	lbs/ac					
NH_4	148	171	137	204	152	164
Total N	260	347	292	251	341	298
P_2O_5	76	84	69	67	91	77
K_2O	233	274	266	189	315	274
Rate (gal/ac)	9,100	10,700	9,300	9,200	9,200	9,500

Table 14. The effect of frequency of manure application and tillage on corn yields on a Timula silt loam soil (Typic Eutrochrept) in Goodhue County, Minnesota.

	1983		1984		1985		1986		1987		Average	
	NT	Ch	NT	Ch	NT	Ch	NT	Ch	NT	Ch	NT	Ch
	bu/ac											
Fertilizer[1]	121	130	154	160	134	149	151	149	160	164	145	151
Annual	126	134	143	162	147	149	153	149	166	154	147	149
Yr. of app.	124	113	154	154	132	145	145	153	168	158	145	145
Yr. after	104	124	98	137	115	121	104	134	149	145	112	132
Control	55	90	66	85	62	77	55	89	62	103	60	89