SOIL SERIES 114

A REPORT ON FIELD RESEARCH IN SOIL SCIENCE

The 1984 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 SEA-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 county agents, farmers, technical assitants, 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 1983 experiments only and should be regarded on this basis. Since most data are from only 1983 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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The Northward "Speed" of Spring

Earl L. Kuehnast, Donald G. Baker, and James Zandlo

The end of freezing atmospheric conditions in the spring results in dramatic changes at the earth's surface. Warmer air temperatures together with the increasing length of day and the attendant increase in available solar energy, eventually eliminate the snow cover. Once that stage is reached, soils and lake surface no longer have the insulative cover that snow provides. Thus snow-end date, ice-out day, and end of frozen soil have an expected correlation. However, the exact juxtaposition of these events in time, along with other factors such as total winter snow and soil moisture amounts, can produce widely varying consequences for residents of Minnesota. This complex of events has impacts on spring runoff and lake recharge as well as on soil and curface moisture and temperature conditions as related to agriculture and forestry. An iso-line map of "mean lake ice-out date" for a 20-year period, 1960-1979, is shown in Figure 1. The "ice-out date" was collected from 19 lakes generally with depths greater than 20 feet. These 19 lakes are distributed across the state and listed in Table 1. Lake ice-out data were in the most part collected by the Department of Natural Resources fisheries staff and field personnel and in general procured from reports in local newspapers. The observation of the "ice-out date" is subject to some error, probably of a day or so, due to the various methods of observing ice-out. For example, some observers wait until all of the ice has disappeared, others look for no ice between two pre-selected points of land, and some use a percentage of the ice melted, such as 90 percent, as the criterion.

The mean ice-out date of lakes moves progressively northward. Beginning on April 15 it is in the Twin Cities area and by May 5 it has moved into Canada. From this it can be calculated that "spring" moves northward from the Twin Cities at a rate of about 13 to 14 miles per day.

The "movement" of spring may also be monitored by examining the progression of isotherms northward. The mean daily air temperature on the mean date of ice-out for the Minneapolis-St. Paul area is 45°F. This mean 45°F isotherm can be found in Springfield, Missouri, on March 22 and in International Falls on May 2, which is close in time to the ice-out date there. Thus "spring" moves northward from Springfield to Minneapolis-St. Paul at a rate of 22 miles per day (525 miles in 24 days) and then northward from Minneapolis-St. Paul at a rate of about 16 miles per day (266 miles in 17 days). The decrease in the northward rate of movement of the 45°F air temperature line from Missouri to the Canadian Border is most probably due to the additional energy needed to melt the heavier snow cover in the forested area of central and northern Minnesota.

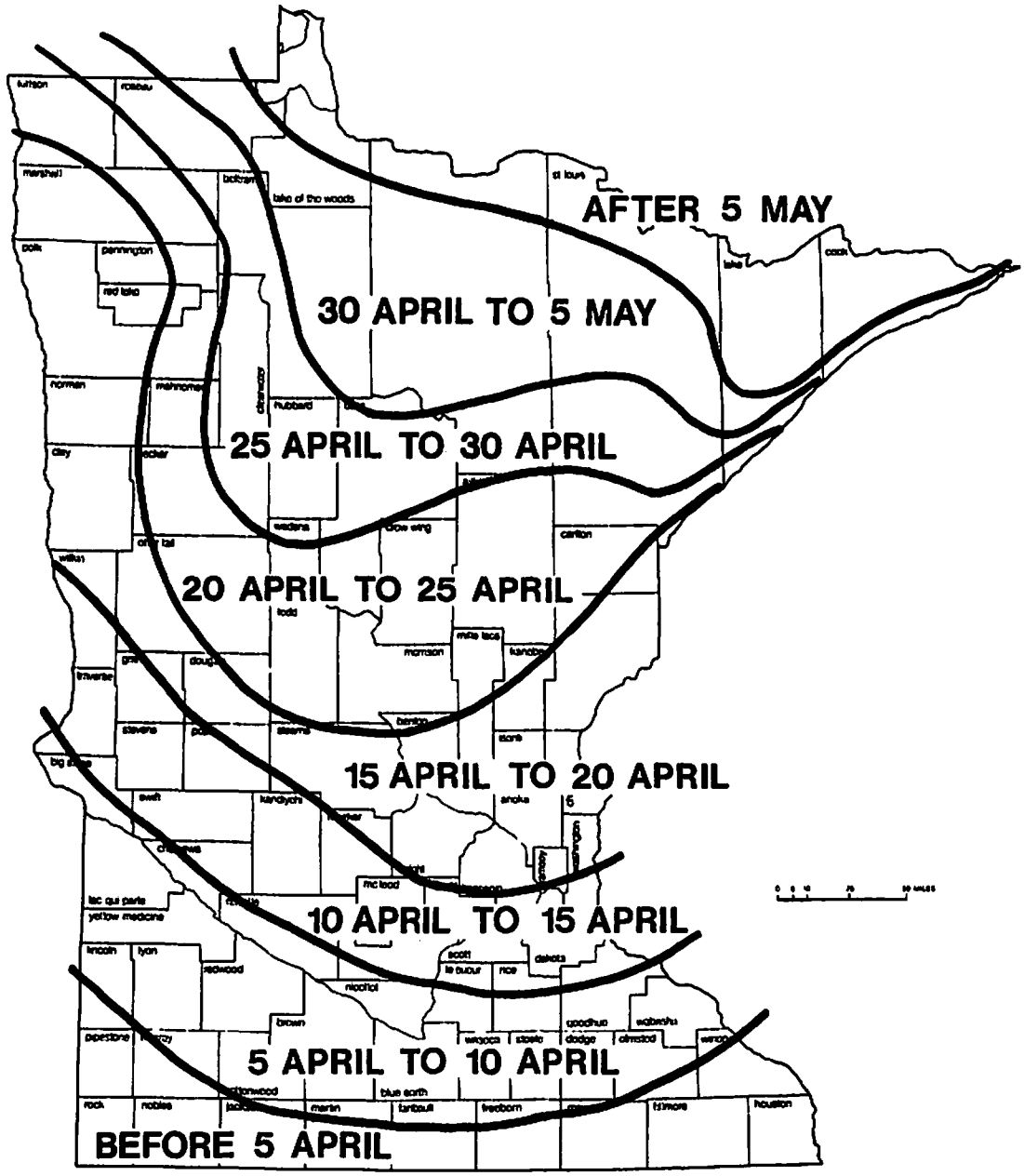
Five lakes - Minnetonka, Minnewaska, Osakis, Detroit and Vermilion - all with more than 70 years of ice-out information, show 1950 as the year with latest ice-out date and 1965 as the next latest. The years with the earliest ice-out dates were 1910, 1945, and 1981. However, old Fort Snelling temperature records dating back to 1819 show the winter of 1877-1878 as the warmest to date. The 1878 newspapers of that spring recorded Lake Minnetonka ice-out on March 11. The average range in dates between the earliest and latest ice-out date is approximately 40 days. The southern Minnesota lakes do not follow these ice-out patterns as well because the lakes are small and shallow, the area is subject to more southerly warm air advection, and the area has less snow cover. All of these factors permit the absorption of more solar radiation and heat energy than where there is a heavier snow cover to the north.

Table 1. Mean ice-out dates at selected lakes, 1959-1979.

Lake	County	Mean Ice-Out Date	Lake	County	Mean Ice-Out Date
Big Stone Lake	Big Stone	10 April	Lake Minnewaska	Pope	15 April
Clear Lake	Waseca	8 April	Lake Osakis	Todd-Douglas	22 April
Crane Lake	St. Louis	*5 May	Ox Lake (big)	Crow Wing	23 April
Detroit Lake	Becker	24 April	Shetek	Murray	8 April
Gull Lake	Cass-Crow Wing	23 April	Sandy Lake	Aitkin	21 April
Gunflint Lake	Cook	9 May	Sissaton	Martin	5 April
Leech Lake	Cass	29 April	Vermilion	St. Louis	2 May
Mille Lacs Lake	Mille Lacs	*25 April	Waconia	Carver	14 April
Lake Minnetonka	Hennepin	15 April	White Bear	Ramsey	16 April
Lake of the Woods	Lake of the Woods	*9 May			

* Estimated by local residents when less than 20 years of data were available.

FIGURE 1.


AFTER 5 MAY
30 APRIL TO 5 MAY
25 APRIL TO 30 APRIL
20 APRIL TO 25 APRIL
15 APRIL TO 20 APRIL
10 APRIL TO 15 APRIL
5 APRIL TO 10 APRIL
BEFORE 5 APRIL

Hydrologic Year Precipitation
(October 1982 - September 1983)

Earl L. Kuehnast and Donald G. Baker

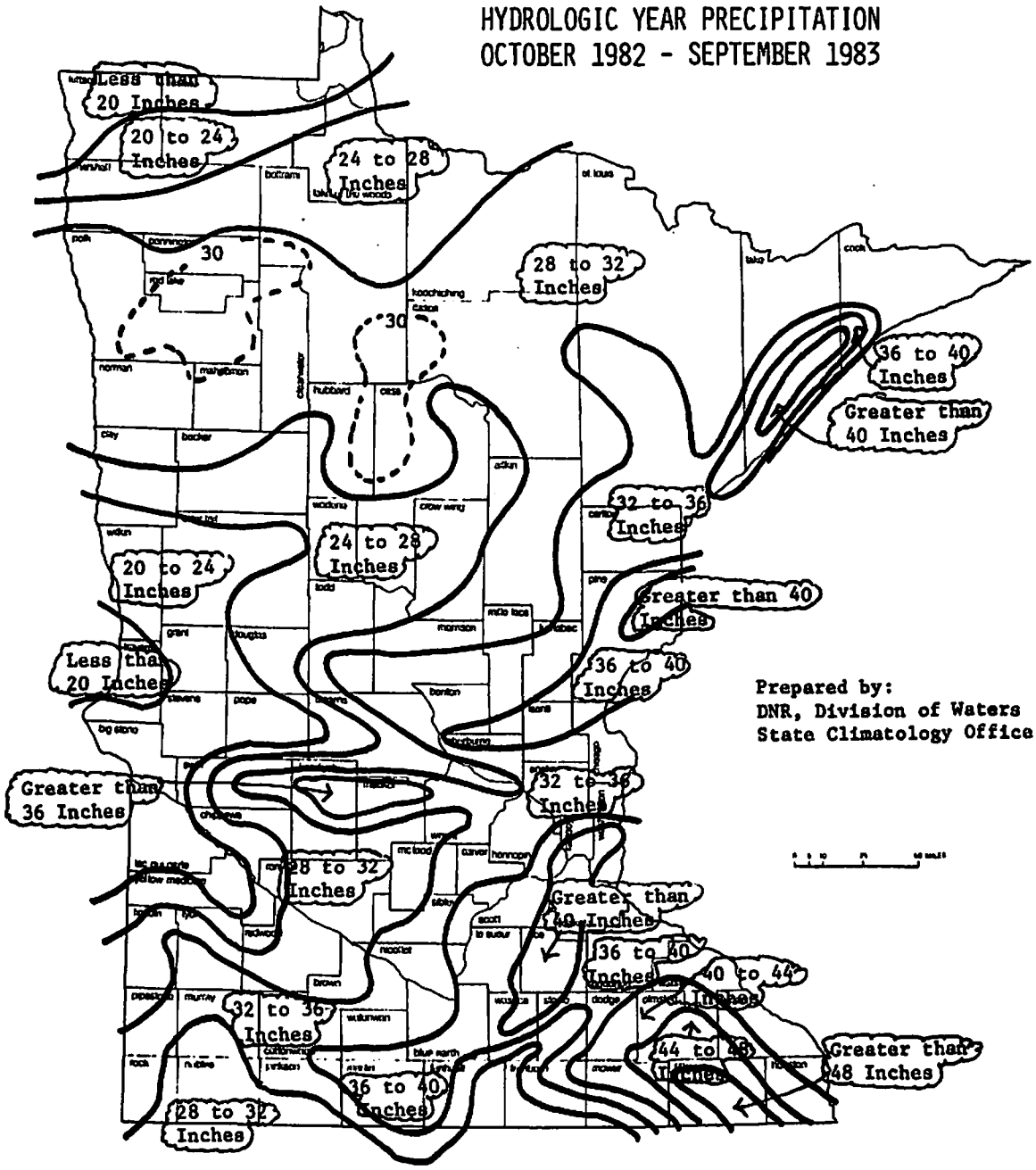
The custom has alwasy been to view climatic data, such as precipitation, on a calendar year basis. For some years the hydrologists have considered a more appropriate period for water supplies to be the October-September period. For example, rivers and streams ordinarily reach their lowest levels about in October, and only after supplies are replenished by late autumn rain and over-winter precipitation do rivers and lakes show increases.

For agriculture, too, the calendar year of January - December does not coincide with the water supply year. Our soil moisture measurements have shown that in most years the soils under full season crops reach their minimum water content in late August or early September. After this date the precipitation is ordinarily greater than the crop requires and soil reserves begin to be replenished. These replenished reserves are then available to the succeeding year's crop. As a result crop yields are more directly related to the September (or October) - August (or September) precipitation rather than that of the calendar year.

For this reason we are showing the October 1982 - September 1983 period in Figure 2. The excessive precipitation of the south-central and eastern part of the state is very apparent. The smallest amount recorded was at Caribou in northern Kittson county with but 15.52 inches and the highest was at Preston in Fillmore county with 51.67 inches.

The average hydrologic year precipitation for the state as a whole is 25.55 inches. For this latest hydrologic year it was 31.27 inches or 5.72 inches above average. The very wet areas across the state were: all of the Southeast District with central Fillmore county receiving 23-26 inches above average; parts of the South-Central District from Martin County northeastward; the Central District from western Kandiyohi east into Wright and Sherburne counties; then generally northeast into the East Central District through Isanti and Pine counties; then another very wet area beginning in the Northwest District in Polk and Norman counties extending eastward through Pennington, Red Lake, and Clearwater counties and parts of Beltrami, Hubbard, Cass and Itasca counties. The only areas of near average precipitation were a small strip in the northwest along the Canadian border and most of the West Central District.

FIGURE 2.
HYDROLOGIC YEAR PRECIPITATION
OCTOBER 1982 - SEPTEMBER 1983



Soil Moisture Situation, Spring 1984

Donald G. Baker, Earl L. Kuehnast, and David Ruschy

This situation report is from a mathematically modeled soil moisture analysis that is based on more than 700 precipitation station data. The model estimates the amount of plant-available water that is contained within a 5-foot column of medium to fine textured soil. The indicated results should be adjusted according to whether the actual soil within a given area can hold more (a heavy or clay soil) or less (a light or sandy soil) than the basic 10 inches.

Almost all areas of the state entered the 1983-84 winter with the soils very high in soil moisture. Indeed the soils as of November 1, 1983, are at about the highest moisture content of the last 15 years as shown in Figure 3. Other years in which the soils entered the winter with high fall soil moisture were 1968, 1979, 1981, and 1982. This means that the state will have had four wet spring conditions in the last five years.

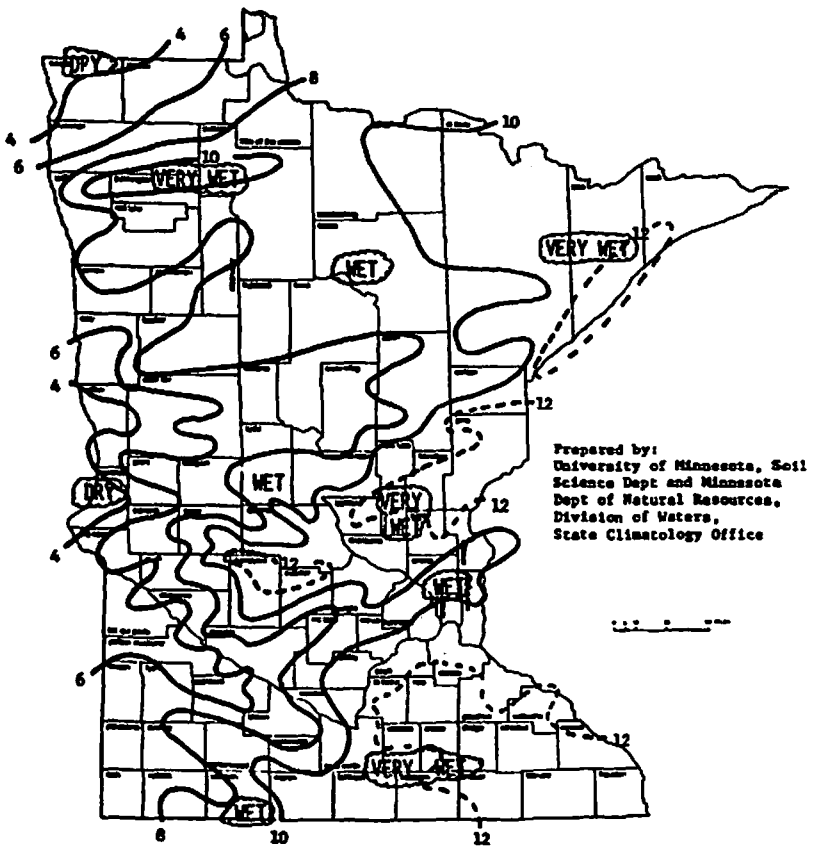
Areas with 10-inches of soil moisture on the map are considered to be at or near their maximum water holding capcity. Soils in the 8 to 10 inch areas should also be near maximum capacity this spring after the winter snow melt and the spring rain. Thus, all of Minnesota except the western 20 or 25 percent is expected to have soils at their maximum capacity this spring. The only areas expected to have a normal to less than normal water content are Kittson, Traverse and Wilken and parts of Redwood, Lyon, Yellow Medicine, Lac Qui Parle, Big Stone, Stevens, Grant, Ottertail, Clay, Marshall and Roseau counties.

The 1984 spring soil water outlook is very similar to the spring of 1983. The important difference between the two years is the early, heavy, and continuous snow cover amounting to anywhere from 10 or more than 20 inches that occurred across the state during the last eight days of November, 1983. This created a most unusual condition. The insulating blanket of snow has reduced the heat loss from the soils to such an extent that over more than two-thirds of the state there is virtually no frost in the soil, Figure 4. Exceptions are found in southwestern Minnesota as far east as Nicollet, Blue Earth, and Martin counties with 6-18 inches of frost. Extending northward along the North and South Dakota border in a band about 50-75 miles wide from approximately Lac Qui Parle county to the Canadian border, the frozen soil is from 18 to 48 inches deep.

At St. Paul, where a long soil temperature record exists, the snow cover since late November has remained greater than 10 inches for much of the winter. As a result the soil has remained above 32°F at all levels. Under average winter conditions the soil at St. Paul would be frozen to 42 inches in mid February and reach a maximum depth of 44 inches in the first week of March.

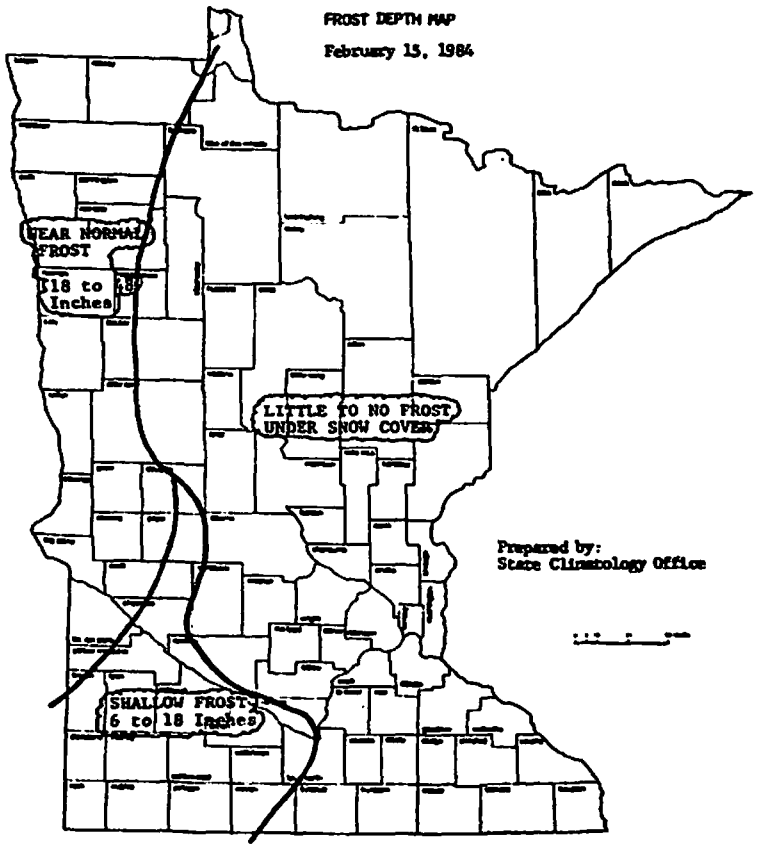
There are several important consequences arising from the deep and persistent snow cover and the shallow or non-existent soil frost. One is that a greater than average amount of snowmelt runoff in the spring can enter the soil - except in those areas where the soil is already wet. In the areas of well-drained and tiled soils much of the water will percolate into the lower profile or the tile drains and therefore should not be a factor in planting with normal spring weather. Areas of poorly drained soils with high moisture and little or no frost will experience a delayed planting season due to excessive moisture in the soil profile unless a drier than usual spring occurs.

Figure 3.



Plant available soil moisture on November 1, 1983 expressed in inches for the top five feet of medium to fine textured soils. Data derived from a soil moisture model based on precipitation from more than 700 weather stations.

Figure 4.



The Modification of Evapotranspiration Calculation Methods to Minnesota Conditions

Brenton S. Sharratt and Donald G. Baker

The monitoring of crop water use is not only important in terms of conserving water but also energy, since it assumes increasing importance as a dollar input when irrigation is practiced. The purpose of this study was to modify empirical evapotranspiration calculation methods that were developed in other regions so they could be used with confidence in Minnesota.

Alfalfa (Medicago Stiva L. "Blazer") was the crop grown on the agricultural weather station on the St. Paul campus of the University of Minnesota. The plot can be irrigated when desired, and there is a precision weighing lysimeter on the plot which permits determination of the water loss from the soil and alfalfa.

The weighing lysimeter consists of a heavy-gauge steel box that contains soil and in which the crop is grown. The surface area of the lysimeter is 30 sq. ft. and it measures 4 ft. deep. The lysimeter is surrounded by a plot of alflafa. The dimensions of the lysimeter are such that its contents - soil, soil moisture, and the crop - weigh more than 7 tons. The lysimeter is resting on a modified truck scale which is counterbalanced so that it becomes a precision scale. It is capable of detecting weight changes that are equivalent to the addition or subtraction of less than 0.001 in. of water.

The weighing lysimeter recording system provides an hourly output of the weight of the tank and its contents. This whole apparatus and system was used to determine the water consumed (the evapotranspiration) by the alfalfa crop. At the same time various meteorological parameters were also measured at the agricultural weather station.

Two evapotranspiratioon calculation methods were compared to the measured evapotranspiration. They were the Blaney-Criddle method and the Jenson-Haise method. The former requires only average daily air temperature and the latter requires daily total solar radiation and average daily temperature. A total of 64 days was available for the comparison in which no rain or irrigation occurred and no adjustments to the weighing lysimeter were required during the years 1981-1983. The alfalfa was planted in 1980 and it had been preceded by 4 years of soybeans. The lysimeter was installed in 1975.

Results indicate that the Jenson-Haise method did the better job of predicting water use of the alfalfa as shown in Table 1.

Table 1. Comparison of Two Evapotranspiration Calculation Methods.

Average Daily Water Use	Average Daily Difference Jenson-Haise	Average Daily Difference Blaney-Criddle
0.297 in.	0.084 $^{+}$ 0.057 in.	0.089 $^{+}$ 0.070 in.

The correlation between the calculated and measured data over the 3-year period was 0.87 and 0.77 for the Jenson-Haise and the Blaney-Criddle methods, respectively.

Based upon the measured data the Jenson-Haise calculation method was modified to:

$$\text{Potential Evapotranspiration} = (0.014\ T^{1} - 0.132)\ (SR)$$

where T^{1} is the average daily temperature and SR is the daily total solar radiation.

References:

Soil Conservation Science. 1979. Irrigation water requirements. U.S. Dept. Agric. Eng. Div., Tech. Release 21.

Jenson, M.E., and H.R. Haise. 1963. Estimating evapotranspiration from solar radiation. Amer. Soc. Civil Eng. Proc., Jour. Irrig. and Dain. Div. 89(IR-4):15-41.

INFLUENCE OF NITROGEN FORM, NITROGEN RATE, TIMING OF NITROGEN APPLICATION AND NITRIFICATION INHIBITORS FOR IRRIGATED CORN - BECKER, MN 1983

G.L. Malzer and T. Graff

Nitrogen management on the coarse textured irrigated soils of Minnesota is a major decision that all corn growers must make in their production system. Nitrogen management includes many aspects of nitrogen fertilization such as rates, forms, methods, times, equipment, and additives. Nitrogen fertilizer application is an essential component for top yields on these coarse textured soils, and many times the producer does not have the flexibility in nitrogen management that a producer on a finer textured soil might have. The use of nitrification inhibitors under irrigation also presents some new nitrogen management techinques that should be considered. The most common method for application of nitrification inhibitors is with simultaneous application of anhydrous ammonia. Under irrigation, nitrogen application may take place in several manners, ranging from one single application to multiple application, which may be facilitated through the irrigation water. With such management systems a variety of fertilizer nitrogen forms may be utilized. These management alternatives often add to the cost of production and require a reasonable amount of timeliness to avoid yield reductions. A new trial was established in 1982 to evaluate the significance of nitrogen rates, nitrogen form, timing of nitrogen application and the use of nitrification inhibitors for irrigated corn production.

Experimental Procedures

An experiment consisting of 25 treatments, with four replications was arranged in a randomized complete block design and established at the Sand Plain Research Farm near Becker, Minnesota. Variables in the experiment consisted of three nitrogen rates (0, 75, 150 #N/A), three nitrogen sources (anhydrous ammonia, urea and 28% nitrogen solution), two types of application (preplant or sidedress at 10-leaf growth stage) and three nitrification inhibitors (none, N-Serve and DCD). Due to the different types and rates of material utilized, the experiment was not conducted in a complete factorial arrangement. Modifications include: 1) Nitrification inhibitor treatments were applied only with preplant N applications; 2) only 28% N solutions and anhydrous ammonia were applied as sidedress N application; 3) N-Serve applications were made at 0.5 lbs. a.i./a rate of application; 4) the DCD treatments were applied as a percentage of the total N applied. Urea and 28% N solution were applied at rates of 10% DCDN while anhydrous ammonia was applied at a rate of 2.5% and 5% N as DCD. Urea was supplied by SKW containing 10% DCDN, applications of DCDL were made to 28% N solution and DCDG to anhydrous ammonia to obtain the appropriate concentration of DCDN.

Prior to planting, broadcast application of potassium-magnesium sulfate (300 #/a 0-0-22), potassium (225 #/a 0-0-60), and phosphorus (90 #/a 0-46-0) were made and incorporated by plowing. Nitrogen applications were made prior to planting (May 3rd) and at the 10-leaf stage of growth (June 23rd). Corn (Pioneer 3906 - 95 day maturity) was planted on June 4th in 30" rows at a population of 30,700 seeds/a. Starter fertilizer was applied at the rate of 165 #/a 8-10-30 side banded at planting. The insecticide Lorsband was banded at planting at the rate of 7#/a. A tank mix of Atrazine (2# ai/A) and Lasso (1½ #ai/A) was applied on May 4th for weed control.

Leaf samples from opposite and below the ear at mid-silking were obtained on July 21st, dried and analyzed for Kjeldahl nitrogen. Total dry matter production and final yields were determined on September 19th by hand harvesting 100 ft.^{2} of plot area. Ears were separated from the stalks, field weights of each obtained, and samples removed for moisture and nitrogen determination. Grain yields were adjusted to 15.5% moisture.

The irrigation program was started on July 8th and continued through August 25th with a total 10.31 inches being applied through irrigation. An additional 23.35 inches of water obtained during the growing season through rainfall. Over one-half of the growing season precipitation was obtained during the month of June. Over one-half of the June precipitation was obtained on June 20-21st.

General Results

The experimental results and statistical analysis are presented in Tables 1 and 2. Due to the incomplete factorial nature of the treatments the statistical analysis was conducted utilizing several different combinations of the treatments. The different methods included: 1) mean comparison of the 25 treatments, and factorial combinations including 2) two nitrogen rates with three nitrogen forms with and without N-Serve, 3) two N rates with two N forms applied at two

different times of application, 4) two N rates with four nitrification inhibitor treatments applied with anhydrous ammonia, and 5) two N rates with three nitrification inhibitor treatments with urea.

The information included in Tables 1 and 2 present information regarding grain, stover, and total dry matter production as well as nitrogen concentrations within the plant parts and N removal. This brief discussion will include evaluation of only grain yields.

The leaching losses of nitrate-N associated with early spring applications were extremely severe at this location in 1983. This is primarily the result of the major precipitation event that occurred approximately six weeks after the early nitrogen applications. This time period allowed for substantial nitrification of ammonium-N to nitrate-N so relatively large quantities of nitrate were lost by leaching. The extent of N loss on yield reduction can be evaluated by comparing the yields associated with preplant N applications with treatments applied at the 10-leaf stage of growth.

Nitrogen rate - Grain yields was significantly increased up through the highest rate of N application (150 #N/a). The factorial combinations for grain yield indicated significant interactions for N-rate x form x time and N rate x inhibitor with anhydrous ammonia. The first interaction would suggest that when N was applied at the low rate delayed application of anhydrous ammonia were superior to 28% N solution application, but at the higher rate of N application the delayed applications produced similar yields. The second interaction for grain yield (N-rate x inhibitor with anhydrous ammonia) would suggest that DCD was more effective in stopping nitrogen loss at the low N rate than was N-Serve, while at the high N rate both inhibitors provided significant yield increases.

Nitrogen Form - When nitrogen losses are minimal, different N fertilization materials tend to provide similar results. However, in 1983 leaching losses were very severe. Under the conditions anhydrous ammonia was superior to the other nitrogen materials. Broadcast forms of fertilizer N such as urea and 28% solution produced similar results. Although urea is 100% ammonium forming, it is possible that differential nitrification may take place due to the method of application (broadcast incorporated vs. injected).

Nitrification inhibitors - All nitrification inhibitors tested provided significant positive yield increases. At the low nitrogen rate (75 #N/A) N-Serve provided a yield increase only when it was used with 28% N solution. The product DCD provided significant yield increases at the low N rate for all three fertilizer products tested. At the higher N rate (150 #N/a) both nitrification inhibitors provided significant yield increases with all fertilizer materials. With anhydrous ammonia, N-Serve and DCD produced similar results. With 28% N solution and urea, DCD was superior to N-Serve.

Table 1. Influence of nitrogen form, nitrogen rates, nitrification inhibitors, timing of nitrogen application on yield grain, and dry matter production on irrigated corn. Becker, MN - 1983

Treatments				Grain	Dry Matter Production		
N-Rate	N-Form	Inhibitor	Time	Yields	Grain	Stover	Total
#/A				Bu/A	T/A		
Control	--------	----------	----	57.8	1.36	1.53	1.53
75	AA	----------	PPL	86.7	2.05	2.05	4.11
75	AA	----------	10-lf	142.5	3.37	2.06	5.43
75	28%	----------	PPL	64.6	1.52	1.90	3.43
75	28%	----------	10-lf	99.8	2.36	1.86	4.47
75	UREA	----------	PPL	71.7	1.69	1.90	3.75
75	AA	N-Serve	PPL	93.4	2.21	2.13	4.34
75	28%	N-Serve	PPL	92.3	2.18	1.95	4.14
75	UREA	N-Serve	PPL	84.7	2.00	1.94	3.94
150	AA	----------	PPL	106.6	2.52	2.21	4.73
150	AA	----------	10-lf	147.9	3.49	2.28	5.78
150	28%	----------	PPL	89.7	2.12	1.92	4.04
150	28%	----------	10-lf	153.4	3.63	2.34	5.98
150	UREA	----------	PPL	79.2	1.87	1.85	3.72
150	AA	N-Serve	PPL	129.1	3.05	2.42	5.48
150	28%	N-Serve	PPL	113.0	2.67	2.20	4.88
150	UREA	N-Serve	PPL	115.8	2.74	2.16	4.90
75	UREA	10% DCDN	PPL	104.2	2.46	1.94	4.41
75	AA	2.5% DCDG	PPL	117.1	2.77	2.14	4.91
75	AA	5% DCDG	PPL	128.7	3.04	2.39	5.43
75	28%	10% DCDL	PPL	93.5	2.21	2.02	4.23
150	UREA	10% DCDN	PPL	134.1	3.17	2.46	5.41
150	AA	2.5% DCDG	PPL	138.8	3.28	2.37	5.66
150	AA	5% DCDG	PPL	133.0	3.14	2.32	5.47
150	28%	10% DCDL	PPL	140.3	3.32	2.56	5.88
P-Value				99	99	99	99
BLSD(.05)				13.2	0.31	0.28	0.28
Factorial Arrangement (N-Rate X N-Form X Inhibitor)							
N-Rate							
75				82.2	1.94	1.98	3.95
150				105.5	2.49	2.13	4.63
P-Value				99	99	96	99
N-Form							
AA				103.9	2.46	2.20	4.66
28%				89.9	2.12	1.99	4.12
UREA				87.8	2.07	1.96	4.08
P-Value				99	99	98	99
BLSD (.05)				8.6	0.20	0.16	0.36
Inhibitor							
Control				83.1	1.96	1.97	3.96
N-Serve				104.7	2.47	2.13	4.61
P-Value				99	99	97	99
Rate X Form				37	37	32	48
Rate X Inhibitor				88	88	88	92
Form X Inhibitor				61	61	2	27
Rate X Form X Inhibitor				72	72	8	49

Table 1 continued on next page

Table 1 continued

Treatments N-Rate #/A	N-Form	Inhibitor	Time	Grain Yield Bu/A	Dry Matter Production Grain	Stover	Total
					T/A		
Factorial Arrangement (N-Rate X N-Form X Time)							
N-Rate							
75				98.4	2.32	1.97	4.36
150				124.4	2.94	2.19	5.13
P-Value				99	99	99	99
N-Form							
AA				120.9	2.86	2.15	5.01
28%				101.9	2.41	2.00	4.48
P-Value				99	99	96	99
Time							
PPL				86.9	2.05	2.02	4.08
10-1f				135.9	3.21	2.13	5.42
P-Value				99	99	91	99
Rate X Form				99	99	36	94
Rate X Time				74	74	94	82
Form X Time				12	12	75	71
Rate X Form X Time				99	99	86	95
Factorial Arrangement (N-Rate X Inhibitor with AA)							
N-Rate							
75				106.5	2.52	2.18	4.70
150				126.8	3.00	2.33	5.34
P-Value				99	99	95	99
Inhibitor							
Control				96.7	2.28	2.13	4.42
N-Serve				111.2	2.63	2.27	4.91
2.5% DCDG				128.0	3.02	2.25	5.28
5% DCDG				130.8	3.09	2.35	5.45
P-Value				99	99	76	99
N-Rate X Inhibitor				99	99	64	96
Factorial Arrangement (N-Rate X Inhibitor with Urea)							
N-Rate							
75				86.9	2.05	1.93	4.03
150				109.7	2.59	2.16	4.68
P-Value				99	99	97	98
Inhibitor							
Control				75.5	1.78	1.87	3.73
N-Serve				100.2	2.37	2.05	4.42
10% DCDN				119.1	2.82	2.20	4.91
P-Value				99	99	96	99
N-Rate X Inhibitor				90	90	92	82

Table 2. Influence of nitrogen form, nitrogen rates, nitrification inhibitors, timing of nitrogen application on leaf N content, grain N content and nitrogen removal by irrigated corn. Becker, MN - 1983

Treatments				N-Concentration			N-Removal		
N-Rate	N-Form	Inhibitor	Time	Leaf	Grain	Stover	Stover	Grain	Total
#/A				---------%---------			-------lbs/A--------		
Control	--------	----------	-------	1.19	1.25	0.46	14.4	34.0	48.4
75	AA	----------	PPL	1.58	1.22	0.47	19.6	50.1	69.8
75	AA	----------	10-1f	2.68	1.43	0.56	23.0	96.6	119.6
75	28%	----------	PPL	1.38	1.27	0.42	16.0	38.7	54.8
75	28%	----------	10-1f	2.17	1.31	0.53	19.9	62.0	81.9
75	UREA	----------	PPL	1.52	1.28	0.47	18.1	43.3	61.4
75	AA	N-Serve	PPL	2.04	1.30	0.43	18.2	57.5	75.8
75	28%	N-Serve	PPL	1.86	1.30	0.47	18.5	57.4	75.9
75	UREA	N-Serve	PPL	1.72	1.17	0.44	17.3	46.8	64.1
150	AA	----------	PPL	2.32	1.37	0.49	21.7	68.7	90.4
150	AA	----------	10-1f	2.83	1.51	0.62	28.4	105.9	143.3
150	28%	----------	PPL	1.72	1.28	0.42	16.2	54.6	70.9
150	28%	----------	10-1f	2.97	1.39	0.61	28.8	100.8	129.7
150	UREA	----------	PPL	1.68	1.23	0.43	16.2	46.0	62.2
150	AA	N-Serve	PPL	2.50	1.43	0.50	24.6	82.4	107.1
150	28%	N-Serve	PPL	2.30	1.21	0.49	21.8	64.9	86.7
150	UREA	N-Serve	PPL	2.40	1.28	0.52	22.9	70.2	93.2
75	UREA	10% DCDN	PPL	2.19	1.27	0.49	19.3	62.8	82.1
75	AA	2.5% DCDG	PPL	2.21	1.31	0.42	18.3	72.7	91.0
75	AA	5% DCDG	PPL	2.40	1.23	0.51	2.43	75.3	99.7
75	28%	10% DCDL	PPL	1.84	1.26	0.47	18.9	56.4	75.4
150	UREA	10% DCDN	PPL	2.90	1.45	0.61	30.6	92.0	122.6
150	AA	2.5% DCDG	PPL	2.52	1.36	0.49	23.4	89.0	112.4
150	AA	5% DCDG	PPL	2.63	1.38	0.52	24.3	87.3	111.7
150	28%	10% DCDL	PPL	2.65	1.42	0.51	26.2	94.7	120.9
P-Value				99	99	99	99	99	99
BLSD (.05)				0.26	0.17	0.08	4.7	10.4	12.7
Factorial Arrangement (N-Rate X N-Form X Inhibitor)									
N-Rate									
75				1.68	1.26	0.45	18.0	48.9	67.0
150				2.15	1.28	0.47	20.6	64.5	85.1
P-Value				99	63	87	98	99	99
N-Form									
AA				2.11	1.31	0.47	21.0	64.7	85.8
28%				1.81	1.26	0.45	18.1	53.9	72.1
UREA				1.83	1.24	0.47	18.6	51.6	70.2
P-Value				99	83	55	92	99	99
BLSD(.05)								5.7	7.8
Inhibitor									
Control				1.70	1.27	0.45	18.0	50.2	68.2
N-Serve				2.14	1.27	0.47	20.5	63.2	83.8
P-Value				99	15	85	97	99	99
Rate X Form				63	78	35	42	79	74
Rate X Inhibitor				56	28	96	53	78	90
Form X Inhibitor				56	28	85	53	21	97
Rate X Form X Inhibitor				95	87	56	29	93	93

Table 2 continued on next page

Table 2 continued

Treatments				N-Concentration			N-Removal		
N-Rate	N-Form	Inhibitor	Time	Leaf	Grain	Stover	Stover	Grain	Total
				----------%		--------	--------lbs/A--------		
Factorial Arrangement (N-Rate X N-Form X Time)									
N-Rate									
75				1.95	1.31	0.49	19.6	61.8	81.5
150				2.46	1.39	0.53	23.8	82.5	106.6
P-Value				99	96	89	99	99	99
N-Form									
AA				2.35	1.38	0.53	23.2	80.3	103.5
28%				2.06	1.31	0.49	20.2	64.0	84.3
P-Value				99	94	90	98	99	99
Time									
PPL				1.75	1.28	0.45	18.4	53.6	71.5
10-lf				2.66	1.41	0.58	25.0	91.3	116.4
P-Value				99	99	99	99	99	99
Rate X Form				50	64	1	28	97	96
Rate X Time				29	62	84	98	77	94
Form X Time				75	83	65	82	79	45
Rate X Form X Time									
Factorial Arrangement (N-Rate X Inhibitor in AA)									
N-Rate									
75				2.06	1.27	0.46	20.1	63.9	84.0
150				2.49	1.36	0.50	23.5	81.9	105.4
P-Value				99	99	95	99	99	99
Inhibitor									
Control				1.95	1.29	0.48	20.7	59.4	80.1
N-Serve				2.27	1.32	0.46	21.4	70.0	91.4
2.5% DCDG				2.37	1.33	0.45	20.8	80.8	101.7
5% DCDG				2.51	1.31	0.51	24.3	81.3	105.7
P-Value				99	14	84	81	99	99
N-Rate X Inhibitor				93	52	42	68	99	99
Factorial Arrangement (N-Rate X Inhibitor with Urea)									
N-Rate									
75				1.81	1.24	0.47	18.2	50.9	69.2
150				2.32	1.32	0.52	23.2	69.4	92.7
P-Value				99	94	97	99	99	99
Inhibitor									
Control				1.60	1.25	0.45	17.2	44.6	61.8
N-Serve				2.06	1.22	0.48	20.1	58.5	78.7
10% DCDN				2.54	1.36	0.55	24.9	77.4	102.4
P-Value				99	97	99	99	99	99
N-Rate X Inhibitor				97	96	97	98	99	99

HIGH CORN YIELD EXPERIMENTS ON THE COARSE TEXTURED SOILS OF MINNESOTA

G.L. Malzer, J. Gesdelmann and T. Graff

The agricultural producer is becoming increasingly aware of the importance of management for maximum economic return. With the severe economic pressures producers are currently encountering, the tendency is to cut back on some of the variable inputs used in crop production. The lowering of production cost is a viable consideration in increasing economic return, as long as decreased production does not offset the benefit from decreasing the production cost. An alternative to the above approach is improved management. If a producer can obtain higher yields with relatively little change in inputs, higher economic returns would result. Management for higher production and at the same time highest economic return is very complicated and it takes a top manager to evaluate all of the alternatives which are available. A trial was established at the Sand Plain Research Farm near Becker, Minnesota to evaluate the impact of nine corn hybrids. The nine hybrids were evaluated under high population and high fertilization in a corn following corn and corn following soybean sequence.

Experimental Procedure

Two separate experiments consisting of nine treatments with four replications were arranged in randomized complete block designs. The treatments consisted of nine corn hybrids. The hybrids selected included Pioneer 3978, Pride 1142, A654XCM105 (85 day realative maturity - R.M.), Funks G4256, Trojan T950, LH39XA641 (95 day R.M.), Cargill 835, Pioneer 3901, and Mo17XA641 (95-100 day R.M.).

Prior to planting, potassium magnesium sulfate (300 #/a 0-0-22), phosphorus (80 #/a 0-46-0), potassium (275 #/a 0-0-60), boron (2 #/a as solubor) and zinc (10 #/a as $ZnCl_2$) was broadcast and incorporated into both experimental areas. Nitrogen was applied in split applications as anhydrous ammonia. The first application of nitrogen (175 #N/a) was made on May 20th (emergence) and contained N-Serve (0.5 #ai/a). A second application of N (100 #N/a) was made on June 23rd when the corn was at the 10-leaf growth stage.

Corn was planted on May 1st in 30 inch rows at a population of 46,000 seeds/a. After emergences the stand was thinned to 42,000 plants/a. Weed control was accomplished with a preemergence application of Lasso (1.5 #ai/A) plus Atrazine (2 #ai/a). To minimize corn bore damage, Lorsban was applied through the irrigation system on August 12th.

Leaf samples from opposite and below the ear at mid-silking were taken on July 19 (85-day R.M.) and on July 21st. Samples were dried ground, and analyzed for elemental concentrations. Grain yields and total dry matter production was measured on September 14th (85-day R.M.) and September 19th. Samples were obtained by hand harvesting 100 $ft.^2$ of plot area. From the above ground portion, ears were separated from the stalks and separate field weights, and samples obtained from each portion (grain and stover) for moisture determination and elemental concentrations. Grain yields were adjusted to 15.5% moisture.

The irrigation program was started on July 9th and continued through August 23rd with a total of 9.6 inches of water being applied through irrigation. An additional 23.5 inches of water was obtained during the growing season as rainfall. Over 50% of the growing season rainfall was obtained during the month of June and over 50% of the June precipitation was obtained on June 20-21.

Results and Conclusions

The specific results from both experiments are presented in Tables 1-6. In general, yield levels were very disappointing. Factors which may have been involved with the lower yields will be discussed later. It is interesting to note that grain yields were significantly influenced by hybrids when it was grown in a corn following corn sequence, but were not significantly different in a corn following soybean sequence. Conversely, stover and total dry matter yields were not significantly different between hybrids with the corn followign corn sequence. It therefore appears that the hybrids used responded differently to the rotation effect. Pioneer 3901 was an example of one hybrid which did not appear to be sensitive to the crop sequence while Cargill 834 yielded much better in the corn soybean sequence (similar relative maturities).

Concentrations of many of the plant essential nutrients in the different plant parts were significantly influenced by hybrid. At least a portion of this variation can be explained due to the differences in relative maturity. This cannot be the sole reason associated with the bybrid variability since certain hybrids within the same maturity ranges were different from each other. The practical significance associated with differential plant concentrations (when sufficient quantities are available) remains to be investigated.

Total elemental removal was influenced by hybrid selection, with again difference being observed between the two cropping systems. The nutrients being affected most included N, P, Ca, Mg, Mn, Zn, and Cu. The elements K, Fe, and B were also found to be different between varities, but only when the sequence was corn following soybeans. There are numerous comparisons that can be made between nutrients and corn hybrids. One interesting comparison was between Cargill 834 and Pioneer 3901 (similar maturities). In a corn following soybean sequence both varities produced similar yields. The potassium removal by Cargill 834 was significantly higher than Pioneer 3901. When the same two hybrids were compared in the corn following corn sequence, the potassium removal was very similar. The grain yield of Cargill 834 was however significantly lower than Pioneer 3901. Relationships such as these deserve continued evaluation.

Yield Limiting Factors:

As was mentioned earlier, the yields obtained in 1983 were very disappointing. The yields obtained not only from these experiments but others at the research station rate among the lowest obtained in the last 6-7 years. As is the case in many years, the reduced yields were probably not the result of one thing, but as results from the combination of a number of factors. Many of these factors were external and could not be controlled.

The growing season was characterized by being very cold early. At the critical stage of germination some of the hybrids reflected reduced emergence. Even though all plots were over-seeded and thinned to a desired stand, one hybrid, LH39XA641, was reduced to an extent that the emergence was 25% below the desired population. The stress conditions associated with cold weather were dramatically reversed to create substantial heat stress during vegetive production and pollination. The net result was the creation of a plant that was extremely spindly and weak. Combine this with several severe storms and one of the worst infestations of corn borer in the last 25 years and we have a tremendous lodging problem. The problems of lodging and barren stalks are typically not a problem at this location. The high stress conditions (high plant population and weather) experienced in 1983 produced severe lodging and barren stalks (barreness was as high as 30-40%). Barren stalks of less than 5% are normally observed at this location.

Table 1. Leaf N content, grain yield, dry matter production, grain N content and nitrogen removal by nine corn varieties following corn - Becker MN. 1983.

Treatments	Leaf N	Grain Yield	Dry Matter Production Grain	Stover	Total	N-Conc. Grain	Stover	N-Removal Grain	Stover	Total
	%	Bu/A	T/A			%		lbs/A		
Pioneer 3978	2.78	138.3	3.27	2.19	5.47	1.34	0.70	88.1	30.5	118.7
Pride 1142	2.85	124.9	2.95	2.49	5.45	1.41	0.90	83.7	45.3	129.0
A654 X CM105	2.79	151.3	3.58	2.15	5.74	1.46	0.72	104.7	31.2	136.0
Funks G4256	2.85	133.2	3.15	2.61	5.77	1.49	1.04	94.5	54.9	149.4
Trojan T950	3.19	138.7	3.28	2.29	5.57	1.51	0.94	99.5	43.3	142.9
LH39 X A641	3.22	148.3	3.51	2.44	5.95	1.50	0.91	105.7	44.7	150.4
Cargill 834	3.01	126.2	2.98	2.47	5.46	1.47	0.89	88.3	44.1	132.4
Pioneer 3901	2.99	145.8	3.45	2.63	6.08	1.48	0.77	102.4	40.6	143.1
Mo17 X A641	3.13	133.8	3.16	2.83	6.00	1.42	0.87	90.4	49.7	140.2
P-Value	98	98	98	89	55	69	99	95	99	84
BLSD (.05)	0.31	17.7	0.42				0.15	18.1	13.2	

Table 2. The elemental concentration of silage stover silage grain and leaf oppsite and below the ear at silking on nine corn varieties following corn.

Treatment	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
	Elemental Concentration										
	%				ppm						
Silage Stover											
Pioneer 3978	0.06	1.88	0.31	0.21	166	135	61	68	17	10	11
Pride 1142	0.08	1.80	0.33	0.24	172	141	68	71	21	8	12
A645 X CM105	0.04	2.11	0.31	0.22	194	153	68	79	16	8	12
Funks G4256	0.10	2.13	0.31	0.25	200	176	60	92	30	8	12
Trojan T950	0.09	2.23	0.40	0.25	284	242	76	100	27	8	13
LH39 X A641	0.08	1.95	0.39	0.21	200	174	62	108	26	8	11
Cargill 834	0.07	1.99	0.26	0.18	254	207	70	86	22	6	12
Pioneer 3901	0.06	1.70	0.28	0.22	209	189	59	70	24	10	11
Mo17 X A641	0.08	1.71	0.29	0.23	320	259	65	84	26	8	10
P-Value	99	99	99	97	52	68	49	99	99	99	99
BLSD (.05)	0.03	0.25	0.04	0.05				19	7	1	2
Silage Grain											
Pioneer 3978	0.23	0.36	0.003	0.11	1	16	4	6	25	2	3
Pride 1142	0.23	0.35	0.001	0.12	1	17	10	6	25	2	3
A654 X CM105	0.26	0.35	0.002	0.12	1	15	4	5	23	2	4
Funks G4256	0.26	0.37	0.002	0.12	1	14	3	6	19	1	4
Trojan T950	0.28	0.37	0.003	0.14	1	15	3	8	27	1	3
LH39 X A641	0.23	0.36	0.003	0.13	1	16	4	7	25	2	3
Cargill 834	0.21	0.32	0.003	0.11	1	17	3	8	21	2	3
Pioneer 3901	0.26	0.38	0.003	0.13	1	20	3	7	25	2	4
Mo17 X A641	0.24	0.40	0.004	0.10	1	18	3	6	21	3	4
P-Value	99	95	99	99	42	99	72	99	99	99	99
BLSD (.05)	0.04	0.05	0.001	0.02		2		1	3	1	1
Leaf											
Pioneer 3978	0.26	3.37	0.46	0.24	71	127	54	67	27	12	14
Pride 1142	0.27	3.42	0.45	0.28	70	123	57	62	25	12	16
A654 X CM105	0.24	3.15	0.42	0.25	86	126	59	71	26	12	15
Funks G4256	0.27	3.05	0.38	0.22	67	111	58	69	26	12	13
Trojan T950	0.28	2.96	0.42	0.24	46	103	49	83	30	12	13
LH39 X A641	0.30	2.91	0.55	0.26	44	113	53	90	37	12	12
Cargill 834	0.26	2.76	0.40	0.22	54	113	50	81	33	12	13
Pioneer 3901	0.28	2.40	0.40	0.32	51	109	50	93	27	12	11
Mo17 X A641	0.28	2.82	0.38	0.24	52	106	46	89	35	12	10
P-Value	99	99	99	99	99	99	97	87	99	76	99
BLSD (.05)	0.02	0.12	0.05	0.03	16	11	9		5		3

Table 3. The total elemental removal of silage stover and silage grain at physiological maturity on nine corn varieties following corn.

Treatment	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
	Total Elemental Removal										
	Silage Stover										
	lbs/A										
Pioneer 3978	2.8	83.6	13.7	9.3	0.7	0.27	0.26	0.30	0.07	0.04	0.04
Pride 1142	4.1	89.8	16.3	12.0	0.8	0.28	0.33	0.35	0.10	0.03	0.06
A654 X CM105	2.0	91.4	13.3	9.6	0.8	0.30	0.29	0.34	0.07	0.03	0.05
Funks G4256	5.6	112.1	16.2	13.1	1.0	0.35	0.31	0.48	0.16	0.04	0.06
Trojan T950	4.4	102.7	18.2	11.3	1.2	0.48	0.34	0.46	0.12	0.03	0.05
LH39 X A641	4.2	96.0	19.1	10.2	1.0	0.34	0.30	0.53	0.12	0.03	0.05
Cargill 834	3.8	96.4	12.9	8.7	1.2	0.41	0.34	0.42	0.11	0.03	0.06
Pioneer 3901	3.5	90.3	14.5	11.5	1.1	0.37	0.31	0.36	0.12	0.05	0.06
Mo17 X A641	4.6	97.5	16.4	13.1	1.6	0.51	0.35	0.47	0.15	0.04	0.05
P-Value	99	70	99	99	77	68	51	99	99	99	64
BLSD (.05)	1.8		2.8	2.3				0.13	0.04	0.01	
	Silage Grain										
Pioneer 3978	15.6	23.7	0.2	7.4	0.003	0.10	0.03	0.04	0.16	0.01	0.02
Pride 1142	13.9	20.9	0.1	7.1	0.003	0.10	0.06	0.04	0.15	0.02	0.01
A654 X CM105	18.9	25.7	0.2	8.3	0.004	0.11	0.02	0.04	0.16	0.01	0.03
Funks G4256	16.5	23.0	0.1	7.6	0.002	0.10	0.02	0.04	0.12	0.01	0.02
Trojan T950	18.5	24.3	0.2	9.4	0.003	0.10	0.02	0.05	0.18	0.01	0.02
LH39 X A641	16.7	25.0	0.3	8.9	0.003	0.11	0.03	0.05	0.18	0.01	0.02
Cargill 834	12.6	19.3	0.2	6.7	0.002	0.10	0.02	0.05	0.13	0.01	0.02
Pioneer 3901	18.6	26.6	0.3	9.2	0.003	0.13	0.02	0.05	0.17	0.02	0.03
Mo17 X A641	15.3	25.3	0.3	6.9	0.002	0.11	0.02	0.04	0.13	0.01	0.03
P-Value	99	99	99	99	64	99	63	99	99	99	99
BLSD (.05)	2.9	4.0	0.1	1.4		0.02		0.01	0.02	0.01	0.01
	Total										
Pioneer 3978	18.4	107.3	14.0	16.7	0.7	0.38	0.29	0.34	0.24	0.06	0.07
Pride 1142	17.9	110.8	16.5	19.2	0.8	0.38	0.40	0.39	0.26	0.06	0.08
A654 X CM105	20.9	117.1	13.5	18.0	0.8	0.41	0.32	0.38	0.24	0.05	0.08
Funks G4256	22.1	135.2	16.3	20.7	1.1	0.44	0.34	0.51	0.28	0.05	0.09
Trojan T950	22.9	127.1	18.4	20.7	1.3	0.59	0.37	0.51	0.30	0.05	0.08
LH39 X A641	21.0	121.1	19.4	19.1	1.0	0.46	0.34	0.58	0.31	0.05	0.07
Cargill 834	16.4	115.7	13.2	15.4	1.2	0.52	0.36	0.48	0.24	0.04	0.08
Pioneer 3901	22.1	116.9	14.8	20.7	1.1	0.52	0.33	0.41	0.30	0.07	0.08
Mo17 X A641	19.9	122.8	16.7	20.0	1.7	0.63	0.38	0.51	0.29	0.06	0.08
P-Value	99	60	99	99	77	77	56	99	97	99	75
BLSD (.05)	4		2.8	3.1				0.13	0.06	0.01	

Table 4. Leaf N content, grain yield, dry matter production, grain N content and nitrogen removal by nine corn varieties following soybeans - Becker MN. 1983.

Treatments	Leaf N	Grain Yield	Dry Matter Production Grain	Stover	Total	N-Conc. Grain	N-Removal Stover	Grain	Stover	Total
	%	Bu/A	T/A			%		lbs/A		
Pioneer 3978	2.70	147.7	3.49	2.27	5.77	1.27	0.70	89.3	33.2	136.1
Pride 1141	2.53	133.2	3.15	2.68	5.84	1.33	0.96	84.3	51.7	136.1
A654 X CM105	2.68	149.0	3.52	2.12	5.65	1.44	0.67	102.2	28.4	130.6
Funks G4256	2.82	143.9	3.40	2.98	6.39	1.48	1.00	101.1	59.9	161.0
Trojan T950	3.15	152.1	3.60	2.62	6.22	1.43	0.97	103.3	51.1	154.4
LH39 X A641	2.91	157.1	3.72	2.34	6.06	1.39	0.99	103.4	46.3	149.7
Cargill 834	2.87	150.3	3.56	3.32	6.88	1.46	0.86	104.5	57.4	161.9
Pioneer 3901	2.91	146.8	3.47	2.93	6.40	1.40	0.81	97.5	47.8	145.3
Mo17 X A641	2.83	143.9	3.40	2.70	6.11	1.35	0.83	92.6	45.4	138.1
P-Value	98	80	80	99	99	97	99	89	99	99
BLSD (.05)	0.32			0.42	0.64	0.14	0.16		10.6	17.5

Table 5. The elemental conceration of silage stover, silage grain and leaf oppsite and below the ear at silking on nine corn varieties following soybeans.

Treatment	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
	Elemental Concentration										
	%				ppm						
Silage Stover											
Pioneer 3978	0.06	1.78	0.32	0.02	305	222	64	83	16	7	12
Pride 1142	0.09	1.54	0.32	0.23	162	145	65	76	19	6	12
A654 X CM105	0.05	1.84	0.31	0.22	185	144	63	78	17	8	13
Funks G4256	0.09	1.89	0.31	0.25	212	182	59	83	20	7	12
Trojan T950	0.08	2.21	0.37	0.22	252	216	68	121	20	6	13
LH39 XA641	0.08	1.96	0.36	0.20	244	196	66	104	23	6	12
Cargill 834	0.06	1.84	0.29	0.18	225	189	61	79	16	5	12
Pioneer 3901	0.07	1.51	0.32	0.25	225	187	60	80	21	91	11
Mo17 X A641	0.07	1.73	0.27	0.21	313	242	63	73	18	5	13
P-Value	98	99	99	96	86	94	5	99	84	99	57
BLSD (.05)	0.03	0.20	0.05	0.05				26		1	
Silage Grain											
Pioneer 3978	0.20	0.33	0.003	0.10	2	14	8	5	22	2	2
Pride 1142	0.23	0.34	0.002	0.12	1	17	8	6	24	2	3
A654 X CM105	0.25	0.34	0.003	0.11	1	14	10	5	21	1	4
Funks G4256	0.27	0.36	0.003	0.12	1	14	9	6	19	1	3
Trojan T950	0.26	0.36	0.003	0.13	1	16	6	8	25	1	3
LH39 X A641	0.24	0.37	0.003	0.13	1	18	5	7	25	1	2
Cargill 834	0.22	0.35	0.003	0.12	1	18	9	8	20	2	3
Pioneer 3901	0.24	0.34	0.003	0.13	1	19	5	6	22	2	3
Mo17 X A641	0.25	0.40	0.004	0.12	1	19	5	6	20	2	3
P-Value	82	93	99	98	55	99	39	99	99	99	99
BLSD (.05)			0.001	0.02		3		1	3	1	1
Leaf											
Pioneer 3978	0.25	3.45	0.40	0.21	75	149	54	59	24	9	12
Pride 1142	0.26	3.28	0.43	0.27	76	119	58	58	22	8	11
A654 X CM105	0.23	3.10	0.42	0.25	81	130	63	50	21	9	13
Funks G4256	0.28	3.07	0.36	0.25	63	107	54	73	25	8	12
Trojan T950	0.28	3.14	0.40	0.23	57	111	53	82	27	8	11
LH39 X A641	0.28	2.98	0.51	0.27	59	114	55	77	32	8	11
Cargill 834	0.25	2.83	0.38	0.22	52	111	43	71	26	7	10
Pioneer 3901	0.29	2.63	0.38	0.30	54	114	51	88	26	9	10
Mo17 X A641	0.28	2.83	0.39	0.24	56	106	50	80	29	7	8
P-Value	99	99	99	99	99	99	99	95	99	99	88
BLSD (.05)	0.02	0.22	0.04	0.03	11	15	12	24	5	5	

Table 6. Total elemental removal of silage stover and silage grain at physiological maturity on nine corn varieties following soybeans.

Treatment	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
	Total Elemental Removal										
	Silage Stover										
	lbs/A										
Pioneer 3978	2.8	82.3	14.5	9.5	1.4	0.44	0.29	0.38	0.07	0.03	0.05
Pride 1142	5.0	83.2	17.1	12.5	0.8	0.29	0.34	0.40	0.10	0.03	0.06
A654 X CM105	2.1	78.6	13.3	9.3	0.7	0.28	0.26	0.33	0.07	0.03	0.05
Funks G4256	5.5	113.2	18.8	15.2	1.2	0.36	0.35	0.49	0.12	0.04	0.07
Trojan T950	4.7	116.7	19.5	11.4	1.3	0.43	0.35	0.63	0.10	0.03	0.07
LH39 X A641	3.9	92.0	17.2	9.6	1.1	0.39	0.30	0.49	0.11	0.03	0.05
Cargill 834	4.1	123.0	19.3	12.4	1.5	0.37	0.40	0.52	0.10	0.03	0.08
Pioneer 3901	4.4	88.6	18.5	14.7	1.3	0.37	0.35	0.47	0.12	0.05	0.06
Mo17 X A641	4.0	93.5	14.7	11.5	1.7	0.48	0.35	0.40	0.10	0.03	0.07
P-Value	99	99	99	99	87	94	74	99	91	99	98
BLSD (.05)	1.7	20.7	3.4	2.3				0.15		0.01	0.02
	Silage Grain										
Pioneer 3978	14.6	23.6	0.2	7.1	0.012	0.10	0.06	0.07	0.15	0.01	0.02
Pride 1142	15.1	21.8	0.1	7.6	0.001	0.11	0.06	0.04	0.15	0.01	0.02
A654 X CM105	18.2	24.3	0.2	8.0	0.001	0.10	0.07	0.04	0.15	0.01	0.03
Funks G4256	18.4	24.2	0.2	8.4	0.001	0.10	0.06	0.04	0.13	0.01	0.02
Trojan T950	18.8	25.9	0.2	9.7	0.001	0.12	0.04	0.05	0.18	0.01	0.02
LH39 X A641	18.5	27.4	0.2	9.9	0.001	0.13	0.04	0.05	0.18	0.01	0.02
Cargill 834	16.3	25.3	0.3	8.6	0.001	0.13	0.06	0.06	0.14	0.01	0.02
Pioneer 3901	17.2	24.1	0.2	8.8	0.001	0.13	0.04	0.04	0.15	0.02	0.02
Mo17 X A641	17.6	27.8	0.3	7.9	0.001	0.13	0.04	0.04	0.13	0.01	0.02
P-Value	88	90	99	99	61	99	43	99	99	99	99
BLSD (.05)		5.1	0.1	1.7		0.02		0.01	0.02	0.01	0.01
	Total										
Pioneer 3978	17.6	106.0	14.7	16.6	1.4	0.54	0.35	0.41	0.23	0.05	0.07
Pride 1142	20.1	105.1	17.2	20.1	0.8	0.40	0.40	0.44	0.25	0.04	0.08
A654 X CM105	20.3	102.8	13.5	17.3	0.8	0.38	0.33	0.37	0.22	0.04	0.08
Funks G4256	24.0	137.4	19.0	23.6	1.3	0.46	0.41	0.54	0.25	0.05	0.09
Trojan T950	23.5	142.6	19.7	21.1	1.3	0.55	0.40	0.69	0.29	0.04	0.09
LH39 X A641	22.5	119.5	17.5	19.5	1.1	0.52	0.34	0.54	0.29	0.04	0.07
Cargill 834	20.5	148.3	19.6	21.0	1.5	0.50	0.47	0.58	0.25	0.05	0.10
Pioneer 3901	21.6	112.8	18.7	23.5	1.3	0.51	0.39	0.51	0.27	0.07	0.09
Mo17 X A641	21.6	121.4	15.0	19.4	1.7	0.61	0.38	0.44	0.24	0.04	0.09
P-Value	95	99	99	99	87	98	69	99	99	99	99
BLSD (.05)	4.4	18.4	3.4	2.4		0.14		0.15	0.05	0.01	0.02

SOIL TEST LAB COMPARISON ON IRRIGATED POTATOES - BECKER, 1983

W. E. Fenster, W. E. Jokela and M. O'Leary

Several commercial laboratories test soils and make fertilizer recommendations in Minnesota. The experiment was established to compare soil test results, recommended fertilizer rates and costs, and yields of irrigated potatoes fertilized according to the recommendations of five soil testing labs. Similar experiments are being conducted on corn at Waseca and on corn and wheat in rotation at Morris.

Experimental Procedures

This experiment was established in 1980 on a Hubbard loamy sand at the Sand Plains Irrigation Farm at Becker, MN. Each year samples were dried, thoroughly mixed, and divided into five subsamples which were sent to five soil testing labs, including the University of Minnesota. In 1983 fertilizer recommendations were requested for Russet Burbank potatoes grown under irrigation. Fertilizer as recommended by each of the five labs was applied. The sixth treatment was a no-fertilizer check. Experimental design is randomized complete block with four replications.

Results and Discussion

Soil test results and fertilizer recommendations are shown in Table 1 and 2. Recommended N rates were quite similar, but there were differences in amounts of P and K and in which secondary and micronutrients were recommended. The university of Minnesota recommendations for P_2O_5 and K_2O were considerably higher than other labs and somewhat higher for sulfur.

Tuber yield and an economic comparison are shown in Table 3. Potato yields varied from 407 to 499 CWT with lab C being significantly higher than other labs except lab D.

It is difficult to explain why lower recommendations of lab C gave significantly higher yields. It appears that lab E (U of M) recommendations for P and K are higher than necessary.

Table 1. Soil test results[1/] for 1983 after 3 years of fertilization and cropping. Becker, MN. 1982 fall sampling.

	A	B	C	D	E(U of M)	Check[2/]
pH	6.8	6.5	6.4	6.5	6.8	6.6
Buffer Index	--	7.0	--	7.1	--	--
P	29	28	28	24	18	18
K	104	121	105	70	60	111
Ca	786	880	960	1000	--	--
Mg	138	188	160	150	154	122
S	5	6	9	9	2	4
Fe	19.7	18	16	8	--	--
Mn	5.5	5	5.2	2	--	--
Zn	2.4	1.8	2.1	1.7	2.0	1.8
Cu	.8	.6	.5	.4	--	
B	.5	.9	.6	.8	--	
NO_3-N (0-6")	3	--	3.2	--	--	
O.M. %	1.4	1.8	--	1.7	2.4	1.9
CEC (Mg/100g)	5.3	6.8	--	6.5	--	--

1/ ppm unless otherwise noted

2/ soil test U of M lab

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

Table 2. Fertilizer recommendations from five soil testing labs for potatoes. Becker, MN 1983.

Lab	N[1/]	P_2O_5	K_2O	S	Mg	B	Zn	Mn	Cu
	nutrients in lb/A								
A	185	110	195	25	3	1.2	--	--	--
B	150	75	190	16	--	1	2.5	3	1
C	163	0	135	20	--	1	--	--	--
D	159	49	224	20	--	--	--	--	--
E (U of M)	170	150	400	30	--	--	--	--	--

[1/] N added as follows:
20% preplant, 40% at 12" height, 40% at hilling

Table 3. Potato yield and economic return over fertilizer costs for 6 fertilizer programs, Becker 1983.

Lab	Yield CWT	Gross[1/] Tuber Value per acre	Fertilizer Cost[2/] per acre	$ Benefit above check[3/]
A	438	$ 2,628	101.10	$ 930.90
B	407	2,442	90.55	755.45
C	499	2,994	61.82	1,336.18
D	465	2,790	80.29	1,113.71
E	438	2,628	139.30	892.18
Check	266	1,596	-0-	
Significance	**			
BLSD (.05)	52			
C.V.	8.9			

[1/] Potatoes valued at $6/cwt

[2/] Fertilizer costs per lb.
N = $.24 (urea), P_2O_5 = $.23, K_2O = .12, S = $.20, Zn = $.90, Mn = $1.25, Mg = $.70, B = $2.50, and Cu = $2.80.

[3/] Crop value minus fertilizer cost minus value of check.

MICRONUTRIENT FERTILIZATION OF POTATOES AND CORN UNDER IRRIGATION

G.L. Malzer, T. Graff and G. Titrud

The need for micronutrient fertilization and application of fertilizer other than those which supply N, P and K continue to be a concern to the producers of potatoes and corn as well as other crops on the coarse textured soil under irrigation. Because of the intensive management operations, high yield potentials, and often low nutrient supplying capacities of the soils, conditions may develop where yield reductions due to the lack of an essential nutrient other than N, P and K may occur. Three separate experiments were established in 1978 at the Sand Plains Research Farm near Becker, MN to assess the significance of certain plant nutrients other than N, P and K on yield and nutrient composition of the plant tissues for potatoes and corn.

Experimental Procedures

Seven treatments, including a control, four micronutrient treatments, and two macronutrient treatments were established in a randomized complete block design with four replications. Rates and types of fertilizer included: 5 lbs. of copper/a as $CuSO_4 5H_2O$, 2 lbs. of boron/a as Solubor, 25 lbs. of sulfur/a as $CaSO_4$, 75 lbs. of magnesium, as $MgCl_2$, 10 lbs. of zinc/a as $ZnCl_2$ and 3 lbs. of manganese/a as $MnCl_2$. Application of materials were made to the same plots as in the past 5 years. The corn and potato areas were rotated in 1983 so the corn was planted into the 1982 potato area (eight replications) and the potatoes were planted into the corn areas (four replications of each variety).

Fertilizer treatments were broadcast, incorporated by plowing on April 18, and the potatoes planted on April 21. Norlands were planted in 9 inch spacing utilizing 36 inch rows, while Russet Burbanks were planted in 12 inch spacing with the same row width. A starter was used at the rate of 1000 lbs./a of 8-10-30 and the insecticide Temik 15G was banded at 14 lbs./a at planting time. A tank mix of Linoran 2# ai/a and Lasso 2# ai/a, along with a tank of Eptan 4.25# ai/a was used for control. Nitrogen was sidedressed on May 25 (185 lbs./a 34-0-0) and on June 13 (250 lbs./a 34-0-0), along with hilling at the last sidedressing. Samples of the youngest mature potato leaves were obtained 81 days after planting for nutrient concentration. The Norlands were harvested on September 8 and the Russet Burbank on September 20. Irrigation water was applied during the period of June 13 through August 24 with a total addition of 10.88 inches. Precipitation during the growing season was 18.4 inches for the Norlands and 19.7 inches for the Russet Burbanks. Utilizing the 1982 potato experiment, eight replications of the aforementioned treatments were planted to corn. The experimental area had been fertilized with 800 lbs./a 8-10-30 prior to planting on April 29. A commercial corn variety (Pioneer 3901) was planted in 30 inch rows at a population of 30,700 seeds/a. Starter fertilizer at the rate of 165 lbs./a of 8-10-30 was banded at planting. For weed control Lasso (1.6 lbs. ai/a) was used as a preemergence application and 2,4-D (1 lb. ai/a) was applied on June 6 for weed control. The insecticides Lorsban 15G (8 lbs. ai/a) was handled at planting. Nitrogen applications were made on May 25 (220 lbs./a 34-0-0) and June 22 (260 lbs./a 34-0-0).

Leaf samples from opposite and below the ear at mid-silking were taken on July 21, dried ground and analyzed for elemental concentrations. Total dry matter production and final yield was determined on September 19 by hand harvesting 100 ft.^{2} of plot area. Ears were separated from the stalks, separate field weights and sub-samples removed for moisture determineation and elemental concentrations. Grain yeilds were adjusted to 15.5% moisture. The irrigation program was started on June 13 and continued through August 24 with a total of 10.88 inches of water being applied through irrigation. An additional 24.0 inches of water was obtained during the growing season through rainfall.

General Results

The results from 1983, along with the six-year average yields are presented in Tables 1-4. Norland tuber yields in 1983 were similar to the six-year average while Russet Burbank yields were slightly above the six-year average. Corn grain yields in 1983 were substantially lower than the long-term average yields. There was no yield advantage in 1983 to the application of any of the six elements added. The six-year averages suggest some interesting differences especially with potatoes. With the Norland variety significant (.05) yield increases were obtained with both boron and zinc application. A substantial yield increase was also obtained with Norland when magnesium was applied. By contrast, the six-year average yields for the Russet Burbank potatoes reflected no response to any applied treatment. Positive trends were observed with zinc and boron and a negative trend for manganese, but these trends were not significant (.10). Corn grain yields, when evaluated over a

six-year period, reflected differences only at the 90% probability level. Magnesium and zinc applications produced the higher yields while the manganese treatment had the lowest yield.

Nutrient concentrations in the leaf and total nutrient uptake tended to follow those nutrients which suggested a yield response. Increased utilization of zinc, boron, and magnesium were the most predominant. Copper application frequently resulted in increased tissue concentrations and uptake. Reduced concentrations and uptake of calcium in corn stover were associated with mangesium application. This did not appear to have a detrimental influence on grain yield.

Table 1. Influence of micronutrient fertilization (also Mg and S) on tuber yield and nutrient concentration on the youngest mature leaves 81 days following planting for Norland and Russet Burbank potatoe.

Treatment	Rate/A #/A	Tuber Yield cwt/a	6yr. Ave. cwt/a	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
				Norland Potatoes Leaf Concentration											
				%					ppm						
Control	-	382	399	4.74	0.38	5.38	1.44	0.45	192	161	67	318	19	14	59
Cu	5	398	402	4.92	0.36	5.12	1.49	0.44	124	148	63	319	18	18	58
B	2	437	422	4.92	0.35	5.33	1.29	0.39	155	161	71	378	18	14	71
S	25	398	404	5.09	0.35	5.10	1.39	0.42	127	160	67	340	18	14	58
Mg	75	404	415	4.76	0.36	5.35	1.45	0.55	247	182	55	308	19	11	59
Zn	10	426	423	4.91	0.35	5.21	1.39	0.43	190	158	30	368	26	13	62
MN	3	414	414	4.79	0.35	5.04	1.53	0.49	162	173	60	312	17	12	63
P-Value		92	99	76	61	41	26	88	50	42	93	27	99	91	82
BLSD (.05)			17										2		
				Russet Burbank Potatoes											
Control	-	458	441	5.04	0.33	4.49	0.88	0.50	294	166	47	269	16	12	44
Cu	5	485	447	4.85	0.34	4.41	0.89	0.50	226	160	37	225	16	17	42
B	2	503	459	4.90	0.33	4.33	0.80	0.49	294	169	67	244	16	12	48
S	25	501	447	5.08	0.33	4.38	0.87	0.49	360	175	70	240	17	11	46
Mg	75	473	442	5.01	0.32	4.45	0.82	0.57	361	180	53	204	17	10	40
Zn	10	464	457	4.97	0.33	4.36	0.86	0.48	187	158	42	258	20	11	44
Mn	3	442	429	5.05	0.34	4.27	0.93	0.53	259	174	70	237	16	12	45
P-Value		75	89	77	3	33	31	95	19	22	97	52	99	96	36
BLSD(.05)											26		1	4	

Table 2. Influence of micronutrient fertilization (also Mg and S) on corn yield and dry matter production.

Treatment	Rate/a #/A	Grain Yield Bu/A	6 yr. Ave. Bu/A	Dry Matter Production Stover	Grain	Total
				T/A		
Control	-	151.7	181.8	2.66	3.59	6.26
Cu	5	162.1	184.9	2.78	3.83	6.62
B	2	154.9	183.7	2.66	3.63	6.33
S	25	155.9	184.2	2.59	3.68	6.28
Mg	75	152.8	185.5	2.62	3.61	6.24
Zn	10	155.6	186.3	2.67	3.68	6.35
Mn	3	155.3	180.4	2.55	3.67	6.22
P-Value		50	90	28	50	42
BLSD (.05)						

Table 3. Influence of micronutrient fertilization (also Mg and S) on the elemental concentration of silage stover, silage grain and leaf opposite and below the ear at silking.

Treatment	Rate/A	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
		Elemental Concentration											
		Silage Stover											
	#/A	%					ppm						
Control	-	0.65	0.14	1.87	0.28	0.13	204	171	49	64	12	8	8
Cu	5	0.67	0.11	1.86	0.29	0.14	225	207	47	61	12	10	8
B	2	0.68	0.13	1.95	0.27	0.13	217	187	50	63	12	9	9
S	25	0.65	0.14	1.91	0.29	0.13	214	180	49	63	12	9	8
Mg	75	0.63	0.11	2.09	0.25	0.14	212	177	49	60	12	9	8
Zn	10	0.65	0.11	1.84	0.31	0.14	237	191	51	61	29	8	8
MN	3	0.62	0.12	1.89	0.27	0.12	227	191	49	62	11	9	8
P-Value		20	99	79	99	31	20	37	8	1	99	98	99
BLSD (.05)			0.02		0.03						4	1	1
		Silage Grain											
Control	--	1.26	0.33	0.46	0.003	0.13	1	16	1	7	23	2	3
Cu	5	1.31	0.32	0.46	0.003	0.12	1	16	1	6	22	2	3
B	2	1.31	0.33	0.47	0.003	0.13	1	17	1	7	23	2	3
S	25	1.31	0.33	0.46	0.003	0.13	1	17	1	6	25	2	2
Mg	75	1.30	0.33	0.46	0.003	0.14	1	18	1	7	23	2	3
Zn	10	1.31	0.32	0.45	0.003	0.13	1	17	1	6	27	2	3
Mn	3	1.35	0.33	0.48	0.003	0.13	1	16	1	6	22	2	3
P-Value		39	79	68	84	93	56	20	45	57	84	69	99
BLSD(.05)													1
		Leaf											
Control	--	2.72	0.33	2.68	0.43	0.21	34	106	67	97	18	9	6
Cu	5	2.79	0.32	2.69	0.45	0.22	35	106	66	92	19	11	6
B	2	2.77	0.32	2.71	0.44	0.21	37	107	67	92	19	9	7
S	25	2.85	0.33	2.74	0.46	0.20	38	109	68	94	18	9	6
Mg	75	2.93	0.32	2.80	0.44	0.24	38	111	70	92	20	9	6
Zn	10	2.68	0.31	2.68	0.44	0.21	36	105	67	84	31	8	6
Mn	3	2.82	0.32	2.68	0.45	0.21	37	107	68	93	19	9	7
P-Value		98	79	36	5	91	26	81	36	50	99	99	96
BLSD(.05)		0.16									3	1	1

Table 4 Influence of micronutrient fertilization (also Mg and S) on the elemental removal of silage stover, and silage grain at physiolical maturity.

Treatment	Rate/A	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
		Total Elemental Removal											
		Silage Stover											
	#/A	lbs/A											
Control	-	35.5	7.5	100.7	14.9	7.2	1.1	0.34	0.26	0.33	0.06	0.04	0.04
Cu	5	37.1	6.3	103.6	16.6	7.8	1.3	0.41	0.26	0.34	0.06	0.05	0.04
B	2	36.4	7.2	104.4	14.9	7.0	1.1	0.37	0.26	0.33	0.06	0.05	0.05
S	25	33.5	7.0	99.6	15.1	6.7	1.1	0.35	0.25	0.32	0.06	0.04	0.04
Mg	75	32.9	5.8	109.5	13.4	7.2	1.1	0.35	0.25	0.31	0.06	0.04	0.04
Zn	10	34.8	6.0	99.7	16.6	7.4	1.3	0.38	0.27	0.33	0.16	0.04	0.04
Mn	3	31.7	6.3	96.2	13.8	6.4	1.1	0.38	0.24	0.31	0.06	0.04	0.04
P-Value		45	92	22	96	61	25	37	6	10	99	89	99
BLSD(.05)					2.6						0.03		0.01
		Silage Grain											
Control	-	90.9	23.7	33.6	0.22	9.3	0.003	0.12	0.01	0.05	0.16	0.02	0.02
Cu	5	100.9	24.7	35.0	0.22	9.6	0.004	0.12	0.01	0.05	0.16	0.02	0.02
B	2	96.2	24.5	34.6	0.21	9.5	0.003	0.12	0.01	0.05	0.16	0.02	0.02
S	25	96.6	24.5	34.2	0.22	9.5	0.003	0.13	0.01	0.05	0.18	0.02	0.02
Mg	75	94.0	24.4	33.4	0.21	9.7	0.004	0.13	0.01	0.05	0.16	0.02	0.02
Zn	10	96.7	23.6	33.1	0.24	9.5	0.000	0.12	0.01	0.05	0.19	0.02	0.02
Mn	3	99.0	24.3	35.0	0.20	9.4	0.003	0.12	0.01	0.05	0.16	0.02	0.02
P-Value		53	16	47	69	5	62	41	43	5	86	83	97
BLSD(.05)													
		Total											
Control	-	126.5	31.3	134.4	15.1	16.5	1.1	0.46	0.27	0.39	0.23	0.06	0.06
Cu	5	138.1	31.1	138.7	16.9	17.4	1.3	0.53	0.27	0.39	0.23	0.07	0.06
B	2	132.7	31.7	139.1	15.1	16.4	1.1	0.50	0.28	0.39	0.23	0.07	0.07
S	25	130.2	31.6	133.8	15.4	16.3	1.1	0.48	0.26	0.37	0.24	0.06	0.06
Mg	75	126.9	30.2	142.9	13.6	17.0	1.1	0.48	0.26	0.36	0.23	0.06	0.06
Zn	10	131.5	29.7	132.9	16.8	16.9	1.3	0.51	0.29	0.38	0.35	0.06	0.06
Mn	3	131.1	30.7	131.2	14.0	15.9	1.2	0.50	0.25	0.36	0.22	0.06	0.06
P-Value		34	61	14	96	37	25	38	6	10	99	90	99
BLSD(.05)					2.6						0.04		0.01

EVALUATION OF FORMOLENE FOLIAR FEED N SOURCE ON POTATOES AT BECKER, 1983

W. E. Fenster, M. O'Leary and G. Buzicky

The objective of using a liquid nitrogen product is to add substantial amounts to the potato foliage when the nutrient demand is the greatest. The Formolene fertilizer (30-0-2) efficiency was compared to normal amounts of soil applied ammonium nitrate (34-0-0) on irrigated sandy textured soils. Fifty pounds per acre of N were applied during tuberization to the control plots to offset the possibility of blight spreading from the control area to the adjacent plots. All plots were replicated four times. Applications at planting time (4/22) across all plots except control based on U of M soil tests were as follows:

P_2O_5 - 150#A
K_2O - 400#A
S - 15#A
N - 20# + 60# at emergence

The U of M recommendation indicated in Table 1 had 60 pounds of N applied at tuberization. On another set of plots there was an additional 40 pounds of N applied for the plots labeled U of M Rec. + 40#.

Thus in addition to basic soil treatments for all plots (except control) the comparisons of two nitrogen sources and two rates of N were:

60# N ammonium nitrate (U of M rec.)
60# N as Formolene
100# N as Formolene
100# N as ammonium nitrate (U of M rec. + 40#)

The Formolene treatment schedule was as follows:

60# N rate of Formolene -

10# N	10 to 12 inch height	June 15
30# N	at tuberization	June 21
20# N	at canapy closure	June 30

100# N rate of Formolene -

20# N	10 to 12 inch height	June 15
30# N	at tuberization	June 21
20# N	at flowering	June 27
30# N	at canapy closure	June 30

Tuber yields in CWT per acre and percent of sample in several weight categories are shown in Table 1.

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

Table 1. Yields and size differences of potatoes comparing Formolene and ammonium nitrate fertilizers.

Treatment	Tuber Yield CWT/A	% of sample by weight (oz.) 0-3	3-6	6-9	9-12	12-16
Control	334	18	40	34	8	0
U. of M Rec.	460	9	37	34	10	10
Formolene (60#)	427	9	29	36	19	6
Formolene (100#)	458	10	30	34	20	7
U. of M. Rec. + 40# N	427	9	30	37	16	8
Significance	**					
BLSD (.05)	50					
C.V.	7.8					

Table 2. Nitrate - N (NO_3 + NO_2) in leaf plus petiole at 3 growth stages of potatoes. Becker, 1983.

1st stage 6/27 initial flowering

Treatment	Replicates I	II	III	IV	$\bar{X}$
Control	1682	423	975	491	893
U. of M. Rec.	833	726	923	578	765
Formolene (60#)	990	1009	624	1240	966
Formolene (100#)	1492	2090	1085	1172	1460
Significance					ns
BLSD (.05)					--
C.V.					40.4

2nd stage 7/11 full flower

Treatment	Replicates I	II	III	IV	$\bar{X}$
Control	1452	1822	1926	1784	1746
U. of M. Rec.	2038	1979	1848	1227	1773
Formolene (60#)	2552	1432	1440	1383	1702
Formolene (100#)	2707	2862	1753	2040	2341
Significance					ns
BLSD (.05)					--
C.V.					21.7

3rd stage 7/26 late flowering

Treatment	Replicates I	II	III	IV	$\bar{X}$
Control	413	456	302	230	350
U. of M. Rec.	339	247	379	154	280
Formolene (60#)	482	164	340	178	291
Formolene (100#)	520	1116	511	1000	787
Significance					**
BLSD (.05)					350
C.V.					49.3

Results

There was a highly significant response from foliar applied Formolene and from the ammonium nitrate soil applied over the control plot, even though some nitrogen was added to the control area. There were no significant differences in yields among nitrogen comparisons.

There was a shift to larger tuber sizes due to Formolene leaf treatments with both the 60 and 100 pounds of N as Formolene and the 100 pounds per acre ammonium nitrate treatment, (table 1). Although there was no apparent effect on tuber yield the plant tests (leaf & petiole) showed trends to higher nitrate N in the plant from the Formolene product at all three sampling dates but significant at the 5% level only on the third stage of sampling, (table 2).

1983 WEATHER

R. K. Severson

Mild temperatures during the first three months of 1983 made winter in the Red River Valley very enjoyable this year. January, February, and March average temperatures were all well above normal being +9.5°, +10.2°, and +4.7°, respectively. The area snow depth reached a maximum of 6 inches on February 20 and the depth of ground frost reached a maximum of 34 inches on February 15. With temperatures in the mid-30's during the last week of March, the snow pack was completely melted by the first week of April. The ground frost also began melting during the first week of April and the frost was out by April 29.

April and May temperatures were below normal with the average temperature for May being 4.5° cooler than normal. Precipitation for April was also 1.35 inches below normal making the early spring season less desirable for the warm season crops. June realized 1.62 inches above normal precipitation and average temperatures. A stormy period during June 12 and 13 dumped 3.09 inches of rain leaving water standing in some fields which was devastating to crops like sugarbeet. Another storm system came through June 21 and 22 dumping nearly an inch of precipitation along with strong winds and a couple of tornados producing property damage just to the east of Crookston.

July, August and September were all above normal in regard to average temperature with monthly departures from normal of +3.4°, +5.3°, and +5.3°F, respectively. July was relatively hot and dry recording 1.83 inches of precipitation which was 1.26 inches below normal. August and September were both above normal for precipitation with August at 1.67 inches and September at 0.27 inches above normal. Yet another strong storm system moved through the area on August 25 and 26 dumping 2.10 inches of precipitation together with strong winds which caused severe damage to corn and sunflower fields through lodging of the crops. October and November were above normal in regard to precipitation. October was below normal and November above normal in regard to average temperature. December marked the coldest December in the history of the Crookston weather station with an average monthly temperature of -1.8° which was 13.3° below normal. Three new low maximum daily temperature records were set during the month of December. December 12, 23, and 24 records were -12, -15, and -18°F, respectively. During the period of time from December 16 through December 25, the temperature was below zero.

The mean temperature for the year was 1.1° above normal with 4 all-time high temperature records surpassed. They occurred on 2/14, 8/8, 9/3, and 10/28 with respective temperatures of 46°, 104°, 98°, and 74°F. The last spring frost was recorded May 25 (31°) which initiated a 120-day growing season ending September 22 (31°) when the first fall frost occurred.

The precipitation for 1983 totaled 23.24 inches of which 20.88 inches were recorded as rain and 2.36 inches were contained in 35.3 inches of snow. Three record daily amounts of precipitation were also recorded in 1983 on 1/6, 6/13, and 9/15 with .25, 2.34, and 1.27 inches of precipitation recorded, respectively.

Table 1. Weather summary for 1983 with averages for precipitation and mean temperature (1890-1979).

Month	Precipitation					Mean Temperature	
	Snow	Precip.	Rain	Total	1890-1979	1983	1890-1979
	Inches					°F	
January	6.0	.36	.01	.37	.56	13.2	3.7
February	6.9	.52	.04	.56	.59	18.3	8.1
March	6.7	.64	1.40	2.04	.84	27.6	22.9
April	0.5	T	.22	.22	1.57	39.9	41.4
May	1.0	.03	2.59	2.62	2.59	50.1	54.6
June	--	--	5.18	5.18	3.56	64.3	64.4
July	--	--	1.83	1.83	3.09	73.0	69.6
August	--	--	4.57	4.57	2.90	72.7	67.4
September	--	--	2.43	2.43	2.16	56.8	51.5
October	--	--	2.13	2.13	1.43	42.6	45.3
November	8.0	.43	.48	.91	.78	29.8	26.7
December	6.2	.38	--	.38	.60	-1.8	11.5
TOTAL	35.3	2.36	20.88	23.24	20.67	40.54	39.4

STARTER FERTILIZER STUDY--SPRING WHEAT

G. E. Varvel and H. L. Meredith

Objective of Study: To compare commercially available fertilizer materials with experimental urea phosphates prepared by TVA as starter fertilizers on a highly calcareous soil.

Location: University of Minnesota, Northwest Experiment Station, Crookston, MN.

Carriers: 1) urea phosphate (17-44-0), 2) diammonium phosphate (18-46-0), 3) urea phosphate (17-44-0) + UAN solution (28-0-0) to give (13-28-0), and ammoniated phosphoric acid (10-34-0) + UAN solution (28-0-0) to also give (13-28-0).

P Rate: 50 and 100 lb P_2O_5/A.

Methods: All treatments were applied with the seed. The test variety was Marshall and all treatments (seed + fertilizer) were applied on May 4, 1983. Emergence (stand counts) were taken on June 2, 1983. Whole plant samples were taken at jointing (June 24, 1983) and maturity (August 2, 1983) for total N and ICP analyses. Whole plant samples taken at maturity (soft dough) were used to calculate N, P, and K uptake. Grain was harvested on August 12, 1983 to determine yields and subsamples were taken for test weight and protein analyses. Soil test data for the study were: pH-8.2, NO_3-N (0-2')-60 lb/A, NO_3-N (0-6')-124 lb/A, $NaHCO_3$ P (0-6")-23, and exchangeable K (0-6")-320 lb/A. The experiment was done on a Wheatville loam soil.

Table 1. The effect of starter fertilizer on elemental analyses of whole plant samples of spring wheat taken at jointing.

Treatment		Elemental Analyses								
Carrier	P_2O_5 Rate	N	P	K	Ca	Mg	Mn	Zn	Cu	B
	lb/A	%					ppm			
Check	0	2.95	0.30	2.97	0.29	0.24	52	17	7	4
17-44-0	50	3.42	0.34	3.10	0.32	0.28	59	19	8	4
	100	3.42	0.36	3.47	0.33	0.30	59	20	13	5
18-46-0	50	3.11	0.33	3.15	0.32	0.27	53	17	8	5
	100	3.04	0.34	3.46	0.33	0.27	54	19	11	5
13-28-0	50	2.77	0.31	3.10	0.27	0.23	50	17	10	4
	100	3.11	0.33	3.22	0.30	0.26	52	18	11	5
13-28-0	50	3.17	0.33	3.04	0.30	0.27	55	18	9	4
	100	3.20	0.36	3.11	0.35	0.29	55	19	8	5
Significance		N.S.	**	*	*	**	N.S.	N.S	N.S.	N.S.
B.L.S.D. (.05)			0.03	0.39	0.05	0.03				
C.V. (%)		10.6	6.3	7.1	9.0	8.1	10.7	9.3	29.3	8.3
Main Effects										
Carrier										
17-44-0		3.42	0.35	3.28	0.33	0.29	59	19	10	5
18-46-0		3.08	0.33	3.30	0.33	0.27	53	18	9	5
13-28-0		2.94	0.32	3.16	0.28	0.24	51	17	11	5
13-28-0		3.18	0.35	3.07	0.33	0.28	55	18	8	5
Significance		*	*	N.S.	**	**	N.S.	*	N.S.	N.S
P_2O_5 Rate										
lb/A										
50		3.12	0.33	3.10	0.30	0.26	54	18	9	4
100		3.19	0.35	3.31	0.33	0.28	55	19	11	5
Significance		N.S.	*	*	**	N.S.	N.S.	*	N.S.	*

Results: Elemental analyses of plant samples taken at jointing and maturity are shown in Tables 1 and 2, respectively. Significant differences in P, K, Ca, and Mg content at jointing (Table 1) were obtained when all of the treatments, including a check, were analyzed. Significant differences in N, P, Ca, Mg and Zn content were obtained between carriers and in P, K, Ca, Zn, and B content between the two rates of applied P at jointing (Table 1). No significant differences at maturity were obtained (Table 2).

Stand counts, grain yield, protein, test weight, forage yield, N, P, and K uptake at maturity are shown in Table 3. No significant differences in any of the measured variables except emergence were obtained. Emergence was significantly affected by both carrier and rate of applied P.

Discussion: Soil test levels of P and K were sufficient for maximum crop production at this location. Nitrate-N levels in the 0-2' level were low enough that a response to N would have been expected, but variability in the results negated it. Significant differences in stand were obtained, but as in previous years they did not cause or correlate with any reduction in yield. These results support those obtained in the previous two years and indicate that urea phosphates can be safely used as starter fertilizers on spring wheat at the levels tested in these studies.

Table 2. The effect of starter fertilizer on elemental analyses of whole plant samples of spring wheat taken at maturity (soft dough).

Treatment		Elemental Analyses								
Carrier	P_2O_5 Rate	N	P	K	Ca	Mg	Mn	Zn	Cu	B
	lb/A	%					ppm			
Check	0	1.61	0.30	1.07	0.11	0.17	29	25	15	2
17-44-0	50	1.66	0.27	1.07	0.12	0.17	32	23	18	2
	100	1.50	0.27	1.03	0.10	0.17	30	23	16	2
18-46-0	50	1.56	0.28	1.00	0.11	0.17	33	24	18	2
	100	1.43	0.27	1.00	0.10	0.17	30	24	16	2
13-28-0	50	1.45	0.29	0.96	0.10	0.17	33	26	20	2
	100	1.40	0.28	1.05	0.11	0.18	31	23	18	2
13-28-0	50	1.55	0.28	0.98	0.11	0.17	31	24	17	2
	100	1.53	0.29	1.05	0.12	0.17	33	25	17	2
Significance		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	.S.
C.V. (%)		10.2	7.2	11.4	13.6	7.6	9.1	9.7	12.4	18.2
Main Effects										
Carrier										
17-44-0		1.58	0.27	1.05	0.11	0.17	31	23	17	2
18-46-0		1.49	0.28	1.00	0.10	0.17	31	24	17	2
13-28-0		1.42	0.28	1.00	0.11	0.17	32	25	19	2
13-28-0		1.54	0.29	1.01	0.11	0.17	32	24	17	2
Significance		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
P_2O_5 Rate										
lb/A										
50		1.55	0.28	1.00	0.11	0.17	32	24	18	2
100		1.47	0.28	1.03	0.10	0.17	31	24	17	2
Significance		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Table 3. The effect of starter fertilizer on emergence (stand count), grain yield, protein, test weight, forage yield, N, P, and K uptake of spring wheat.

Treatment			Grain			Forage			
	P_2O_5	Stand			Test	D.M.	Uptake		
Carrier	Rate	Count	Yield	Protein	Weight	Yield	N	P	K
	lb/A	Plants/A	bu/A	%	lb/Bu	- - - - - - lb/A - - - - - - -			
Check	0	750,105	35.7	14.5	58.5	5018	82.3	14.9	54.3
17-44-0	50	881,655	49.8	15.1	58.8	7619	126.5	20.1	81.8
	100	778,850	47.2	15.0	58.9	7016	106.3	18.8	72.6
18-46-0	50	885,140	42.5	14.6	59.2	6646	104.0	18.6	67.8
	100	820,670	44.3	14.2	59.0	6441	92.0	17.5	63.6
13-28-0	50	1,014,080	38.9	14.0	58.9	5515	80.5	15.8	53.3
	100	966,160	42.2	14.0	58.2	6673	94.4	18.3	70.4
13-28-0	50	1,046,310	47.9	15.1	58.5	7425	114.9	20.7	73.0
	100	969,645	45.7	14.5	58.8	6803	104.2	19.7	71.6
Significance		**	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
B.L.S.D. (.05)		110,280							
C.V. (%)		8.6	18.2	5.7	1.2	18.8	24.9	15.1	25.6
Main Effects									
Carrier									
17-44-0		830,255	48.5	15.1	58.8	7318	116.4	19.5	77.2
18-46-0		852,905	43.4	14.4	59.1	6543	98.0	18.0	65.7
13-28-0		990,120	40.5	14.0	58.6	6094	87.4	17.0	61.9
13-28-0		1,007,980	46.8	14.8	58.6	7114	109.6	20.2	72.3
Significance		**	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
P_2O_5 Rate									
lb/A									
50		956,795	44.8	14.7	58.8	6801	106.5	18.8	69.0
100		883,830	44.8	14.4	58.7	6733	99.2	18.6	69.5
Significance		**	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

BROADCAST FERTILIZER STUDY - SPRING WHEAT

G. E. Varvel and H. L. Meredith

Objective: To evaluate experimental N carriers with varying urea content on a highly calcareous soil.

Location: University of Minnesota, Northwest Experiment Station, Crookston, MN.

Carriers: 1) Cogranulated urea-urea phosphate (38-12-0), 2) urea-ammonium phosphate (28-28-0), 3) urea phosphate (17-44-0), and 4) urea phosphate (17-44-0) + UAN (28-0-0) mixed to give (15-28-0).

N Rates: 30 and 60 lb N/A.

Methods: The treatments were applied and incorporated immediately on May 4, 1983 on a Wheatville loam soil. Phosphorus rates were equalized between all treatments with superphosphate (0-44-0). Marshall wheat was planted on the same day the treatments were applied. Emergence was evaluated on June 2, 1983 by taking stand counts. Whole plant samples were taken at jointing (June 24, 1983) and at maturity (August 2, 1983) for total N and ICP analyses. Grain was harvested on August 12, 1983 and subsamples were taken for protein and test weight determinations. Soil test data for the study were: pH-8.2, NO_3-N (0-2')-91 lb/A, $NaHCO_3P$ (0-6")-23 lb/A, and exchangeable K (0-6")-320 lb/A.

Results: Elemental analyses of plant samples taken at the jointing and soft dough (maturity) stages are shown in Tables 1 and 2, respectively. No significant differences were obtained between carriers at either sampling stage. All of the significant differences in elemental analyses shown in Tables 1 and 2 were due to increasing N rate.

Table 1. The effect of broadcast fertilizer materials on elemental analyses of whole plant samples of spring wheat taken at jointing.

Treatment		Elemental Analyses								
Carrier	N Rate	N	P	K	Ca	Mg	Mn	Zn	Cu	B
	lb/A	%					ppm			
Check	0	3.45	0.36	3.48	0.33	0.28	63	20	11	5
38-12-0	30	3.83	0.39	3.50	0.41	0.31	68	21	8	5
	60	3.92	0.42	3.52	0.44	0.35	76	25	10	5
28-28-0	30	3.69	0.37	3.60	0.36	0.31	64	21	10	5
	60	3.96	0.40	3.44	0.41	0.34	75	24	10	5
17-44-0	30	3.68	0.39	3.44	0.36	0.30	68	20	7	5
	60	3.85	0.42	3.46	0.43	0.33	75	23	9	5
15-28-0	30	3.66	0.40	3.36	0.40	0.32	68	23	13	5
	60	3.87	0.42	3.50	0.40	0.33	72	23	8	5
Significance		**	N.S.	N.S.	**	**	**	**	N.S.	N.S.
B.L.S.D. (.05)		0.30			0.06	0.03	8	3		
C.V. (%)		5.4	8.4	8.2	10.4	7.1	8.0	9.5	43.6	7.9
Main Effects										
Carrier										
38-12-0		3.87	0.40	3.51	0.43	0.33	72	23	9	5
28-28-0		3.83	0.39	3.52	0.39	0.32	70	23	10	5
17-44-0		3.76	0.40	3.45	0.40	0.32	71	21	8	5
15-28-0		3.77	0.41	3.43	0.40	0.33	70	23	10	5
Significance		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
N Rate lb/A										
30		3.71	0.39	3.48	0.38	0.31	67	21	9	5
60		3.90	0.41	3.48	0.42	0.34	74	23	9	5
Significance		**	*	N.S.	**	**	**	**	N.S.	N.S.

Table 2. The effect of broadcast fertilizer materials on elemental analyses of whole plant samples of spring wheat taken at maturity (soft dough).

Treatment		Elemental Analyses								
Carrier	N Rate	N	P	K	Ca	Mg	Mn	Zn	Cu	B
	lb/A	%					ppm			
Check	0	1.70	0.30	1.24	0.12	0.18	35	24	16	2
38-12-0	30	1.52	0.29	1.14	0.12	0.18	33	27	19	2
	60	1.72	0.27	1.30	0.13	0.19	35	23	20	2
28-28-0	30	1.66	0.29	1.18	0.11	0.18	33	24	16	2
	60	1.70	0.26	1.35	0.14	0.20	36	24	23	3
17-44-0	30	1.74	0.30	1.27	0.12	0.19	36	24	20	2
	60	1.51	0.27	1.21	0.14	0.19	37	24	23	3
15-28-0	30	1.61	0.28	1.17	0.12	0.18	32	23	19	2
	60	1.65	0.28	1.23	0.13	0.19	34	24	19	2
Significance		**	**	N.S.	N.S.	*	N.S.	N.S.	*	*
B.L.S.D. (.05)		0.11	0.02			0.02			5	1
C.V. (%)		5.0	4.9	10.8	15.1	6.4	9.4	9.6	17.0	21.5
Main Effects										
Carrier										
38-12-0		1.62	0.28	1.22	0.13	0.18	34	25	20	2
28-28-0		1.68	0.28	1.27	0.13	0.19	35	24	20	2
17-44-0		1.63	0.29	1.24	0.13	0.19	37	24	22	3
15-28-0		1.63	0.28	1.20	0.12	0.18	33	24	19	2
Significance		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
N Rate lb/A										
30		1.63	0.29	1.19	0.12	0.18	33	25	19	2
60		1.65	0.27	1.27	0.14	0.19	36	24	21	2
Significance		N.S.	**	*	**	**	N.S.	N.S.	*	N.S.

Stand count (emergence), grain yield, protein, test weight, grain N removal, forage yield, N, P, and K uptake results are shown in Table 3. Significant differences in grain yield, protein, and grain N removal were obtained between carriers. Significant differences in test weight, forage yield, N, and K uptake were obtained due to N rate.

Discussion: A significant response in grain yield was obtained when all treatments were compared to the check (Table 3). This response was expected as soil NO_3-N levels were sufficiently low, but the difference in grain yield between carriers was not expected. Forage yields (dry matter) and other measurements taken do not help explain the difference as they are essentially the same for all of the carriers. Comparison and analyses of the results from the first two years of the study with this year's results should provide additional information from which they can be evaluated.

Table 3. The effect of broadcast fertilizer materials on emergence, grain yield, protein, test weight, grain N removal, forage yield, N, P, and K uptake of spring wheat.

Treatment		Stand	Grain				Forage			
							D.M.	Uptake		
Carrier	N Rate	Count	Yield	Protein	Test Weight	N Removal	Yield	N	P	K
	lb/A	Plants/A	Bu/A	%	lb/Bu	lb/A	lb/A	- - - lb/A - - -		
Check	0	1,032,895	44.8	14.5	58.0	67.8	6508	111.0	18.9	81.8
38-12-0	30	1,000,140	53.7	14.2	58.3	79.6	7504	114.9	21.7	85.2
	60	1,033,590	54.7	15.3	58.0	88.1	8010	138.1	21.8	104.3
28-28-0	30	1,007,110	48.9	15.2	58.4	78.4	7375	122.2	21.5	87.2
	60	1,052,410	48.7	14.9	57.3	76.3	7820	133.0	20.6	105.9
17-44-0	30	1,028,020	47.7	14.9	57.8	74.5	7092	123.2	21.1	88.6
	60	1,058,680	51.2	14.5	58.0	78.2	7892	119.3	21.6	96.1
15-28-0	30	1,057,985	52.5	14.2	58.4	77.8	7547	121.2	21.5	87.9
	60	1,039,865	51.2	13.6	57.8	73.0	7762	128.0	22.0	95.1
Significance		N.S.	**	N.S.	N.S.	**	N.S.	N.S.	N.S.	N.S.
B.L.S.D. (.05)			4.7			9.8				
C.V. (%)		6.9	6.9	5.6	1.1	8.9	10.6	11.8	11.2	16.6
Main Effects										
Carrier										
38-12-0		1,016,865	54.2	14.7	58.2	83.9	7757	126.5	21.7	94.8
28-28-0		1,029,760	48.8	15.1	57.8	77.3	7597	127.6	21.1	96.5
17-44-0		1,043,350	49.5	14.7	57.9	76.4	7492	121.3	21.3	92.3
15-28-0		1,048,925	51.9	13.9	58.1	75.4	7655	124.6	21.7	91.5
Significance		N.S.	**	*	N.S.	*	N.S.	N.S.	N.S.	N.S.
N Rate lb/A										
30		1,023,310	50.7	14.6	58.2	77.6	7380	120.4	21.4	87.2
60		1,046,135	51.5	14.6	57.8	78.9	7871	129.6	21.5	100.3
Significance		N.S.	N.S.	N.S.	*	N.S.	*	*	N.S.	**

HIGH PHOSPHORUS AND POTASSIUM RATES ON CONTINUOUS SPRING WHEAT

G. E. Varvel and R. K. Severson

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. The experiment was located on a Wheatville loam soil.

Experimental procedure:
Ten treatments consisting of P and K combinations have been used. Treatment combinations and applications made to date are shown in Table 1. Treatments applied in the fall of 1983 were broadcast and plowed down. Nitrogen, as urea, was spring applied at 70 lb N/A and incorporated with a field cultivator on April 27, 1983. Marshall wheat was planted on April 27, 1983 and harvested for grain yields on August 8, 1983. Whole plant samples were taken at jointing (June 24, 1983) and soft dough (August 1, 1983) for elemental analyses. Samples taken at soft dough (maturity) were used to determine forage yields and N, P, and K uptake. Soil samples were taken after crop removal to measure the residual effects of the treatments.

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

Treatment No.	Application Date			
	Spring 1980	Fall 1980	Fall 1981	Fall 1982
	P_2O_5 (lb/A) + K_2O (lb/A)			
1	0 + 0	0 + 0	0 + 0	0 + 0
2	0 + 100	0 + 100	0 + 100	0 + 100
3	50 + 100	50 + 100	50 + 100	50 + 100
4	100 + 100	100 + 100	100 + 100	100 + 100
5	150 + 100	0 + 100	0 + 100	150 + 100
6	100 + 0	100 + 0	100 + 0	100 + 0
7	100 + 50	100 + 50	100 + 50	100 + 50
8	100 + 150	100 + 0	100 + 0	100 + 150
9	150 + 100	0 + 0	0 + 0	0 + 0
10	100 + 150	0 + 0	0 + 0	0 + 0

Results:
Elemental analyses of the whole plant samples taken at jointing and soft dough are shown in Tables 2 and 3 respectively. Significant differences in N, P, K, Mg, Zn, and B at jointing (Table 2) and in N and P at maturity (Table 3) were obtained between treatments.

Grain yield, protein, test weight, forage yield, N, P, and K uptake values shown in Table 4 indicate that only protein and P uptake were affected by the treatments.

Soil test results from the fall of 1983 sampling date are shown in Table 5. Samples were analyzed by both the University of Minnesota and North Dakota State University soil testing laboratories. Significant differences in residual P and K levels were obtained by both labs.

Discussion:
The importance of plant sampling being done early is shown in Tables 2 and 3. Plant samples taken at jointing (Table 2) or earlier do a good job of reflecting plant nutrient status while those taken at soft dough (Table 3) are generally too late to indicate anything about plant nutrient status during the growing season. These results agree with those from previous years and also with recommendations in the literature. The results in Table 2 indicate that the P and K being applied are being taken up by the plant but the lack of yield response (Table 4) indicates that neither P or K were limiting in 1983.

Soil test results in the fall of 1983, after 4 years of fertilization and cropping, indicate that soil test levels are being built up (Table 5). This build up has occurred in all cases where fertilizer has been applied, but no reduction in soil test levels has occurred where no fertilizer has been applied.

Table 2. Effect of P and K rate combinations on the elemental analyses of whole plant samples of spring wheat taken at jointing.

Treatment[1/] No.	Elemental Analyses N	P	K	Ca	Mg	Mn	Zn	Cu	B
	%					ppm			
1	3.53	0.32	3.53	0.33	0.30	56	25	9	5
2	3.50	0.32	3.85	0.32	0.25	56	25	9	5
3	3.09	0.40	3.93	0.29	0.25	55	19	4	4
4	3.09	0.42	3.85	0.27	0.25	57	19	7	4
5	3.30	0.41	3.96	0.32	0.24	52	19	5	4
6	3.18	0.40	3.26	0.29	0.29	57	18	8	4
7	3.15	0.42	3.70	0.30	0.26	57	20	7	4
8	2.94	0.40	3.56	0.30	0.24	51	18	5	4
9	3.29	0.36	3.30	0.31	0.27	53	22	7	4
10	3.36	0.36	3.60	0.32	0.27	57	22	6	5
Significance	**	**	**	N.S.	**	N.S.	**	N.S.	**
B.L.S.D. (.05)	0.24	0.03	0.28		0.04		4		1
C.V. (%)	5.0	5.8	5.3	12.0	8.7	9.2	12.2	56.7	9.1

1/ Corresponds to treatments shown in Table 1.

Table 3. Effect of P and K rate combinations on the elemental analyses of whole plant samples of spring wheat taken at maturity (soft dough).

Treatment No.	Elemental Analyses N	P	K	Ca	Mg	Mn	Zn	Cu	B
	%					ppm			
1	1.55	0.27	1.23	0.13	0.19	40	30	12	3
2	1.49	0.27	1.39	0.13	0.17	34	32	15	3
3	1.30	0.28	1.29	0.12	0.17	37	22	10	2
4	1.38	0.29	1.21	0.11	0.17	39	26	17	2
5	1.34	0.28	1.31	0.13	0.16	35	26	14	2
6	1.37	0.29	1.15	0.12	0.18	39	23	15	2
7	1.43	0.29	1.23	0.12	0.16	37	22	13	2
8	1.35	0.28	1.22	0.13	0.17	32	22	14	2
9	1.42	0.27	1.18	0.12	0.17	36	22	6	2
10	1.50	0.28	1.32	0.13	0.17	37	22	6	3
Significance	**	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
B.L.S.D. (.05)	0.14	0.02							
C.V. (%)	6.0	4.4	8.5	12.4	7.9	9.5	22.7	72.3	16.1

Table 4. Effect of P and K rate combinations on grain yield, protein, test weight, forage yield, N, P, and K uptake.

Treatment No.	Grain Yield	Grain Protein	Grain Test Weight	Forage D.M. Yield	Forage Uptake N	Forage Uptake P	Forage Uptake K
	Bu/A	%	lb/Bu	lb/A	lb/A	lb/A	lb/A
1	46.1	14.1	59.9	6599	103.0	17.8	82.6
2	47.7	13.9	60.0	6964	103.9	18.5	98.0
3	46.4	12.8	60.2	7177	93.6	19.9	94.0
4	48.6	13.0	59.6	7478	102.9	21.9	91.1
5	48.4	13.0	60.0	7562	102.0	21.1	100.1
6	46.6	12.9	60.0	7247	99.9	21.1	83.8
7	48.3	13.0	59.9	7172	102.7	21.0	88.2
8	51.4	12.8	60.2	7803	105.5	21.7	95.9
9	45.5	13.2	59.4	7328	104.7	19.9	86.7
10	50.3	13.5	59.9	7320	110.2	20.2	98.3
Significance	N.S.	**	N.S.	N.S.	N.S.	*	N.S.
B.L.S.D. (.05)		0.8				2.9	
C.V. (%)	7.3	3.6	0.8	8.5	11.0	8.2	13.1

Table 5. Effect of P and K rate combinations on residual P and K soil test levels after four years of application as determined by two soil testing laboratories.

Treatment No.	North Dakota State Univ. $NaHCO_3$ P 0-6"	North Dakota State Univ. $NaHCO_3$ P 6-12"	North Dakota State Univ. Exchangeable K 0-6"	North Dakota State Univ. Exchangeable K 6-12"	University of Minnesota Bray P-1 10:1 0-6"	University of Minnesota Bray P-1 10:1 6-12"	University of Minnesota Bray P-1 50:1 0-6"	University of Minnesota Bray P-1 50:1 6-12"	University of Minnesota $NaHCO_3$ P 0-6"	University of Minnesota $NaHCO_3$ P 6-12"	University of Minnesota Exchangeable K 0-6"	University of Minnesota Exchangeable K 6-12"
	lb/A	lb/A	lb/A	lb/A	lb/A	lb/A	lb/A	lb/A	lb/A	lb/A	lb/A	lb/A
1	12	7	284	224	11	4	49	28	10	6	263	227
2	13	8	336	258	24	15	55	36	10	7	321	250
3	30	17	324	264	43	21	96	54	25	14	302	255
4	54	25	393	274	43	17	149	69	44	21	307	263
5	39	22	333	250	52	22	116	61	33	19	319	265
6	48	23	259	216	33	12	109	46	39	20	251	218
7	43	27	288	238	55	28	128	68	36	23	273	250
8	53	32	328	274	70	36	148	76	43	25	309	280
9	20	12	258	203	31	16	78	39	16	9	273	241
10	17	10	274	215	33	20	76	44	14	8	255	231
Significance	**	**	**	**	**	*	**	**	**	**	**	**
B.L.S.D.(.05)	6	5	52	38	25	18	19	15	5	4	30	26
C.V. (%)	14.1	21.9	11.6	10.3	41.9	55.8	14.4	20.7	13.0	20.6	7.3	7.0

SOIL TEST LEVELS AND CROP QUALITY AS AFFECTED BY DIFFERENT FERTILIZER PROGRAMS IN A CONTINUOUS WHEAT CROPPING SYSTEM

G. E. Varvel and R. K. Severson

The objective of this study was to measure the effects of different fertilizer programs, so called maintenance versus build, over a 10-year period on soil test levels and crop quality in a continuous wheat cropping system. Soil test and crop quality measurements are taken to provide information for evaluation and determination of the most effective program. The study was originated in the spring of 1978.

Experimental Procedure: Five treatments with 4 replications were arranged in a randomized complete block design. Each of the 5 fertilizer treatments was based upon soil test data from the plots on which that treatment had been applied to in the previous years. All of the treatments were applied in the fall of 1982 and plowed down. Marshall wheat was planted April 27, 1983 and harvested August 8, 1983. Whole plant samples were taken at jointing (June 24, 1983) and at maturity (August 1, 1983) for elemental analyses. Whole plant samples taken at maturity (soft dough) were used to determine forage yields and to calculate N, P, and K uptake. Soil samples were taken after crop removal to measure the effects of the treatments and to establish the 1984 treatments.

Results: The effects of the treatments on the elemental analyses at jointing and maturity are shown in Tables 1 and 2. Significant differences in N, P, Ca, Mg, and Cu at jointing (Table 1) and Zn and B at maturity (Table 2) were obtained between the treatments. The grain and forage results are shown in Table 3 and all the measured variables were significantly affected by the treatments.

Soil test results from the fall of 1983 are shown in Table 4. The results shown in Table 4 indicate NO_3-N levels at the various depths and total NO_3-N for the 0-2' and 0-5' depths after 6 years of cropping under the various fertilizer programs. Significant differences in NO_3-N in the 0-1', 1-2', 2-3', 0-2', and 0-5' depths were obtained. Table 4 also contains P and K soil test results for samples taken from the 0-6" and 6-12" depths. Significant differences in residual P at both depths and residual K in the 0-6" depth were obtained.

Discussion:
All of the fertilizer programs have increased yields and some soil test levels over those of the check. The differences in yield have largely been due to the applied N, while P and K have increased soil test P and K levels only.

Table 1. The effects of five fertilizer programs on the elemental analyses of whole plant samples taken at jointing of spring wheat.

Treatment			Elemental Analyses								
N	P_2O_5	K_2O	N	P	K	Ca	Mg	Mn	Zn	Cu	B
- - - lb/A - - -			- - - - - - - - - % - - - - - - - - -					- - - - - - ppm - - - - - -			
0	0	0	3.25	0.32	3.54	0.31	0.29	64	33	9	5
90	30	40	2.93	0.35	3.57	0.28	0.26	58	28	8	5
90	30	55	2.70	0.34	3.68	0.26	0.25	57	25	8	5
100	30	40	3.53	0.36	3.42	0.35	0.30	63	32	9	5
90	40	40	3.52	0.39	3.70	0.34	0.32	62	30	11	5
Significance			**	**	N.S.	*	**	N.S.	N.S.	**	N.S.
B.L.S.D. (.05)			0.30	0.02		0.08	0.03			1	
C.V. (%)			6.3	4.6	5.6	14.6	7.2	5.7	11.8	10.1	8.3

Table 2. The effects of five fertilizer programs on the elemental analyses of whole plant samples taken at maturity (soft dough) of spring wheat.

Treatment			Elemental Analyses								
N	P_2O_5	K_2O	N	P	K	Ca	Mg	Mn	Zn	Cu	B
lb/A			%					ppm			
0	0	0	1.55	0.28	1.12	0.10	0.16	37	37	16	2
90	30	40	1.61	0.28	1.20	0.10	0.17	36	30	16	2
90	30	55	1.51	0.28	1.21	0.10	0.17	36	29	17	2
100	30	40	1.70	0.27	1.24	0.13	0.18	37	32	16	4
90	40	40	1.67	0.25	1.24	0.13	0.18	34	30	19	3
Significance			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	**	N.S.	*
B.L.S.D. (.05)									4		1
C.V. (%)			6.6	8.5	9.3	20.2	9.0	6.7	7.9	16.3	28.8

Table 3. The effects of five fertilizer programs on grain yield, test weight, protein, grain N removal, forage yield, N, P, and K uptake of spring wheat.

Treatment			Grain				Forage			
								Uptake		
N	P_2O_5	K_2O	Yield	Test Weight	Protein	N Removal	D.M. Yield	N	P	K
lb/A			Bu/A	lb/Bu	%	lb/A	lb/A			
0	0	0	36.9	59.1	13.9	54.4	5564	86.2	15.2	62.1
90	30	40	46.6	59.6	14.5	71.5	6582	105.8	18.4	78.7
90	30	55	46.1	59.9	14.8	72.2	6333	96.1	17.7	77.3
100	30	40	51.9	57.4	15.5	84.8	7076	120.3	18.9	88.0
90	40	40	47.6	56.9	15.6	78.3	7418	123.8	18.5	91.1
Significance			*	**	**	*	*	**	**	*
B.L.S.D. (.05)			10.5	7.1	0.9	18.3	1150	23.4	2.1	20.8
C.V. (%)			13.4	1.7	4.0	15.3	10.6	13.6	7.3	15.4

Table 4. The effects of five fertilizer programs on residual NO_3-N, P, and K soil test levels after six years in a continuous wheat cropping system.

Treatment			Soil Test Levels										
			NO_3-N							$NaHCO_3$ P		Exchangeable K	
N	P_2O_5	K_2O	0-1'	1-2'	2-3'	3-4'	4-5'	0-2'	0-5'	0-6"	6-12"	0-6"	6-12"
lb/A			lb/depth					lb/A		lb/A			
0	0	0	19	14	17	18	18	33	84	11	7	270	206
90	30	40	17	12	15	22	19	29	84	24	15	260	211
90	30	55	18	10	16	23	20	28	87	25	15	320	244
100	30	40	38	30	41	28	23	68	159	22	15	245	213
90	40	40	39	27	31	25	19	66	141	32	19	243	200
Significance			*	*	*	N.S.	N.S.	*	*	**	**	**	N.S.
B.L.S.D. (.05)			17	14	18			30	58	3	5	47	
C.V. (%)			40.1	46.2	45.9	42.7	37.4	41.7	31.6	9.1	21.5	10.7	10.5

COMPARISON OF TWELVE HARD RED SPRING WHEAT VARIETIES TO NITROGEN FERTILIZATION - CROOKSTON 1983

S. Comfort, G. Malzer, R. Busch, and G. Varvel

Introduction

Maximizing the benefits of nitrogen fertilization depends largely on the responsiveness of the individual plant. Spring wheat genotypes, as with many other crops, differ considerably in growth response to increases in nitrogen fertilizer. The reason why some wheat varieties respond more to nitrogen fertilization than others in not well understood, but it has been suggested that it may be related to favorable plant characteristics both above and below the ground. The general objective of this study was to evaluate twelve spring wheat varieties under three different nitrogen rates. More specifically the study intended to determine which varieties continued to show an increase in growth to added nitrogen and also which varieties performed better within an individual nitrogen rate. It was hoped that knowledge of varietal performances over a range of growing seasons would 1) aid in more efficient use of nitrogen fertilizer for a specific variety and 2) aid in determining which varieties' morphological and physiological characteristics should be more critically examined.

Experimental Procedures

Twelve varieties of hard red spring wheat were compared at 0, 67, and 137 Kg/ha at the Northwest Experimental Station at Crookston, Minn. Nitrogen was applied as a spring application of ammonium nitrate broadcast and incorporated. The field experiment was arranged as split plot design with nitrogen rates as the whole plot treatments and varieties as the subplot treatments. Varieties were planted in an area 5' x 20' utilizing a cone seeder. Each treatment was replicated four times.

Total plant dry matter production was determined at approximately the "soft dough" stage of growth and samples were collected for nitrogen content and calculation of nitrogen uptake. Yield grain was harvested with a 3 row grain binder from a 14 ft.^{2} area. The above ground growth (grain and straw) was removed from the experimental plot and placed in a forced air dryer. After drying, the samples were thrashed and the grain reweighed for yield determination. Straw weight was determined by difference. Samples of both straw and grain were collected and analyzed for nitrogen content and determination of nitrogen removal.

General Results

As was to be expected, all varieties did not respond in a similar manner to increasing rates of nitrogen fertilization. Consequently, a significant nitrogen rate x variety interaction was observed for all response parameters. Significant interaction of main effects necessitates the need to analyze 1) varietal differences within each nitrogen rate and 2) responsiveness of each variety to nitrogen fertilization. With this criteria, varietal comparisons can be made from Table 1. With respect to yield, Butte, Mn73168, and James had the highest yield at the zero N rate, while Butte, Mn7222, and Marshall were among the highest yeilding at the 67 kg N/ha rate of application, with James, Coteau, and Era leading the group when 134 kg N/ha was applied. At the highest N rate Coteau also removed the largest amount of N with the grain.

Table 2 allows for analysis of the ability of each variety to continue to respond to nitrogen fertilizer application. Two kinds of varieties are apparent from this table: 1) those which only significantly responded to the first increment in nitrogen fertilization; and 2) those which continued to respond from the 67 to 134 kg N/ha rate of application. The grain yields of all varieties except Olaf significantly increased with the first increment of fertilization. There was no significant increase in grain yield with any variety going from the 67 to 134 kg N/ha rate of application.

The variety James, however, reflected the largest grain yield increase with the second N increment. The second increment of N fertilization also increased nitrogen removal with the forage for Coteau, Marshall, and Olaf.

Table 1. Comparison of yield, N content, and N removal for forage, straw, and grain at 3 nitrogen rates on 12 varieties of hard red spring wheat. Location: Crookston, MN 1983.

		FORAGE			STRAW			GRAIN		
	N rate	YIELD	N CONT	N REMOV	YIELD	N CONT	N REMOV	YIELD	N CONT	N REMOV
	kg ha^{-1}	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}
Butte	0	7.15	14.2	103.3	3.48	3.68	13.0	2.42	23.8	58.7
Coteau	0	4.80	13.5	65.9	2.72	3.95	10.7	1.96	29.8	59.3
Era	0	5.04	13.3	67.3	2.30	4.38	10.2	2.00	23.8	48.2
Marshall	0	5.14	14.3	75.5	2.35	4.43	10.4	2.07	25.8	53.7
Mn 7125	0	5.38	13.0	70.2	2.25	4.33	9.6	1.77	21.9	38.5
Mn 7222	0	3.95	13.8	54.5	1.86	4.48	8.2	1.90	23.1	43.9
Olaf	0	4.98	15.8	78.5	3.30	6.13	20.7	2.01	27.9	56.5
Thatcher	0	3.56	13.0	46.5	2.09	4.55	9.5	1.28	25.6	32.9
Mn 7357	0	4.20	13.9	58.4	2.23	6.15	13.9	1.81	22.4	40.2
Mn 73167	0	4.69	13.8	64.4	1.67	5.73	9.5	1.63	21.1	36 3
Mn 73168	0	5.58	15.0	84.0	2.65	6.65	17.6	2.37	23.4	55.6
James	0	5.67	15.5	87.3	3.23	3.15	12.8	2.30	27.9	64.2
HSD (.05)*		2.19	2.8	45.0	1.30	1.85	12.0	0.80	3.9	23.7
(.10)		2.02	2.6	41.4	1.19	1.70	11.0	0.74	3.6	21.8
Butte	67	10.15	13.7	139.7	5.06	3.83	19.8	3.77	24.5	92.5
Coteau	67	9.38	14.4	135.7	5.64	3.75	21.3	3.41	30.3	103.5
Era	67	8.66	14.1	121.9	4.21	4.33	18.5	3.40	22.8	77.6
Marshall	67	8.54	14.4	124.2	4.41	4.30	18.9	3.46	24.4	84.7
Mn 7125	67	8.73	12.9	113.2	4.37	5.50	23.8	3.36	23.7	79.6
Mn 7222	67	9.00	14.8	133.0	4.47	5.35	23.7	3.66	23.9	87.0
Olaf	67	8.75	14.5	126.4	4.89	5.05	24.7	2.63	26.4	69.4
Thatcher	67	8.91	13.3	117.9	5.01	4.80	23.9	2.63	25.1	66.1
Mn 7357	67	9.11	14.3	130.6	4.76	5.38	25.5	3.39	22.6	76.7
Mn 73167	67	9.95	13.9	138.6	4.93	5.00	24.6	3.36	22.3	75.1
Mn 73168	67	8.62	13.4	115.4	4.42	5.25	23.0	3.08	22.1	67.9
James	67	8.56	15.3	130.6	5.13	5.28	26.5	3.21	25.4	81.8
HSD (.05)*		2.19	2.8	45.0	1.30	1.85	12.0	0.80	3.9	23.7
(.10)		2.02	2.6	41.4	1.19	1.70	11.0	0.74	3.6	21.8
Butte	134	9.78	16.2	157.8	5.34	5.35	28.3	3.51	27.3	95.6
Coteau	134	10.51	16.0	168.1	6.29	5.60	35.4	3.57	31.0	110.6
Era	134	9.08	15.9	144.4	4.78	6.03	29.0	3.52	26.0	91.5
Marshall	134	10.21	16.2	164.2	4.98	6.35	31.6	3.43	28.4	97.1
Mn 7125	134	8.92	14.8	132.2	4.65	7.30	34.0	3.32	24.6	81.6
Mn 7222	134	8.56	14.9	127.6	4.10	6.83	28.3	2.90	27.7	80.0
Olaf	134	10.47	16.3	171.0	5.73	7.00	40.2	2.94	28.9	85.3
Thatcher	134	9.43	14.8	139.2	5.48	6.28	34.5	2.76	27.4	75.7
Mn 7357	134	8.53	16.7	142.9	5.17	7.20	37.1	2.99	28.7	84.2
Mn 73167	134	10.20	15.9	162.5	5.31	7.75	41.2	3.49	27.0	93.6
Mn 73168	134	9.33	15.8	146.7	5.29	8.03	42.7	3.06	27.3	82.2
James	134	9.97	14.9	148.8	5.46	6.10	33.2	3.72	26.9	99.9
HSD (.05)*		2.19	2.8	45.0	1.30	1.85	12.0	0.80	3.9	23.7
(.10)		2.02	2.6	41.4	1.19	1.70	11.0	0.74	3.6	21.8

*HSD values for comparison of variety means within one nitrogen rate.

Table 2. Comparison of means for nitrogen rates within one variety for forage, straw and grain. Crookston, Mn. 1983.

		------Forage------			-------Straw------			------Grain------		
VARIETY	N RATE	YIELD	N CONT	N REMOV	YIELD	N CONT	N REMOV	YIELD	N CONT	N REMOV
	kg/ha	Mg/ha	g/kg	kg/ha	Mg/ha	g/kg	kg/ha	Mg/ha	g/kg	kg/ha
Butte	0	7.15	14.2	103.3	3.48	3.68	13.0	2.42	23.8	58.7
	67	10.15	13.7	139.7	5.16	3.83	19.8	3.77	24.5	92.5
	134	9.78	16.2	157.8	5.34	5.35	28.3	3.51	27.3	95.6
Coteau	0	4.80	13.5	65.9	2.72	3.95	10.7	1.96	29.8	59.3
	67	9.38	14.4	135.7	5.64	3.75	21.3	3.41	30.3	103.5
	134	10.51	16.0	168.1	6.29	5.60	35.4	3.57	31.0	110.6
Era	0	5.04	13.3	67.3	2.30	4.38	10.2	2.00	23.8	48.2
	67	8.66	14.1	121.9	4.22	4.33	18.5	3.40	22.8	77.6
	134	9.08	15.9	144.4	4.78	6.03	29.0	3.52	26.0	91.5
Marshall	0	5.14	14.3	75.5	2.35	4.43	10.4	2.07	25.8	53.7
	67	8.54	14.4	124.2	4.41	4.30	18.9	3.46	24.4	84.7
	134	10.21	16.2	164.2	4.98	6.35	31.6	3.43	28.4	97.1
Mn 7125	0	5.38	13.0	70.2	2.25	4.33	9.6	1.77	21.9	38.5
	67	8.73	12.9	113.2	4.37	5.50	23.8	3.36	23.7	79.6
	134	8.92	14.8	132.2	4.65	7.30	34.0	3.32	24.6	81.6
Mn 7222	0	3.95	13.8	54.5	1.86	4.48	8.2	1.90	23.1	44.0
	67	9.00	14.8	133.0	4.47	5.35	23.7	3.66	23.9	87.0
	134	8.56	14.9	127.6	4.10	6.83	28.3	2.90	27.7	80.0
Olaf	0	4.98	15.8	78.5	3.30	6.13	20.7	2.01	27.9	56.5
	67	8.75	14.4	126.4	4.89	5.05	24.7	2.63	26.4	69.4
	134	10.47	16.3	171.0	5.73	7.00	40.2	2.94	29.0	85.3
Thatcher	0	3.56	13.0	46.5	2.09	4.55	9.5	1.28	25.6	32.9
	67	8.91	13.2	117.9	5.01	4.80	23.9	2.63	25.1	66.1
	134	9.43	14.8	139.2	5.48	6.28	34.4	2.76	27.4	75.7
Mn 7357	0	4.20	13.9	58.4	2.23	6.15	13.9	1.81	22.4	40.2
	67	9.11	14.3	130.6	4.76	5.38	25.5	3.39	22.6	76.7
	134	8.53	16.7	142.9	5.17	7.20	37.1	3.00	28.7	84.2
Mn 73167	0	4.69	13.8	64.4	1.67	5.73	9.5	1.63	22.1	36.3
	67	9.94	13.9	138.6	4.93	5.00	24.6	3.36	22.3	75.1
	134	10.20	15.9	162.5	5.31	7.75	41.2	3.49	27.0	93.6
Mn 73168	0	5.58	15.0	84.0	2.65	6.65	17.6	2.37	23.4	55.6
	67	8.62	13.4	115.4	4.42	5.25	23.0	3.08	22.1	67.9
	134	9.33	15.8	146.7	5.29	8.03	42.7	3.06	27.3	82.2
James	0	5.67	15.5	87.3	3.23	3.95	12.8	2.30	27.9	64.2
	67	8.56	15.3	130.6	5.13	5.28	26.5	3.22	25.4	81.8
	134	9.97	14.9	148.8	5.46	6.10	33.2	3.72	26.9	99.9
BSD(.05)*		1.55	2.7	31.8	1.05	1.99	11.0	0.68	4.3	18.1

*BSD values for comparison of nitrogen means for one variety

EFFECTS OF HIGH NITROGEN RATES IN STARTER FERTILIZERS ON SPRING WHEAT

G. E. Varvel and R. K. Severson

Many studies have been done at various locations to determine how much N can be applied with the seed of various crops at planting time. This study was initiated in 1982 because results from other trials at Crookston had indicated that fairly high N rates could be applied with the seed of spring wheat without reducing germination or yield.

Experimental Procedure:

Three materials, urea (46-0-0), diammonium phosphate (18-46-0), and urea phosphate (17-44-0) were used in the study. One check treatment, four rates of urea (45, 60, 80 and 100 lb N/A) and one rate each of DAP (55 lb N/A) and urea phosphate (40 lb N/A) were randomized in a complete block design with four replications. Marshall wheat was planted along with the various N treatments on May 4, 1983 and harvested on August 12, 1983. Emergence (stand counts) were taken on June 2, 1983. Soil test results for the study were: pH-8.2, $NaHCO_3$ P-21 lb/A, exchangeable K-320 lb/A, and NO_3-N (0-2')-56 lb/A.

Results:

Stand count (emergence) was significantly reduced when N rates with the seed were 80 lb/A or greater with urea. No reduction in emergence was obtained with either the DAP or urea phosphate at the N rates used in this study. A significant yield increase was obtained when treatments were compared to the check, except when urea was applied at 100 lb N/A. At that point, the stand count had been reduced enough to affect yield. Test weight was significantly reduced with each successive rate of urea, which is consistent with other N rate studies. Test weight was not significantly different from the check for the DAP or urea phosphate treatments. No significant differences in protein or grain N removal were obtained, but trends indicated higher protein and N removal with the N treatments.

Discussion:

Results indicated that higher levels of N fertilizer in starters may be used at planting time on spring wheat on the medium to heavy textured soils of the Red River Valley than had previously been recommended. Emergence was reduced, but not until levels far above current recommendations were reached. These results will permit greater flexibility in N recommendation programs for spring wheat.

Table 1. The effects of starter fertilizers with high N levels on emergence, grain yield, protein, test weight, and grain N removal.

Treatment		Stand	Grain			
Source	N Rate	Count	Yield	Protein	Test Weight	N Removal
	lb/A	Plants/A	Bu/A	%	lb/Bu	lb/A
Check	0	722,225	39.3	16.3	59.0	61.9
Urea	45	737,035	48.9	16.3	59.3	76.6
	60	830,255	49.8	16.6	58.7	79.6
	80	663,855	47.6	16.8	57.7	76.8
	100	553,212	43.3	17.3	56.9	71.8
18-46-0	55	775,370	50.4	16.1	58.9	78.3
17-44-0	40	703,060	48.7	16.1	59.3	75.3
Significance		**	+	N.S.	**	N.S.
B.L.S.D. (.05)		12,430	9.1		1.0	
C.V. (%)		11.1	11.0	3.9	1.2	13.8

EFFECTS OF NITROGEN AS UREA IN STARTER FERTILIZER ON SPRING BARLEY

G. E. Varvel and R. K. Severson

This study was initiated because results from other trials at Crookston had indicated that fairly high N rates could be used in starter fertilizers without reducing germination or yield of spring barley on soils of the Red River Valley.

Experimental Procedure:
Six rates of N (0, 45, 60, 75, 85, 100 lb/A) as urea were randomized in a complete block design with four replications. Robust barley was seeded with the various treatments shown above on May 5, 1983. Emergence (stand counts) were taken on June 2, 1983. Grain was harvested on August 8, 1983 and subsamples were used to determine test weight, protein content, and percentage plump kernels. Soil test results for the study were: pH-8.2, $NaHCO_3$ P-22 lb/A, exchangeable K-275 lb/A, and NO_3-N (0-2')-53 lb/A.

Results:
The effects of the treatments are shown in Table 1. Significant differences in stand count, grain yield, test weight, and N removal were obtained between the treatments. Stand count and test weight were both significantly reduced while grain yield and N removal increased up to their maximum with the 75 lb/A N rate and then decreased with additional N.

Discussion:
The use of urea as a starter fertilizer was not as detrimental as had been expected. Stand count (emergence) was reduced, but it did not become critical until N rates in excess of 75 lb/A were used. This level is far above any that have been recommended in the literature. These findings indicate that urea can be used as a starter fertilizer on spring barley when N rates of 50-60 lb/A or less are needed. These results coincide with those obtained in a starter fertilizer study that has been conducted at Crookston during the last three years on spring wheat. These findings should allow greater flexibility when fertilizer recommendations are being made.

Table 1. The effects of N as urea in starter fertilizer on emergence (stand counts), grain yield, test weight, protein, plump kernels, and N removal of spring barley.

		Grain				
N Rate	Stand Count	Yield	Test Weight	Protein	Plump Kernels	N Removal
lb/A	Plants/A	Bu/A	lb/Bu	%	%	lb/A
0	547,985	32.8	46.4	13.9	88	35.3
45	459,995	52.1	46.6	14.5	86	57.6
60	461,735	47.6	46.1	15.3	88	55.7
75	363,290	52.2	45.5	15.5	87	61.9
85	339,770	41.0	44.6	15.3	86	48.2
100	315,375	32.8	42.3	16.3	87	41.1
Significance	*	**	**	N.S.	N.S.	**
B.L.S.D. (.05)	150,850	9.0	1.2			10.7
C.V. (%)	22.0	14.1	1.8	7.7	3.0	14.4

EFFECTS OF NITROGEN RATE AND PLACEMENT ON THREE MALTING BARLEY VARIETIES

G.E. Varvel and R.K. Severson

The importance of malting barley in northwestern Minnesota has generated the need for additional information on N fertilization with the release of new higher yielding varieties. The higher yield potential of these varieties is due in part to greater straw strength and disease resistance which may allow higher levels of N fertilization. This study was established in 1981 to evaluate two varieties, Morex and Glenn, under various N management programs. Robust, a new variety released in the spring of 1983, has been included in this year's study.

Experimental Procedure:
The treatments consisted of N from UAN solution (28-0-0) at rates of 0, 50, 100, and 150 lb/A both surface applied (broadcast) and injected (6 inches deep, 12 inches apart) on three malting barley varieties in a factorial arrangement. A randomized complete block design with four replications was used. Soil test results for the experiment were: NO_3-N (0-2')-60 lb/A, $NaHCO_3$ P-20 lb/A, and exchangeable K-420 lb/A.

The fertilizer treatments were applied and the varieties planted on May 2, 1983. Whole plant samples were taken at jointing (June 20, 1983) and soft dough (July 25, 1983) for N analyses. The samples taken at soft dough (maturity) were used to calculate forage yield and N uptake. Grain was harvested August 1, 1983 for yield and quality determinations (protein, bushel weight, percent plump kernels). Harvest index (HI) was calculated as the ratio of grain yield to forage yield and nitrogen harvest index (NHI) was calculated as the ratio of total grain N content to N content of the forage.

Table 1. The effects of variety, N rate, and N placement on early plant N, forage yield, forage N content, N uptake, grain yield, test weight, protein content, plump kernels, N removal, HI and NHI of malting barley.

		Forage			Grain						
Variety	N[1/]	D.M. Yield	N[2/]	N Uptake	Yield	Test Weight	Protein[3/]	Plump Kernels	N Removal	HI	NHI
	%	lb/A	%	lb/A	Bu/A	lb/Bu	%	%	lb/A		
Morex	3.38	6057	1.33	80.9	50.3	44.3	12.1	77	47.0	0.41	0.60
Glenn	3.18	6458	1.33	86.6	53.1	44.1	11.8	81	48.4	0.41	0.59
Robust	3.31	6630	1.34	89.5	55.2	47.0	12.6	89	53.9	0.40	0.62
Significance	**	**	N.S.	*	**	**	**	**	**	N.S.	N.S.
B.L.S.D. (.05)	0.11	348	--	6.5	2.5	0.3	0.3	3	2.6	--	--
N-Rate lb/A											
0	2.62	4456	1.32	59.4	38.7	45.4	11.5	89	34.3	0.43	0.61
50	3.15	6475	1.29	84.3	53.8	45.3	11.9	82	49.4	0.40	0.61
100	3.53	7154	1.32	94.8	58.5	45.0	12.2	83	55.1	0.40	0.59
150	3.86	7441	1.40	104.2	60.5	44.7	13.0	77	60.3	0.39	0.59
Significance	**	**	*	**	**	**	**	**	**	*	N.S.
B.L.S.D. (.05)	0.11	361	0.07	6.5	2.6	0.4	0.4	4	2.9	0.03	--
N Placement											
Surface	3.23	6415	1.33	86.4	53.8	45.2	12.1	83	50.6	0.41	0.61
Injected	3.35	6349	1.33	85.0	52.0	45.0	12.2	82	49.0	0.40	0.60
Significance	**	N.S.	N.S.	N.S.	+	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

1/ Kjeldahl N (early plant)

2/ Kjeldahl N

3/ Kjeldahl N x 6.25

Results:
The main effects of variety, N rate, and fertilizer placement are shown in Table 1 for all of the measured variables. All possible interactions were analyzed and those that were significant will be discussed below. Significant differences between varieties were obtained on all the measured variables except forage N, HI, and NHI. Nitrogen application caused significant differences in all of the mesaured variables except for NHI. Nitrogen placement significantly affected only N content in the plant at jointing.

Discussion:
Results obtained in 1983 provide additional information on N fertilization of malting barley. The application of additional N significantly increased early plant N, forage yield, N uptake, grain yield, protein content, and N removal and significantly decreased test weight on all three varieties. A significant N rate by variety interaction was obtained with respect to the percent plump kernels because the addition of N significantly decreased plump kernels with Morex and Glenn but had no effect on the percent plump kernels of Robust.

The differences between the varieties were significant with respect to many of the measured variables as can be seen in Table 1. Robust had the highest forage yield, N uptake, grain yield, protein content, percent plump kernels, and N removal of the three varieties. These results indicate that even though the varieties are all responding similarly to applied N, inherent characteristics in the varieties cause them to respond at different levels. These differences have been seen consistently over the duration of this study and will provide a greater flexibility when it comes to choosing the right variety for various situations which exist.

COMPARISON OF NITROGEN SOURCES ON SPRING WHEAT AND BARLEY

G.E. Varvel and R.K. Severson

Nitrogen fertilization is a large investment for small grain farmers in northwestern Minnesota. Information on the source and amount of N to use is available, but improving the efficiency of the applied N has become more important. These studies were designed to evaluate the N sources available using two application methods on spring wheat and barley.

Experimental Procedure:
The treatments used are shown in Tables 1 and 2. Four nitrogen sources, anhydrous ammonia (82-0-0), urea (46-0-0), ammonium nitrate (34-0-0), and UAN solution (28-0-0) were used. Urea, ammonium nitrate, and UAN solution were surface applied (broadcast) and injected (6 inches deep, 12 inches apart) at two N rates (50 and 100 lb/A) so that application methods could be analyzed. Anhydrous ammonia was injected only at the same N rates as above which then allows analyses of all the injected treatments so that the sources could be compared. Two check plots with 0 N were also included. All fertilizer treatments were made on April 29, 1983 for both the spring wheat and barley studies. Marshall wheat and Robust barley were seeded on April 30, 1983 on their respective studies. Whole plant samples taken at soft dough (July 25, 1983) from the barley study and at jointing (June 25, 1983) and soft dough (August 2, 1983) from the wheat study were analyzed for total N content. Samples taken at soft dough were used to calculate N uptake. Grain yields were taken on August 2, 1983 from the barley study and on August 8, 1983 from the wheat study. Test weight and protein analyses were run on the grain samples. Soil test results for the barley study were: NO_3-N (0-2')-50 lb/A, $NaHCO_3$-P (0-6")-23 lb/A, and exchangeable K (0-6")-330 lb/A. Soil test results for the wheat study were: NO_3-N (0-2')-45 lb/A, $NaHCO_3$-P (0-6")-18 lb/A, and exchangeable K (0-6")-410 lb/A.

Table 1. The effect of nitrogen source, rate, and application method on barley yield and quality.

Treatment			Forage			Grain				
Source	N Rate	Method[1/]	D.M. Yield	N	N Uptake	Yield	Test Weight	Protein	N Removal	Plump Kernels
	lb/A		lb/A	%	lb/A	Bu/A	lb/Bu	%	lb/A	%
Check	0	B	4190	1.37	59.2	33.2	47.7	12.1	31.1	91
	0	I	3632	1.38	50.8	29.1	47.0	11.3	25.4	88
Anhy. Amm.	50	I	7126	1.32	95.0	63.2	46.6	11.8	57.2	85
82-0-0	100	I	7839	1.46	114.6	68.8	46.5	12.7	67.3	87
Urea	50	B	7428	1.21	90.2	62.1	47.6	11.6	55.9	90
46-0-0	100	B	7676	1.41	109.6	72.5	47.0	13.2	73.1	87
	50	I	7437	1.31	97.2	62.9	46.9	11.6	56.4	89
	100	I	8288	1.42	117.1	64.9	46.3	12.9	64.2	83
UAN	50	B	4374	1.26	55.9	40.4	47.2	11.1	34.5	90
28-0-0	100	B	5757	1.13	66.1	51.1	46.2	11.2	44.0	89
	50	I	6190	1.23	79.0	55.8	46.9	11.4	49.3	92
	100	I	7115	1.17	83.6	56.9	46.9	11.5	50.4	92
Ammonium	50	B	7220	1.26	91.5	64.1	46.9	11.9	58.8	87
Nitrate	100	B	8497	1.49	126.2	70.1	46.8	13.4	72.2	84
34-0-0	50	I	7751	1.23	95.6	58.0	47.4	11.3	50.7	91
	100	I	8530	1.44	122.8	69.0	46.3	12.7	67.3	86
Significance			**	**	**	**	*	**	**	N.S.
B.L.S.D. (.05)			1061	0.15	18.2	8.8	1.1	0.9	10.8	
C.V. (%)			11.9	7.8	15.2	11.6	1.3	5.5	15.2	5.6

1/ B - Broadcast, I - Injected.

Results:
The effects of the treatments are shown in Tables 1 and 2 for the barley and wheat studies, respectively. Results from the UAN treatments created problems because it appears that the material obtained had been diluted at some point before we received it. This can be seen when the results in Tables 1 and 2 are examined. Results from another study in which the same UAN material was used indicate the same problem.

Despite this problem, several things are still apparent from the results in both tables. The addition of N significantly increased all of the measured variables on both wheat and barley except for test weight, which was significantly reduced. Carrier differences were harder to assess because of the problem with UAN. The only apparent difference between carriers and methods of application was obtained in the N content in the wheat plant at jointing (Table 2). These results indicate that even though we are able to get more N in the plant early by injecting it, these differences are lost later in the growing season.

Table 2. The effect of nitrogen source, rate, and application method on wheat yield and quality.

Treatment				Forage			Grain			
Source	N Rate	Method[1/]	N[2/]	D.M. Yield	N	N Uptake	Yield	Test Weight	Protein	N Removal
	lb/A		%	lb/A	%	lb/A	Bu/A	lb/Bu	%	lb/A
Check	0	B	2.38	3307	1.34	43.6	19.9	60.0	13.9	28.9
	0	I	2.52	3181	1.37	44.2	20.4	60.1	13.2	28.3
Anhy. Amm.	50	I	3.19	6882	1.42	97.9	44.5	60.7	12.9	60.4
82-0-0	100	I	3.63	6790	1.49	102.7	49.9	60.4	13.6	71.2
Urea	50	B	2.98	6133	1.36	83.6	40.5	60.4	12.7	54.2
46-0-0	100	B	3.63	8222	1.55	127.9	54.3	59.8	13.8	78.8
	50	I	3.24	6662	1.36	91.2	43.4	60.9	13.0	59.2
	100	I	3.79	8189	1.53	125.5	53.3	60.4	13.8	77.2
UAN	50	B	2.41	4567	1.32	61.1	26.4	60.6	12.5	34.7
28-0-0	100	B	2.67	5179	1.43	74.3	33.1	60.7	12.4	43.4
	50	I	2.96	6021	1.37	84.2	36.2	60.7	12.7	48.5
	100	I	3.34	6552	1.33	88.1	45.8	60.7	13.0	62.7
Ammonium	50	B	3.27	6781	1.37	93.1	43.0	60.6	12.7	57.4
Nitrate	100	B	3.85	8045	1.58	127.3	54.9	59.9	14.5	83.6
34-0-0	50	I	3.27	6529	1.38	90.0	42.3	60.4	12.9	57.5
	100	I	3.84	7653	1.57	121.0	55.1	59.9	14.3	82.6
Significance			**	**	+	**	**	**	**	**
B.L.S.D. (.05)			0.21	822	0.27	16.8	4.4	0.7	0.8	7.1
C.V. (%)			5.1	10.1	9.6	14.2	8.3	0.7	4.1	9.6

1/ B - Broadcast, I - Injected.

2/ Kjeldahl N (early plant)

EFFECTS OF NITROGEN ON SUNFLOWER

G. E. Varvel and R. K. Severson

The objective of this study was to evaluate the effect of anhydrous ammonia applied at planting time on the germination of sunflower and subsequently plant N status, seed yield, and oil content.

Experimental Procedure:
The treatments consisted of 4 rates of N (0, 50, 100 and 150 lb/A) as anhydrous ammonia which were applied just prior to planting. The anhydrous application was made at a depth of 5-6 inches with a knife spacing of 12 inches on May 18, 1983. Sunflower, Dahlgren 704, was planted in 30 inch rows perpendicular to the direction in which the anhydrous was applied immediately after the anhydrous application. Stand counts were taken on June 8, 1983 to determine the effects of the treatments on germination. Leaf samples were taken August 5, 1983 to determine plant N status at pollination.

Results:
Insect problems again destroyed the experiment in 1983 so only stand counts and leaf N analyses were obtained. The effect of the N as anhydrous ammonia on germination and leaf N analyses is shown in Table 1. A significant reduction in germination was obtained with the 150 lb/A N rate and N in the leaf increased significantly as the applied N increased.

Discussion:
The reduction (approximate 10%) in stand with anhydrous ammonia at planting time was obtained at the 150 lb/A N rate which indicates that N rates commonly applied to sunflower could be made safely at planting time. These results also agree with results from the 1982 study.

Table 1. The effects of anhydrous ammonia at planting time on sunflower germination and leaf N analyses.

N Rate	Stand Count	Leaf N
lb/A	Plants/Plot	%
0	569	3.02
50	572	3.26
100	594	3.35
150	533	3.44
Significance	*	+
B.L.S.D. (.05)	36	0.37
C.V. (%)	3.7	5.2

TITLE: Phosphorus, Potassium and Nitrogen Fertility Studies on Sunflower

PROJECT LEADER: Gary E. Varvel, University of Minnesota, Northwest Experiment Station, Crookston, MN.

LOCATIONS: Three experiments were conducted at each of two locations. Location 1 - Ron Peterson farm, Crookston, MN. Location 2 - Gerald Green farm, Ada, MN. Additional information on each location is shown below.

Location	Variety	Herbicide	Date (1983) Fertilizer Application & Planting	Harvest
1	Dahlgren 704	Treflan & Amiben	5-25	9-20
2	Dahlgren 704	Treflan & Amiben	5-18	10-12

Location	Soil Tests pH	Organic Matter	NO_3-N	$NaHCO_3$ P	Exchangeable K
		%	lb/A-2'	lb/A	lb/A
1	8.2	4.7	148	12	125
2	8.2	2.8	100	11	168

EXPERIMENTAL METHODS: All experiments were fertilized, planted, and cultivated with equipment of the experiment station. The recent purchase of a planter with starter fertilizer attachments (dry materials only) made the comparisons of P methods possible. A description of each of the experiments is given below:

1) The N experiment at both locations had five treatments (0, 30, 60, 90 and 120 lb N/A) in a randomized complete block design with four replications. Blanket applications of 100 lb K_2O/A and 100 lb P_2O_5/A were applied at both locations over the experimental area.

2) The K experiment at both locations had five treatments (0, 50, 100, 150, and 200 lb K_2O/A) in a randomized complete block design with four replications. Blanket applications of 90 lb N/A and 100 lb P_2O_5/A were applied at both locations over the experimental area.

3) The P experiment at both locations had six treatments, a check plot, two rates of P_2O_5 from TSP (50 and 100 lb/A) broadcasted and banded, and a 50 lb P_2O_5/A DAP banded treatment in a randomized complete block design with four replications. Blanket applications of 90 lb N/A and 100 lb K_2O/A were applied at both locations over the experimental area. The banded treatments were applied in the conventional 2x2 method at planting.

All experiments had leaf samples taken at 50-80% bloom. Whole plant samples were also taken at maturity from each experiment. The samples taken at maturity were separated into heads and stems with leaves for analyses. Results will be presented in the tables which follow for the plant parts separately and also the total analyses.

RESULTS: The effects of the N, P, and K treatments on sunflower at location 1 are shown in Tables 1-15. Nitrogen did not cause any significant differences. Phosphorus significantly increased P content in the head (Table 5) and whole plant (Table 7) and P uptake by the head (Table 5) and whole plant (Table 7). Other differences were obtained and they are shown in Table 5-8. Potassium significantly increased K content (Tables 9-12) and K uptake (Tables 9 and 10) in all cases. Seed yield was also significantly increased (Table 14).

The effects of the N, P and K treatments on sunflower at location 2 are shown in Tables 16-30. Nitrogen significantly increased N content in the head (Table 16). Phosphorus significantly increased P content in the leaves (Table 23). Potassium had no effect on any of the measured variables.

DISCUSSION: The lack of response and general variability of the results were not unexpected. The growing season of 1983 was one which had constant insect pressure at both locations. The constant pressure of sunflower beetle, midge, and banded sunflower moth damaged the experiments even though an extensive spray program was conducted at both locations. The damage inflicted was severe enough to mask any differences that could or should have been obtained.

Table 1. The effect of N on sunflower head dry matter yield, elemental analyses, and N uptake at maturity (Location 1).

N Rate	Elemental Analyses									Dry Matter	N
	N	P	K	Ca	Mg	Mn	Zn	Cu	B	Yield	Uptake
lb/A	%					ppm				lb/A	lb/A
0	2.12	0.49	2.01	0.88	0.78	27	45	38	52	2330	49.1
30	2.21	0.50	1.96	0.98	0.75	29	46	34	54	2263	49.8
60	2.05	0.47	2.08	0.97	0.74	28	44	36	54	2522	51.6
90	2.12	0.47	2.02	0.99	0.79	29	44	36	55	2364	49.8
120	2.13	0.49	2.01	0.90	0.74	27	45	36	52	2458	52.2
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)	3.1	6.5	4.1	5.4	5.0	5.9	6.1	16.6	4.0	9.8	8.1

Table 2. The effect of N on sunflower stems and leaves dry matter yield, elemental analyses, and N uptake at maturity (Location 1).

N Rate	Elemental Analyses									Dry Matter	N
	N	P	K	Ca	Mg	Mn	Zn	Cu	B	Yield	Uptake
lb/A	%					ppm				lb/A	lb/A
0	1.67	0.19	1.47	1.53	2.14	46	12	7	49	3229	53.6
30	1.73	0.20	1.43	1.67	2.23	52	16	6	54	3096	52.9
60	1.73	0.19	1.72	1.56	1.96	44	10	6	55	3321	57.7
90	1.73	0.19	1.61	1.56	2.07	45	11	6	53	3069	52.6
120	1.77	0.18	1.63	1.60	2.15	46	15	5	49	3329	59.1
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)	8.0	14.2	12.4	9.1	5.7	9.6	37.5	17.7	9.3	10.1	9.4

Table 3. The effect of N on elemental analyses of sunflower whole plants at maturity (Location 1).

N Rate	Elemental Analyses								
	N	P	K	Ca	Mg	Mn	Zn	Cu	B
lb/A	%					ppm			
0	1.85	0.32	1.70	1.26	1.57	38	26	20	50
30	1.93	0.32	1.65	1.38	1.60	42	29	18	54
60	1.87	0.31	1.78	1.30	1.43	37	25	19	54
90	1.90	0.31	1.78	1.31	1.52	38	25	19	53
120	1.92	0.31	1.79	1.30	1.55	38	28	18	51
S.L.S.D. (.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)	4.6	8.1	7.8	6.5	4.2	6.5	15.3	14.2	5.5

Table 4. The effect of N on elemental analyses of sunflower leaf samples taken at 50-80% bloom (location 1).

N Rate	Elemental Analyses								
	N	P	K	Ca	Mg	Mn	Zn	Cu	B
lb/A	%					ppm			
0	3.69	0.46	2.65	2.77	2.59	73	24	9	104
30	3.76	0.43	2.60	3.09	2.52	83	23	8	121
60	3.68	0.41	2.62	2.94	2.47	75	24	10	114
90	3.80	0.42	2.66	2.81	2.46	76	23	8	114
120	3.75	0.39	2.57	2.87	2.45	75	24	7	107
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)	3.1	6.6	9.7	6.2	4.9	5.3	7.5	19.7	11.2

Table 5. The effect of P on sunflower head dry matter yield, elemental analyses, and P uptake at maturity (location 1).

Treatment			Elemental Analyses									Dry Matter	P
Source	P_2O_5 Rate	Method	N	P	K	Ca	Mg	Mn	Zn	Cu	B	Yield	Uptake
	lb/A		%					ppm				lb/A	
--	0	--	2.02	0.30	1.97	1.04	0.65	28	51	35	53	2317	7.0
TSP	50	B	2.24	0.41	2.00	1.09	0.69	28	51	33	56	2403	9.9
TSP	50	S	2.10	0.38	1.93	0.99	0.65	26	48	40	50	2466	9.4
TSP	100	B	2.13	0.43	1.97	1.17	0.84	33	45	33	56	2472	10.5
TSP	100	S	2.19	0.40	1.98	1.04	0.68	27	46	33	54	2453	9.8
DAP	50	S	2.06	0.35	1.94	1.07	0.69	29	48	35	52	2357	8.2
Significance			N.S.	**	N.S.	N.S.	*	*	N.S.	N.S.	N.S.	N.S.	*
B.L.S.D. (.05)				0.06			0.11	4					2.4
C.V. (%)			4.9	10.2	5.0	7.9	9.9	9.2	8.7	21.9	5.6	11.4	15.5

Table 6. The effect of P on sunflower stem and leaves dry matter yield, elemental analyses, and P uptake at maturity (location 1).

Treatment			Elemental Analyses									Dry Matter	P
Source	P_2O_5 Rate	Method	N	P	K	Ca	Mg	Mn	Zn	Cu	B	Yield	Uptake
	lb/A		%					ppm				lb/A	
--	0	--	1.67	0.13	2.00	1.80	1.38	51	23	8	57	3043	4.1
TSP	50	B	1.70	0.16	1.82	2.04	2.01	55	18	7	62	3365	5.3
TSP	50	S	1.69	0.15	1.94	2.04	2.04	54	17	7	65	3399	5.3
TSP	100	B	1.64	0.17	1.90	1.79	1.99	47	14	6	58	3416	5.7
TSP	100	S	1.68	0.15	1.88	1.90	1.92	47	15	6	59	3911	5.9
DAP	50	S	1.61	0.15	1.77	2.04	1.93	54	18	8	61	3524	5.1
Significance			N.S.	N.S.	N.S.	N.S.	N.S.	**	*	*	N.S.	N.S.	N.S.
B.L.S.D. (.05)								5	5	2			
C.V. (%)			7.2	14.5	10.9	9.8	19.2	6.6	18.1	15.1	11.5	14.5	20.0

Table 7. The effect of P on the elemental analyses of sunflower whole plants at maturity (location 1).

Treatment			Elemental Analyses								
Source	P_2O_5 Rate	Method	N	P	K	Ca	Mg	Mn	Zn	Cu	B
- - - -	lb/A	- - - -	- - - - - - - - - -		%	- - - - - - - - - -		- - - - - -		ppm	- - - - - -
--	0	--	1.82	0.21	1.98	1.47	1.04	41	35	20	55
TSP	50	B	1.92	0.26	1.88	1.64	1.45	44	32	18	60
TSP	50	S	1.86	0.25	1.93	1.59	1.45	42	30	21	59
TSP	100	B	1.84	0.28	1.92	1.53	1.50	41	27	17	57
TSP	100	S	1.88	0.25	1.91	1.56	1.43	39	28	17	57
DAP	50	S	1.79	0.23	1.82	1.65	1.43	44	30	19	57
Significance			N.S.	*	N.S.	N.S.	N.S.	*	*	N.S.	N.S.
B.L.S.D. (.05)				0.05				3	5		
C.V. (%)			4.9	11.4	6.1	8.2	15.5	4.8	9.7	18.6	7.4

Table 8. The effect of P on the elemental analyses of sunflower leaf samples taken at 50-80% bloom (location 1).

Treatment			Elemental Analyses								
Source	P_2O_5 Rate	Method	N	P	K	Ca	Mg	Mn	Zn	Cu	B
- - - -	lb/A	- - - -	- - - - - - - - - -		%	- - - - - - - - - -		- - - - - -		ppm	- - - - - -
--	0	--	3.58	0.32	3.13	3.32	1.88	82	39	15	130
TSP	50	B	3.68	0.37	2.93	3.42	2.05	85	32	12	130
TSP	50	S	3.64	0.34	2.81	3.37	2.25	83	33	11	139
TSP	100	B	3.85	0.40	2.77	3.36	2.13	83	30	10	116
TSP	100	S	3.58	0.35	2.65	3.53	2.24	84	30	10	135
DAP	50	S	3.53	0.34	2.70	3.62	2.20	90	34	11	140
Significance			*	*	**	N.S.	N.S.	N.S.	N.S.	**	N.S.
B.L.S.D. (.05)			0.17	0.05	0.17					2	
C.V. (%)			2.9	8.4	4.1	9.1	9.2	6.6	13.4	12.8	8.8

Table 9. The effect of K on sunflower head dry matter yields, elemental analyses, and K uptake at maturity (location 1).

	Elemental Analyses									Dry Matter	K
K_2O Rate	N	P	K	Ca	Mg	Mn	Zn	Cu	B	Yield	Uptake
lb/A	- - - - - - - -		%	- - - - - - - -		- - - -		ppm	- - - -	- - - lb/A	- - -
0	2.12	0.53	1.99	1.19	0.89	32	56	26	62	2278	44.9
50	2.17	0.55	2.22	1.17	0.79	32	55	32	62	2589	57.6
100	2.26	0.56	2.32	1.13	0.79	32	56	27	63	2529	58.5
150	2.31	0.58	2.33	1.17	0.79	32	59	37	61	2316	54.0
200	2.17	0.60	2.41	1.13	0.74	34	59	37	61	2317	56.0
Significance	N.S.	N.S.	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	*
B.L.S.D. (.05)			0.32								8.4
C.V. (%)	6.1	11.0	8.2	13.9	10.3	11.3	14.8	21.0	8.4	8.5	9.5

Table 10. The effect of K on sunflower stems and leaves dry matter yields, elemental analyses, and K uptake at maturity (location 1).

K_2O Rate	Elemental Analyses N	P	K	Ca	Mg	Mn	Zn	Cu	B	Dry Matter Yield	K Uptake
lb/A	%					ppm				lb/A	
0	1.70	0.26	0.70	2.25	2.61	62	17	6	66	3917	28.4
50	1.69	0.27	1.46	2.17	2.33	60	18	6	71	4125	60.4
100	1.72	0.28	1.70	1.94	2.33	59	16	6	63	4049	68.3
150	1.83	0.24	2.02	1.96	2.23	57	17	6	62	3695	75.6
200	1.63	0.25	2.56	1.88	2.16	55	13	6	62	3477	88.0
Significance	N.S.	N.S.	**	N.S.	*	N.S.	N.S.	N.S.	N.S.	N.S.	**
B.L.S.D. (.05)			0.44		0.29						27.9
C.V. (%)	9.0	10.4	18.1	13.4	7.3	12.7	28.0	12.6	14.5	16.3	27.8

Table 11. The effects of K on the elemental analyses of sunflower whole plants at maturity (location 1).

K_2O Rate	Elemental Analyses N	P	K	Ca	Mg	Mn	Zn	Cu	B
lb/A	%					ppm			
0	1.86	0.36	1.18	1.85	1.96	50	31	14	65
50	1.87	0.37	1.75	1.78	1.72	49	32	16	68
100	1.93	0.38	1.93	1.63	1.74	48	31	14	63
150	2.02	0.37	2.15	1.66	1.68	47	33	18	61
200	1.85	0.39	2.50	1.58	1.59	46	31	18	61
Significance	N.S.	N.S.	**	N.S.	**	N.S.	N.S.	N.S.	N.S.
B.L.S.D. (.05)			0.27		0.14				
C.V. (%)	6.7	9.2	10.1	13.8	5.2	12.9	12.6	18.3	11.2

Table 12. The effects of K on the elemental analyses of sunflower leaf samples taken at 50-80% bloom (location 1).

K_2O Rate	Elemental Analyses N	P	K	Ca	Mg	Mn	Zn	Cu	B
lb/A	%					ppm			
0	3.63	0.46	1.56	3.69	2.92	96	36	7	125
50	3.67	0.46	2.17	3.71	2.44	91	36	6	146
100	3.55	0.48	2.29	3.44	2.44	91	34	7	142
150	3.66	0.47	2.60	3.19	2.22	80	33	7	119
200	3.61	0.48	2.73	3.23	2.20	84	30	7	127
Significance	N.S.	N.S.	**	N.S.	**	N.S.	N.S.	N.S.	N.S.
B.L.S.D. (.05)			0.47		0.32				
C.V. (%)	5.7	5.6	13.6	11.7	8.5	11.0	18.2	21.0	14.0

Table 13. The effect of N on plant population, seed yield, oil content, and dry matter yields and nutrient content of sunflower at maturity (location 1).

N Rate	Plant Population	Seed Yield	Seed Oil Content	Dry Matter (Maturity) Yield	Uptake N	Uptake P	Uptake K
lb/A	Plants/A	lb/A	%	lb/A			
0	22,070	675	38.4	5559	102.8	17.6	94.5
30	20,618	690	38.0	5359	102.7	17.2	87.8
60	22,506	713	38.4	5843	109.3	18.2	103.7
90	23,232	729	38.6	5433	102.4	16.8	97.5
120	22,506	867	39.2	5788	111.3	17.9	103.6
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	**
B.L.S.D. (.05)							13.1
C.V. (%)	6.9	16.4	3.6	8.9	8.1	11.1	8.3

Table 14. The effect of K on plant population, seed yield, oil content, and dry matter yields and nutrient content of sunflower at maturity (location 1).

K_2O Rate	Plant Population	Seed Yield	Seed Oil Content	Dry Matter (Maturity) Yield	Uptake N	Uptake P	Uptake K
lb/A	Plants/A	lb/A	%	lb/A			
0	21,054	391	36.7	6196	114.9	21.9	73.3
50	20,473	396	37.9	6714	124.9	24.9	118.1
100	19,602	390	36.0	6578	126.6	25.2	126.8
150	17,860	680	37.8	6011	120.9	22.2	129.5
200	21,344	605	37.6	5794	107.0	22.3	144.0
Significance	N.S.	*	N.S.	N.S.	N.S.	N.S.	**
B.L.S.D. (.05)		259					32.5
C.V. (%)	8.3	30.9	4.2	12.4	12.8	14.0	17.6

Table 15. The effect of P on plant population, seed yield, oil content, and dry matter yields and nutrient content of sunflower at maturity (location 1).

Treatment Source	Treatment P_2O_5 Rate	Treatment Method	Plant Population	Seed Yield	Seed Oil Content	Dry Matter (Maturity) Yield	Uptake N	Uptake P	Uptake K
	lb/A		Plants/A	lb/A	%	lb/A			
--	0	--	21,199	735	38.9	5360	97.4	11.2	103.4
TSP	50	B	21,199	686	37.8	5768	110.2	15.2	108.7
TSP	50	S	22,651	710	37.9	5865	108.9	14.7	112.1
TSP	100	B	21,780	626	36.5	5888	108.4	16.2	112.9
TSP	100	S	21,780	619	37.4	6364	119.8	15.7	119.4
DAP	50	S	20,038	616	37.0	5881	105.0	13.3	106.9
Significance			N.S.	N.S.	N.S.	N.S.	N.S.	*	N.S.
B.L.S.D. (.05)								4.1	
C.V. (%)			7.7	19.7	3.2	11.5	11.8	16.0	11.8

Table 16. The effect of N on sunflower head dry matter yield, elemental analyses, and N uptake at maturity (location 2).

N Rate	Elemental Analyses									Dry Matter Yield	N Uptake
	N	P	K	Ca	Mg	Mn	Zn	Cu	B		
lb/A	%					ppm				lb/A	
0	1.96	0.44	2.21	0.79	0.54	24	41	35	46	3014	59.0
30	1.85	0.44	2.26	0.81	0.56	21	37	33	45	2507	46.4
60	1.97	0.41	2.20	0.81	0.52	20	43	34	47	2626	51.8
90	2.07	0.42	2.20	0.83	0.52	22	43	33	46	2958	61.0
120	2.03	0.42	2.16	0.83	0.54	21	48	34	46	2942	59.6
Significance	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
B.L.S.D. (.05)	0.14										
C.V. (%)	3.5	6.5	5.0	8.2	6.9	7.9	3.4	5.4	4.2	11.1	11.2

Table 17. The effect of N on sunflower stem and leaves dry matter yield, elemental analyses, and N uptake at maturity (location 2).

N Rate	Elemental Analyses									Dry Matter Yield	N Uptake
	N	P	K	Ca	Mg	Mn	Zn	Cu	B		
lb/A	%					ppm				lb/A	
0	1.38	0.13	4.67	1.87	1.36	50	15	9	62	3038	41.7
30	1.23	0.14	4.99	1.84	1.15	48	14	10	58	2960	36.5
60	1.38	0.14	4.34	1.83	1.32	48	16	9	60	3630	50.7
90	1.38	0.11	4.55	1.90	1.33	52	16	8	59	3381	46.4
120	1.39	0.11	4.44	1.80	1.29	49	16	7	61	3252	45.0
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)	9.6	15.8	12.3	12.9	10.6	9.7	24.8	22.8	11.4	13.1	20.5

Table 18. The effect of N on the elemental analyses of sunflower whole plants at maturity (location 2).

N Rate	Elemental Analyses								
	N	P	K	Ca	Mg	Mn	Zn	Cu	B
lb/A	%					ppm			
0	1.67	0.29	3.44	1.33	0.95	37	28	22	54
30	1.52	0.28	3.74	1.37	0.88	35	25	21	52
60	1.64	0.26	3.36	1.40	0.99	36	28	20	55
90	1.70	0.25	3.46	1.40	0.95	38	29	20	53
120	1.69	0.26	3.36	1.34	0.93	35	31	20	54
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)	4.2	7.7	8.6	10.4	11.1	9.3	7.0	7.9	6.8

Table 19. The effect of N on the elemental analyses of sunflower leaf samples taken at 50-80% bloom (location 2).

N Rate	Elemental Analyses								
	N	P	K	Ca	Mg	Mn	Zn	Cu	B
lb/A	%					ppm			
0	3.86	0.40	4.69	2.25	1.27	55	31	21	90
30	3.79	0.41	4.64	2.15	1.28	51	31	19	96
60	3.73	0.39	4.46	2.39	1.28	54	33	20	112
90	3.99	0.37	4.81	2.19	1.23	51	36	18	99
120	3.95	0.37	4.83	2.19	1.37	52	40	16	101
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)	4.0	6.9	3.9	5.8	7.5	7.7	10.6	11.3	10.7

Table 20. The effect of P on sunflower head dry matter yield, elemental analyses, and P uptake at maturity (location 2).

Treatment			Elemental Analyses									Dry Matter	P
Source	P_2O_5 Rate	Method	N	P	K	Ca	Mg	Mn	Zn	Cu	B	Yield	Uptake
	lb/A		%					ppm				lb/A	
--	0	--	2.05	0.38	2.12	0.91	0.46	21	45	36	45	3215	12.1
TSP	50	B	2.03	0.44	2.12	0.94	0.47	19	46	40	46	3041	13.3
TSP	50	S	2.13	0.39	2.21	0.92	0.49	20	46	37	46	3013	11.5
TSP	100	B	2.00	0.42	2.11	0.82	0.47	19	41	37	45	3032	12.6
TSP	100	S	2.11	0.42	2.17	0.90	0.46	19	44	36	47	3032	12.7
DAP	50	S	2.06	0.39	2.19	0.88	0.48	20	44	33	45	3015	11.8
Significance			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)			6.2	10.5	4.8	9.3	6.3	6.9	8.9	10.9	5.7	13.1	10.7

Table 21. The effect of P on sunflower stem and leaves dry matter yield, elemental analyses, and P uptake at maturity (location 2).

Treatment			Elemental Analyses									Dry Matter	P
Source	P_2O_5 Rate	Method	N	P	K	Ca	Mg	Mn	Zn	Cu	B	Yield	Uptake
	lb/A		%					ppm				lb/A	
--	0	--	1.50	0.12	4.47	2.00	1.12	45	16	9	67	3329	3.9
TSP	50	B	1.46	0.11	4.15	1.96	1.15	40	14	10	64	3168	3.6
TSP	50	S	1.38	0.11	4.15	2.03	1.27	50	15	10	62	3362	3.7
TSP	100	B	1.48	0.13	4.39	1.91	1.24	44	13	9	63	3363	4.5
TSP	100	S	1.35	0.10	4.42	1.90	1.13	43	13	9	60	3298	3.4
DAP	50	S	1.57	0.11	4.68	1.86	1.13	40	13	7	61	3338	3.5
Significance			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)			5.7	13.1	7.7	8.3	6.8	10.0	16.9	20.0	8.9	9.9	13.0

Table 22. The effect of P on the elemental analyses of sunflower whole plants at maturity (location 2).

Treatment			Elemental Analyses								
Source	P_2O_5 Rate	Method	N	P	K	Ca	Mg	Mn	Zn	Cu	B
- - - -	lb/A	- - - -	- - - - - - - - - -		%	- - - - - - - - - -		- - - - - -		ppm	- - - - - -
--	0	--	1.77	0.25	3.31	1.46	0.80	33	30	23	56
TSP	50	B	1.74	0.27	3.16	1.46	0.81	29	30	25	55
TSP	50	S	1.73	0.24	3.23	1.51	0.90	36	29	22	55
TSP	100	B	1.72	0.27	3.32	1.40	0.88	32	27	22	54
TSP	100	S	1.71	0.25	3.34	1.42	0.81	31	28	22	54
DAP	50	S	1.80	0.24	3.50	1.39	0.82	31	28	19	54
Significance			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)			4.1	6.9	7.2	8.8	4.6	9.1	9.1	11.3	5.6

Table 23. The effect of P on the elemental analyses of leaf samples taken at 50-80% bloom (location 2).

Treatment			Elemental Analyses								
Source	P_2O_5 Rate	Method	N	P	K	Ca	Mg	Mn	Zn	Cu	B
- - - -	lb/A	- - - -	- - - - - - - - - -		%	- - - - - - - - - -		- - - - - -		ppm	- - - - - -
--	0	--	3.89	0.37	4.49	2.59	1.15	52	38	20	120
TSP	50	B	4.04	0.40	4.37	2.42	1.13	48	37	20	111
TSP	50	S	3.91	0.36	4.59	2.35	1.26	50	37	19	109
TSP	100	B	3.82	0.39	4.46	2.59	1.21	51	34	20	115
TSP	100	S	3.80	0.37	4.48	2.41	1.23	49	33	21	105
DAP	50	S	3.93	0.39	4.38	2.49	1.24	52	36	19	128
Significance			N.S.	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
B.L.S.D. (.05)				0.04							
C.V. (%)			2.7	5.5	4.7	7.8	7.5	7.9	9.0	12.0	8.9

Table 24. The effect of K on sunflower head dry matter yield, elemental analyses, and K uptake at maturity (location 2).

K_2O Rate	Elemental Analyses									Dry Matter Yield	K Uptake
	N	P	K	Ca	Mg	Mn	Zn	Cu	B		
lb/A	- - - - - - - -		%	- - - - - - - -		- - - -		ppm	- - - -	- - - lb/A	- - -
0	1.99	0.47	2.16	0.92	0.61	20	43	36	49	2704	58.2
50	2.03	0.49	2.34	0.91	0.55	21	45	37	49	2963	69.6
100	2.01	0.49	2.28	0.91	0.54	19	43	39	47	2695	61.7
150	2.16	0.49	2.25	0.92	0.60	22	43	35	48	2885	65.0
200	1.94	0.44	2.29	0.87	0.56	21	41	36	47	2813	64.3
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)	2.8	7.5	4.4	10.8	6.5	6.8	7.9	7.7	3.0	11.5	14.3

Table 25. The effect of K on sunflower stem and leaves dry matter yield, elemental analyses, and K uptake at maturity (location 2).

K_2O Rate	Elemental Analyses									Dry Matter Yield	K Uptake
	N	P	K	Ca	Mg	Mn	Zn	Cu	B		
lb/A	%					ppm				lb/A	
0	1.56	0.16	3.01	1.81	1.55	43	16	10	59	3230	98.8
50	1.38	0.12	4.24	1.69	1.17	37	13	8	55	3301	139.1
100	1.33	0.12	4.54	1.85	1.28	45	15	9	53	3529	160.5
150	1.37	0.12	4.55	1.67	1.31	37	13	8	52	3212	146.4
200	1.38	0.11	4.65	1.80	1.29	45	15	9	60	3158	147.3
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)	11.6	14.5	20.6	13.4	12.4	17.0	20.1	15.2	10.0	8.9	25.7

Table 26. The effect of K on the elemental analyses of sunflower whole plants at maturity (location 2).

K_2O Rate	Elemental Analyses								
	N	P	K	Ca	Mg	Mn	Zn	Cu	B
lb/A	%					ppm			
0	1.76	0.30	2.62	1.41	1.13	33	28	22	54
50	1.69	0.29	3.32	1.32	0.88	30	28	22	52
100	1.63	0.28	3.56	1.44	0.96	34	27	22	51
150	1.74	0.30	3.46	1.32	0.97	30	28	21	50
200	1.64	0.27	3.54	1.36	0.95	34	28	22	54
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)	4.7	7.9	14.7	12.3	11.0	12.3	10.9	10.1	6.1

Table 27. The effect of K on the elemental analyses of sunflower leaf samples taken at 50-80% bloom (location 2).

K_2O Rate	Elemental Analyses								
	N	P	K	Ca	Mg	Mn	Zn	Cu	B
lb/A	%					ppm			
0	3.93	0.39	3.89	2.56	1.49	50	30	20	82
50	3.75	0.40	4.52	2.42	1.28	46	33	18	89
100	3.90	0.40	4.34	2.53	1.18	50	33	21	90
150	3.88	0.40	4.66	2.32	1.22	47	31	20	86
200	3.95	0.37	4.44	2.29	1.22	49	31	21	83
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)	7.5	5.9	10.7	12.4	13.7	10.6	7.8	16.4	14.0

Table 28. The effect of N on plant population, seed yield, oil content, and dry matter yield and nutrient content of sunflower at maturity (location 2).

N Rate	Plant Population	Seed Yield	Seed Oil Content	Dry Matter (Maturity) Yield	Uptake N	Uptake P	Uptake K
lb/A	Plants/A	lb/A	%	lb/A			
0	21,344	1332	40.6	6052	100.7	17.4	209.1
30	22,070	1364	42.6	5467	83.0	15.1	204.8
60	21,054	1188	42.5	6256	102.4	16.0	208.6
90	22,942	1390	43.0	6339	107.3	16.1	217.9
120	21,780	1308	42.5	6195	104.6	16.0	207.9
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)	4.6	9.0	3.4	6.6	7.9	4.4	7.7

Table 29. The effect of K on plant population, seed yield, oil content, and dry matter yield and nutrient content of sunflower at maturity (location 2).

K_2O Rate	Plant Population	Seed Yield	Seed Oil Content	Dry Matter (Maturity) Yield	Uptake N	Uptake P	Uptake K
lb/A	Plants/A	lb/A	%	lb/A			
0	22,216	1178	41.6	5934	104.6	18.2	157.0
50	22,216	1272	41.0	6264	105.5	18.3	208.7
100	22,506	1457	41.9	6224	101.0	17.5	222.1
150	22,216	1238	41.1	6098	106.1	17.9	211.4
200	22,216	1321	42.0	5971	98.1	16.0	211.6
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)	5.1	11.7	2.4	9.0	7.3	9.2	21.1

Table 30. The effect of P on plant population, seed yield, oil content, and dry matter yield and nutrient content of sunflower at maturity (location 2).

Treatment Source	Treatment P_2O_5 Rate	Treatment Method	Plant Population	Seed Yield	Seed Oil Content	Dry Matter (Maturity) Yield	Uptake N	Uptake P	Uptake K
	lb/A		Plants/A	lb/A	%	lb/A			
--	0	--	22,651	1564	42.6	6544	115.6	16.0	216.3
TSP	50	B	22,651	1539	42.7	6209	107.9	16.9	196.1
TSP	50	S	21,344	1449	43.3	6374	109.9	15.2	204.4
TSP	100	B	22,361	1547	42.5	6395	110.4	17.1	211.6
TSP	100	S	22,216	1436	42.2	6330	108.6	16.1	211.3
DAP	50	S	21,054	1650	42.4	6353	114.1	15.3	220.4
Significance			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V. (%)			4.5	7.5	2.1	10.1	10.0	9.4	10.2

FERTILIZATION OF SOYBEAN IN NORTHWESTERN MINNESOTA

G. E. Varvel and R. K. Severson

The expansion of the soybean industry into northwestern Minnesota has generated the need for information on how to effectively fertilize them for maximum yield and oil content. These experiments were initiated to determine what levels of response could be attained with various methods of fertilization.

Experimental Procedure:
Two varieties, McCall and Maple Amber were used in these studies. The first study compared TSP (0-44-0) versus DAP (18-46-0) as starter fertilizers and the second study was designed to measure the effects of applied N on soybean. Both studies were conducted on each variety in separate experiments.

The starter fertilizer studies consisted of three rates of applied P_2O_5 (0, 50, and 100 lb/A) from both sources in a randomized complete block design with four replications. The standard 2 x 2 application method was used for the treatments. Blanket applications of N (90 lb/A) and K_2O (150 lb/A) were applied to the plot area before planting. Both varieties were planted on May 25, 1983 with the various fertilizer treatments. The plots were harvested on October 27, 1983. Soil test levels for the study were: pH - 8.2, $NaHCO_3$ P - 12 lb/A, exchangeable K - 125 lb/A, and NO_3-N (0-2') - 148 lb/A.

The nitrogen studies consisted of five rates of N (0, 30, 60, 90, and 120 lb/A) broadcast and incorporated just prior to planting. A randomized complete block design with four replications was used. Both varieties were planted on May 26, 1983 and harvested on October 27, 1983. Soil test levels for the study were: pH - 8.2, $NaHCO_3$ P - 14 lb/A, exchangeable K - 175 lb/A, and NO_3-N (0-2') - 62 lb/A.

Results:
The effects of the starter treatments are shown in Table 1. No significant differences were obtained between either source or P rates with McCall or Maple Amber.

The effects of the N treatments are shown in Table 2. Nitrogen significantly increased yields on both varieties.

Table 1. The effect of starter fertilizer phosphorus on yield of two soybean varieties.

Treatment		Variety	
		McCall	Maple Amber
Source	P_2O_5 Rate	Yield	Yield
	lb/A	Bu/A	Bu/A
TSP	0	30.7	22.3
	50	30.2	19.1
	100	31.4	14.3
DAP	0	30.5	21.2
	50	27.1	15.6
	100	31.1	18.1
Significance		N.S.	N.S.
B.L.S.D. (.05)			
C.V. (%)		13.5	28.5

Table 2. The effect of nitrogen on yield of two soybean varieties.

	Variety	
	McCall	Maple Amber
N Rate	Yield	Yield
lb/A	Bu/A	Bu/A
0	20.2	19.7
30	24.4	22.1
60	27.5	25.2
90	29.0	23.6
120	27.4	27.5
Significance	*	*
B.L.S.D. (.05)	5.5	4.9
C.V. (%)	13.0	12.4

WEST CENTRAL EXPERIMENT STATION - MORRIS

WEATHER SUMMARY - 1983

Month	Period	Precipitation 1983	Precipitation 94-yr. av.	Precipitation Dev. from av.	Temperature 1983	Temperature 94-yr. av.	Temperature Dev. from av.	Soil Temperature (10 cm depth) 1983	Soil Temperature (10 cm depth) 10 yr. av.
January	1-31	.75	.68	+ .07	16.4	8.0	+8.4	22.0	20.7
February	1-28	.15	.67	- .52	22.2	12.6	+9.6	25.9	23.9
March	1-31	2.34	1.09	+1.25	30.8	26.7	+4.1	32.7	29.2
April	1-10	.23	.58	- .35	37.9	37.9	0	35.2	
	11-20	.39	.65	- .26	35.8	44.4	-8.6	35.9	
	21-30	.22	1.08	- .86	48.7	48.2	+0.5	43.5	
Total or av.		.84	2.31	-1.47	40.8	43.5	-2.7	38.2	41.4
May	1-10	.76	.78	- .02	51.4	51.9	-0.5	48.6	
	11-20	1.03	.95	+ .08	51.3	55.8	-4.5	52.2	
	21-31	.34	1.25	- .91	56.0	60.1	-4.1	58.8	
Total or av.		2.13	2.98	- .85	53.0	56.1	-3.1	53.4	57.1
June	1-10	.13	1.26	-1.13	59.5	63.1	-3.6	63.7	
	11-20	1.64	1.27	+ .37	65.5	66.5	-1.0	59.5	
	21-30	1.92	1.38	+ .54	70.4	68.2	+2.2	73.7	
Total or av.		3.69	3.91	- .22	65.1	66.0	-0.9	67.9	69.3
July	1-10	.97	1.48	- .51	71.5	70.0	+1.5	73.2	
	11-20	2.19	1.03	+1.16	75.6	71.3	+4.3	80.0	
	21-31	1.16	1.03	+ .13	74.1	71.5	+2.6	79.9	
Total or av.		4.32	3.54	+ .78	73.7	71.0	+2.7	73.0	76.7
August	1-10	0	1.05	-1.05	75.4	70.3	+5.1	82.6	
	11-20	2.83	.90	+1.93	71.1	69.2	+1.9	78.5	
	21-31	2.40	.98	+1.42	72.7	66.9	+5.8	74.6	
Total or av.		5.23	2.93	+2.30	73.1	68.7	+4.4	78.5	73.9
September	1-30	1.83	2.19	- .36	59.1	59.1	0	61.6	61.5
October	1-31	2.18	1.62	+ .56	45.0	47.3	-2.3	46.9	47.8
November	1-30	2.74	.96	+1.78	31.9	29.7	+2.2	36.2	33.6
December	1-31	.75	.68	+ .07	-1.2	15.5	-16.7	26.4	23.4
April-August Growing Season		16.21	15.67	+ .54	61.2	61.1	+0.1	62.3	63.8
January-December Annual		26.95	23.56	+3.39	42.6	42.0	+0.6	47.0	46.7

MANURE RATE STUDY

West Central Experiment Station - Morris

S. D. Evans, P. R. Goodrich and R. C. Munter

Solid and liquid beef manures were applied at three rates and the effects were compared against check plots. Treatments and results from previous years are given in Soil Series 91, 95, 97, 99, 103, 105, 107, 109, and Misc. Publ. 2-1982 and 1983. The last manure applications were made in the fall of 1978, but fertilizer has been applied to the fertilized check each year.

I. Planting Information

The plots were planted with Pioneer 3901 on May 10, 1983. Counter @ 8.8 lbs/acre (1 lb/acre active ingredient) was applied in the row to the entire area at planting. The plots were fertilized on October 27, 1982, with 10-26-26 urea to provide 63 + 40 + 40 ($N + P_2O_5 + K_2O$) per acre. Lasso (2.5 lbs/acre) and Bladex (2.2 lbs/acre) were broadcast on May 11, 1983. The plots were cultivated on June 21, 1983.

II. Soil Sampling and Analysis

A. 1982 Measurements

NO_3-N was the only variable measured in the fall of 1981. The values shown in Table 1 indicate some changes from those values one year earlier. In general the NO_3-N in the 0-2' zone decreased slightly in the manure treated plots and increased slightly in the 2-4' zone.

B. 1983 Measurements

The soils were sampled again to a depth of 4 feet for NO_3-N analysis but the results are not yet available.

III. Plant Tissue Analysis (Table 2)

There were significant effects on all elements except copper and manganese. There were some significant effects of solid beef manure on increasing leaf levels of P, K, and Fe and decreasing leaf levels of Mg and Zn as compared to the fertilized check. The effects of liquid beef manure were similar to those of solid beef manure but the effects were reduced.

IV. Growth and Yield Measurements (Table 3)

A. Early plant height and dry matter - Plants on the manure treated plots were taller (except for LB1) and weighed more (except for LB1) than on the fertilized check.

B. Grain - Yields of the solid beef manure treatments were not significantly different from the fertilized check, but the liquid beef manure treatments yielded significantly more than the fertilized check.

C. Silage - The LB1 and LB3 treatments yielded significantly less than the fertilized check.

V. Summary

The 1983 season was the fifth since manure had been applied. It appears that even the lowest rates of each manure were sufficient for grain yields equal to or higher than the fertilized check.

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

Table 1. Effect of two types of beef cattle manure and commercial fertilizer on the NO_3-N level of a Tara soil profile - Fall 1982.

Depth - ft -	Treatment CK	FE	SB1	SB2	SB3	LB1	LB2	LB3
				- NO_3-N, ppm -				
0-1	7.3	8.9	10.0	22.0	19.7	9.6	9.7	13.3
1-2	3.7	51.9	13.9	55.1	54.2	9.4	21.6	63.6
2-3	1.5	109.3	81.0	266.7	211.6	34.7	40.8	156.7
3-4	1.1	65.8	95.6	158.7	176.9	32.5	67.3	162.3

Table 2. Summary of analysis of corn leaves at silking - 1983.

Treatment	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%					ppm				
CK	1.92	.18	1.52	.44	.43	78	13.6	5.7	69	5.3
FE	2.83	.23	1.70	.45	.40	86	19.0	5.7	87	6.1
SB1	2.73	.30	2.44	.42	.26	95	13.6	6.4	85	6.2
SB2	2.85	.42	2.83	.42	.22	105	14.5	5.4	83	6.3
SB3	2.79	.44	2.78	.36	.19	100	14.0	4.9	65	6.1
LB1	2.45	.25	1.86	.47	.37	88	14.5	6.4	88	6.2
LB2	2.66	.27	2.10	.45	.33	95	13.3	6.4	96	6.6
LB3	2.71	.34	2.35	.42	.27	101	12.1	5.2	80	6.4
Signif. level (%)	99	96	99	96	99	99	99	86	44	91
BLSD(.05)	.16	.06	.18	.07	.05	13	2.6	-	-	.9
CV(%)	3.8	11.8	5.1	8.0	9.8	7.4	10.2	12.6	18.2	7.1

Table 3. Summary of plant measurements - 1983.

Treatment	Early plant height inches	Early plants (10) dry weight grams	Grain: Moisture at harvest %	Grain: Yield @ 15.5% M Bu/A	Grain: Nitrogen %	Silage: Dry matter at harvest %	Silage: Silage yield (D.M.) lbs/A	Silage: Ear wt. ÷ Silage wt. %
CK	21.0	28.7	36.6	74.8	1.15	43.0	8995	53.3
FE	23.7	38.7	34.9	116.6	1.51	39.7	14901	57.6
SB1	28.7	78.0	31.6	128.0	1.51	41.5	14354	58.2
SB2	31.6	96.7	29.5	117.1	1.59	36.8	14093	53.3
SB3	31.6	105.7	30.2	122.9	1.59	37.5	14985	54.3
LB1	24.0	39.3	35.2	131.5	1.41	40.8	13111	60.3
LB2	27.5	59.3	32.3	130.2	1.45	42.6	14600	60.6
LB3	29.3	80.0	31.9	129.4	1.54	38.5	13312	57.5
Signif. level (%)	99	99	99	99	99	99	99	99
BLSD(.05)	1.5	9.8	2.0	12.3	.07	2.6	1301	4.1
CV(%)	3.4	9.3	3.7	6.3	3.0	3.7	5.9	3.9

RESIDUAL EFFECT OF HEAVY APPLICATIONS OF ANIMAL MANURES ON CORN GROWTH AND YIELD AND ON SOIL PROPERTIES

West Central Experiment Station - Morris
S. D. Evans, P. R. Goodrich and R. C. Munter

The experiment initiated in 1970 was continued. Treatments and results from previous years are given in Soil Series 88, 89, 91, 95, 97, 99, 103, 105, 107, 109, and Misc. Publ. 2-1982 and 1983. Manure was applied in 1970 and 1971 only. Fertilizer has been applied to the fertilized checks each year.

I. Planting Information

Twenty-four rows of corn (var. Pioneer 3901) were planted in each plot on May 10, 1983. Counter at 8.8 lbs/acre (1 lb/acre active ingredient) was applied in the row at planting to all plots. The plots were fertilized on October 27, 1982, with 10-26-26 and urea to provide 63 + 40 + 40 ($N + P_2O_5 + K_2O$) per acre. Lasso (2.5 lbs/acre) and Bladex (2.2 lbs/acre) were broadcast on May 11, 1983. All plots were cultivated on June 21, 1983.

II. Soil Sampling and Analysis

A. 1982 Measurements

NO_3-N was the only variable measured in the fall of 1982. The values shown in Table 1 indicate that levels in most soil zones changed little in the past year. The total NO_3-N in the 0-4' profile was greater on all manure treatments than on the fertilized check.

B. 1983 Measurements

The soils were sampled again to a depth of 4 feet for NO_3-N analysis but the results are not yet available.

III. Plant Tissue Analysis

The nutrient concentrations in the ear leaves at silking in 1983 are given in Table 2. There were significant effects on most elements. The concentration of K was higher and Mg lower in all manure treatments than in the fertilized treatment. There were significant differences between at least one manure treatment and the fertilized treatment for N, P, Mg, Zn, Cu and B.

IV. Growth and Yield Measurements (Table 3)

A. Early plant height and dry matter - Plants on the manure treated plots were taller than those on the fertilized treatment. Dry matter differences were significantly higher on the manure treated plots.

B. Grain - There were no significant differences in grain yield. The grain N content of the LH treatment was significantly lower than that of the fertilized check.

C. Silage - There were no significant differences between the manure treatments and the fertilized treatment in silage yield.

V. Summary

The effects of the manure treatments applied in 1970 and 1971 still show up in most plant and soil measurements. Plant and soil analysis show that the liquid hog manure treatment is starting to lose some of its effect as compared to the other two manure treatments, but grain yield is still not significantly lower than the fertilized check.

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

Table 1. Effect of high rates of manure and commercial fertilizer twelve years (fall 1982) after application on the NO_3-N level of a Tara soil profile.

Depth - ft -	Treatment CK	FE	SB	LB	LB
			- NO_3-N, ppm -		
0-1	5.9	4.8	5.5	8.3	5.8
1-2	3.3	11.4	4.5	10.7	4.0
2-3	1.3	83.1	14.4	48.5	27.5
3-4	2.3	50.0	52.3	83.4	47.2

Table 2. Summary of analysis of corn leaves at silking - 1983.

Treatment	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%					ppm				
CK	1.87	.17	1.49	.48	.44	78	14.2	5.9	80	4.9
FE	2.64	.24	1.73	.47	.41	90	19.2	4.7	74	5.9
SB	2.55	.30	2.57	.44	.24	109	17.9	6.4	88	6.0
LB	2.55	.37	2.64	.43	.23	102	12.5	5.9	70	5.7
LH	2.26	.28	2.29	.47	.32	117	21.0	7.0	75	6.5
Signif. level (%)	99	99	99	53	99	68	90	98	31	99
BLSD(.05)	.19	.06	.20	-	.10	-	7.7	1.3	-	.6
CV(%)	4.5	11.2	5.4	8.0	15.7	22.9	21.4	10.8	19.9	5.2

Table 3. Summary of plant measurements - 1982.

Treatment	Early plant height inches	Early plants (10) dry wt. grams	Grain: Ear moisture at harvest %	Grain: Yield @ 15.5% M. Bu/A	Grain: Nitrogen %	Silage: Dry matter at harvest %	Silage: Silage yield (D.M.) lb/A	Silage: Ear wt. + silage wt. %
CK	18.7	25.3	37.2	64.3	1.07	43.0	9500	52.0
FE	22.3	37.0	35.1	126.3	1.46	40.2	14503	58.7
SB	28.2	75.0	31.6	129.4	1.39	42.0	14606	57.7
LB	28.2	77.7	32.6	129.9	1.39	39.2	15174	60.0
LH	25.0	55.7	33.7	108.8	1.37	40.9	13468	60.7
Signif. level (%)	99	99	99	99	99	76	99	99
BLSD(.05)	2.1	14.5	2.7	17.5	0.13	-	2011	4.1
CV(%)	4.8	14.9	4.1	8.7	5.3	4.7	8.1	3.7

CONTINUOUS CORN SILAGE

West Central Experiment Station - Morris
S. D. Evans

I. Experimental Description

In 1965 an experiment was initiated on 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. Rates of fertilizer used were 74 + 48 + 48 ($N + P_2O_5 + K_2O$) and 148 + 96 + 96. All plots received a broadcast application of 10 lbs/acre of zinc as zinc sulfate in the fall of 1965.

II. 1983 Operations

In 1983 the variety was Trojan TXS99. Counter was applied at 1 lb/acre (active ingredient) at planting on May 10. Lasso @ 2.5 lbs/acre plus Bladex @ 2.2 lbs/acre were applied broadcast on May 11. Silage yields were taken on September 19 and grain yields on September 27.

III. Silage Yields - Dry matter; tons/acre

Treatment	1983 yield	1966-83 yield
Silage, low fertility	6.49	5.68
Silage, high fertility	7.09	6.13
Grain, low fertility	6.58	5.70
Grain, high fertility	6.80	5.95

IV. Grain Yields - Bushels/acre @ 15.5% M.

	1983 yield	1966-83 yield
Grain, low fertility	104.76	90.48
Grain, high fertility	103.72	93.48

V. Check Yields

Yields on an additional unfertilized, unreplicated check adjacent to the experimental area:

	1983 yield	1966-83 yield
Grain (0 + 0 + 0)	31.49	47.98
Silage (0 + 0 + 0)	3.42	3.71

VI. Discussion

A. In 1983 there were no significant differences in silage yields but the silage high fertility plots yielded slightly more than the low fertility plots, especially where the silage was removed.

B. The 18-year average yields show very little difference between silage and grain plots, but there is still a slight advantage for the higher fertility level.

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

COMPARISON OF TWELVE HARD RED SPRING WHEAT VARIETIES TO NITROGEN FERTILIZATION - MORRIS 1983

S. Comfort, G. Malzer, R. Busch, and S. Evans

Introduction

Maximizing the benefits of nitrogen fertilization depends largely on the responsiveness of the individual plant. Spring wheat genotypes, as with many other crops, differ considerably in growth response to increases in nitrogen fertilizer. The reason why some wheat varieties respond more to nitrogen fertilization than others in not well understood, but it has been suggested that it may be related to favorable plant characteristics both above and below the ground. The general objective of this study was to evaluate twelve spring wheat varieties under three different nitrogen rates. More specifically, the study intended to determine which varieties continued to show an increase in growth to added nitrogen and also which varieties performed better within an individual nitrogen rate. It was hoped that knowledge of varietal performances over a range of growing seasons would 1) aid in a more efficient use of nitrogen fertilizer for a specific variety and 2) aid in determining which varieties' morphological and physiological characteristics should be more critically examined.

Experimental Procedures

Twelve varieties of hard red spring wheat were compared at 0, 67, and 137 kg/ha at the West Central Experimental Station at Morris, Minn. Nitrogen was applied as a spring application of ammonium nitrate broadcast and incorporated. The field experiment was arranged as split plot design with nitrogen rates as the whole plot treatments and varieties as the subplot treatments. Varieties were planted in an area 5' x 20' utilizing a cone seeder. Each treatment was replicated four times.

Total plant dry matter production was determined at approximately the "soft dough" stage of growth and samples were collected for nitrogen content and calculation of nitrogen uptake. Yield grain was harvested with a 3 row grain binder from a 14 ft.^{2} area. The above ground gorwth (grain and straw) was removed from the experimental plot and placed in a forced air dryer. After drying, the samples were thrashed and the grain reweighed for yield determination. Straw weight was determined by difference. Samples of both straw and grain were collected and analyzed for nitrogen content and determination of nitrogen removal.

General Results

As was to be expected, all varieties did not respond in a similar manner to increasing rate of nitrogen fertilization. Consequently a significant nitrogen rate x variety interaction was observed for all response parameters. Significant interaction of main effects necessitates the need to analyze 1) varietal differences within each nitrogen rate and 2) responsiveness of each variety to nitrogen fertilization. With this criteria, varietal comparisons can be made from Table 1.

With respect to yield, Mn73167, Mn 73168, and Butte had the highest yield at the zero N rate, while Mn 73167 and Mn7357 were among the highest yielding at the 67 kg N/ha rate of application, with Butte, Mn7125, Mn7357 and Olaf leading the group when 134 kg N/ha was applied.

Table 2 allows for the analysis of the ability of each variety to continue to respond to nitrogen fertilizer application. Of the varieties tested only Era and Olaf provided significant yield increases with the first increment of nitrogen fertilization. The yields of Coteau and Mn7125 were also significantly increased (comparing the control vs. the highest nitrogen rate) with fertilization. The other eight varieties tested did not respond to N fertilization.

Table 1. Comparison of yield, N content, and N removal for forage, straw and grain at 3 nitrogen rates on 12 varieties of hard red spring wheat. Location: Morris, MN 1983.

		FORAGE			STRAW			GRAIN		
	N RATE	YIELD	N CONT	N REMOV	YIELD	N CONT	N REMOV	YIELD	N CONT	N REMOV
	kg ha^{-1}	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}
Butte	0	6.28	13.7	86.1	3.45	3.38	11.5	2.99	23.7	70.9
Coteau	0	5.78	16.0	93.2	3.11	4.65	14.2	2.30	28.6	66.5
Era	0	4.50	15.1	68.1	2.27	3.95	8.9	1.85	23.1	42.9
Marshall	0	5.91	14.2	84.1	2.81	4.33	12.2	2.79	24.1	67.3
Mn 7125	0	6.04	14.0	84.9	2.71	4.28	11.6	2.55	23.8	60.4
Mn 7222	0	5.46	14.8	80.5	2.74	4.15	11.2	2.69	23.5	62.8
Olaf	0	5.05	16.2	81.9	2.59	4.40	11.5	2.16	29.3	63.2
Thatcher	0	5.42	13.0	70.9	3.30	4.43	14.5	2.77	24.8	68.8
Mn 7357	0	6.69	13.7	91.4	2.92	3.80	10.9	2.94	23.1	67.7
Mn 73167	0	4.92	15.0	73.9	2.62	4.28	11.4	3.24	22.7	73.9
Mn 73168	0	6.96	14.6	101.2	2.80	3.83	10.7	3.09	23.4	72.1
James	0	5.93	15.4	91.7	3.69	4.05	15.0	2.61	26.9	70.4
HSD (.05)*		1.77	1.9	30.7	1.07	1.34	7.0	0.75	3.2	21.6
(.10)		1.63	1.7	28.3	0.98	1.23	6.5	0.69	2.9	19.9
Butte	67	7.19	16.5	118.9	4.20	5.28	22.4	3.35	27.5	92.0
Coteau	67	6.92	16.2	111.1	4.05	5.20	21.1	2.86	29.3	83.6
Era	67	6.52	16.6	109.0	3.42	5.15	17.7	3.14	24.1	75.3
Marshall	67	7.00	17.0	119.3	3.64	5.73	21.0	3.33	25.6	85.2
Mn 7125	67	6.94	18.4	100.2	3.23	4.93	16.2	3.08	23.4	72.2
Mn 7222	67	7.81	16.8	130.7	3.79.	4.78	18.1	3.16	25.5	80.7
Olaf	67	7.08	16.7	118.5	3.54	5.25	19.0	2.97	28.3	83.9
Thatcher	67	7.25	16.1	116.7	3.67	5.80	21.4	2.54	26.3	66.8
Mn 7357	67	7.66	16.2	123.9	3.90	6.13	23.7	3.45	23.5	81.1
Mn 73167	67	7.12	15.9	113.5	3.31	5.08	17.0	3.65	23.7	86.5
Mn 73168	67	6.11	16.2	100.3	2.28	5.68	12.9	2.27	24.9	56.5
James	67	7.32	16.4	119.5	3.85	5.13	19.7	2.81	29.3	81.9
HSD (.05)*		1.77	1.9	30.7	1.07	1.34	7.0	0.75	3.2	21.6
(.10)		1.63	1.7	28.3	0.98	1.23	6.5	0.69	2.9	19.9
Butte	134	7.63	18.1	137.8	4.50	6.15	27.7	3.53	28.1	98.9
Coteau	134	7.77	17.8	138.0	4.35	6.23	27.0	3.09	30.2	93.2
Era	134	7.50	17.1	127.8	3.99	7.48	29.8	3.31	25.6	84.5
Marshall	134	7.74	18.3	140.8	3.91	6.88	26.9	3.24	28.0	90.7
Mn 7125	134	7.15	16.1	115.6	4.05	6.40	26.0	3.48	23.6	82.1
Mn 7222	134	6.73	17.4	117.3	3.72	5.48	20.5	3.23	26.5	86.1
Olaf	134	7.43	18.2	135.0	4.27	6.90	29.4	3.41	28.6	97.5
Thatcher	134	7.28	16.4	119.0	3.80	6.73	25.5	2.60	27 7	71.5
Mn 7357	134	7.23	17.7	127.4	3.91	8.30	32.5	3.42	26.9	92.1
Mn 73167	134	6.62	18.0	119.7	4.09	6.60	26.8	3.21	27.7	89.0
Mn 73168	134	7.14	18.3	130.3	4.06	7.90	32.1	3.42	26.7	91.2
James	134	8.01	16.8	134.3	4.40	5.73	25.2	3.11	29.1	90.5
HSD (.05)*		1.77	1.9	30.7	1.07	1.34	7.0	0.75	3.2	21.6
(.10)		1.63	1.7	28.3	0.98	1.23	6.5	0.69	2.9	19.9

*HSD values for comparison of variety means within one nitrogen rate.

Table 2. Comparison of means for nitrogen rates within one variety for forage, straw and grain. Morris, Mn. 1983.

		------Forage------			------Straw------			------Grain------		
VARIETY	N RATE	YIELD	N CONT	N REMOV	YIELD	N CONT	N REMOV	YIELD	N CONT	N REMOV
	kg/ha	Mg/ha	g/kg	kg/ha	Mg/ha	g/ha	kg/ha	Mg/ha	g/ha	kg/ha
Butte	0	6.28	13.7	86.1	3.45	3.38	11.5	2.99	23.7	70.9
	67	7.19	16.5	118.9	4.20	5.28	22.4	3.35	27.5	92.0
	134	7.63	18.1	137.8	4.50	6.15	27.7	3.53	28.1	98.9
Coteau	0	5.78	16.0	93.2	3.11	4.65	14.2	2.30	28.6	66.5
	67	6.92	16.2	111.1	4.05	5.20	21.1	2.86	29.3	83.6
	134	7.77	17.8	138.0	4.35	6.23	27.0	3.09	30.2	93.2
Era	0	4.50	15.1	68.1	2.27	3.95	8.9	1.85	23.1	42.9
	67	6.52	16.6	109.0	3.42	5.15	17.7	3.14	24.1	75.3
	134	7.50	17.1	127.8	3.99	7.48	29.8	3.31	25.6	84.5
Marshall	0	5.91	14.2	84.1	2.81	4.33	12.2	2.79	24.1	67.3
	67	7.00	17.0	119.3	3.64	5.73	21.0	3.33	25.6	85.2
	134	7.74	18.3	140.9	3.91	6.88	26.9	3.24	28.0	90.7
Mn 7125	0	6.04	14.0	84.9	2.71	4.28	11.6	2.55	23.8	60.4
	67	6.94	14.4	100.2	3.23	4.93	16.2	3.08	23.4	72.2
	134	7.15	16.1	115.6	4.05	6.40	26.0	3.48	23.6	82.1
Mn 7222	0	5.46	14.8	80.5	2.74	4.15	11.2	2.69	23.5	62.8
	67	7.81	16.8	130.7	3.79	4.78	18.1	3.16	25.5	80.7
	134	6.73	17.4	117.3	3.72	5.48	20.5	3.23	26.5	86.1
Olaf	0	5.05	16.2	81.9	2.59	4.40	11.5	2.16	29.3	63.2
	67	7.08	16.7	118.5	3.54	5.25	19.0	2.97	28.3	83.9
	134	7.43	18.2	135.0	4.27	6.90	29.4	3.41	28.6	97.5
Thatcher	0	5.42	13.0	70.9	3.30	4.43	14.5	2.77	24.8	68.8
	67	7.25	16.1	116.7	3.67	5.80	21.4	2.54	26.3	66.8
	134	7.28	16.4	119.1	3.80	6.73	25.5	2.60	27.7	71.5
Mn 7357	0	6.69	13.7	91.4	2.92	3.80	10.9	2.94	23.1	67.7
	67	7.66	16.2	123.9	3.90	6.13	23.7	3.45	23.5	81.1
	134	7.23	17.7	127.4	3.91	8.30	32.5	3.42	26.9	92.1
Mn 73167	0	4.92	15.0	73.9	2.62	4.28	11.4	3.24	22.7	73.9
	67	7.12	15.9	113.5	3.31	5.08	17.0	3.65	23.7	86.5
	134	6.62	18.1	119.7	4.09	6.60	26.8	3.21	27.7	89.0
Mn 73168	0	6.96	14.6	101.2	2.80	3.83	10.7	3.09	23.4	72.1
	67	6.19	16.2	100.3	2.28	5.68	12.9	2.27	24.9	56.5
	134	7.14	18.3	130.3	4.06	7.90	32.1	3.42	26.7	91.2
James	0	5.93	15.4	91.7	3.69	4.05	15.0	2.61	26.9	70.4
	67	7.32	16.4	119.5	3.85	5.13	19.7	2.81	29.3	81.9
	134	8.00	16.8	134.3	4.40	5.73	25.2	3.11	29.1	90.5
BSD(.05)*		1.28	1.8	24.6	0.90	1.14	6.7	0.61	2.24	17.2

*BSD values for comparison of nitrogen means for one variety

EFFECTS OF NITROGEN AND PHOSPHORUS APPLICATION METHODS ON SPRING WHEAT - 1983

West Central Experiment Station - Morris

S. D. Evans. W. E. Fenster, J. Grava and G. L. Malzer

The objective of this study was to compare nitrogen and phosphorus application methods on spring wheat. This is the third year of this study initiated to determine if dual banding of nitrogen and phosphorus is more effective than broadcast or drill applications on spring wheat growth and yield.

Experimental Procedures

Soil sample results prior to plowing in September are given in Table 1. In the late fall the plots were sampled by rep prior to fertilizer application and the results are given in Table 2. The broadcast 0-46-0 was applied by hand on November 6, 1982. The anhydrous ammonia and 10-34-0 were applied with a dual applicator on the same day. The material was placed at about an 8-inch depth with a knife spacing of 12 inches. The fertilizer bands in reps 1, 3 and 5 of treatments 3 and 11 were marked with red flags so that the bands could be located after harvest. In the spring on April 28 the area was field cultivated and drug. The study was then seeded to Era wheat @ 1 3/4 bu/A.

Whole plant samples were collected on July 20 and were used to calculate forage yield and N and P uptake. The plots were harvested on August 2 with a plot combine. On selected treatments soil samples after harvest were taken on September 2 and the results are given in Table 3.

Yield and Nutrient Uptake

The nutrient uptake and yield results are given in Table 4. Dry matter yield was significantly affected by N application but there were no significant differences in application methods. The highest yield was where 10 N and 10 P_2O_5 were drill applied and 90 N and 30 P_2O_5 were deep, dual banded (trt. 9).

The phosphorus concentration in the tissue at the soft dough stage decreased as N was increased with the dual NP placement method, but was not significantly affected by N with the other placement methods. There were some differences between placement methods at a given N rate, but there were no definite trends.

Phosphorus uptake did not increase with increased N except when the P was broadcast. At the 50 N rate the P uptake of the treatments where some N and P were drill-applied was lower than where the N and P were deep, dual banded. At the 100 N rate the deep, dual banded treatment had higher P uptake than the broadcast treatment and the treatment with no P applied.

The N concentration was significantly affected by N application rate with all placement methods. The only significant effect of application method was at 50 N where 10 N + 40 P_2O_5 drill applied had a significantly greater N percentage than three other treatments.

Nitrogen uptake in the tissue at the soft dough stage was closely related to N rate and was not significantly affected by application method.

Grain yield was significantly increased by N rate with deep, dual placement, NP2 drill and N only treatments. At the 50 N rate the N only treatment was significantly lower yielding than deep, dual placement and NP2 drill placement. At the 100 N rate the NP2 drill placement was significantly higher yielding than NP1 drill and N only placement methods.

Grain protein levels were closely related to N rate with values at the 100 N rate significantly higher than at the 50 N rate with all placement methods. The only difference between methods of placement was at the 100 N rate where NP2 drill > NP1 drill and N only > NP1 drill.

The 1983 study on placement methods shows very few effects of placement on any of the variables measured. In no case was there a significant difference between deep, dual banding (2 and 3) and broadcast (4 and 5). At the P soil test levels in this study there were no significant differences between deep, dual banding (2 and 3) and N only (10 and 11).

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

Soil Sampling of the Deep Bands

One problem associated with deep banding P is the method of obtaining accurate soil samples of the area banded. An attempt was made again in 1983 to see if the P level in the bands was different than the P level between the bands after harvest. Results in Table 3 compare the band and between band levels with the check treatment (no P) and the broadcast P treatment. The P soil test was determined by three methods.

There was a significant difference between the P soil test in the band compared to between the bands. Only with the Bray 1:50 was there a significant difference between the broadcast P treatment and the check. The between band P levels were not significantly different from the check P levels.

Table 1. Soil test results on September 9, 1982.

Soil Texture	pH	Bray P 1:10	Exch. K	NO_3-N (lb/A) 0-1'	1-2'	2-3'	3-4'	4-5'
SiCl	8.1	17 lb/A	275 lb/A	7	6	6	6	6

Table 2. Soil test results in November 1982.

Rep	P Soil Test Olson	Bray 1:10	Bray 1:50	Exch. K	Soil pH
	lb/A			- lb/A -	
1	13	23	55	283	7.9
2	15	21	50	294	7.8
3	12	20	50	242	7.8
4	12	20	45	270	8.0
5	14	21	50	235	7.9
6	13	24	50	257	7.8

Table 3. The effect of P application methods on P soil test (September 1983).

Trt. No.	P Placement Method	Sample Location	P_2O_5	P Soil Test Method[1] Olson	Bray 1:10	Bray 1:50
			- lb/A -	lb/A		
1	Check	-	0	7	10	27
3	Deep Band	In Band	40	18	17	48
		Between Bands	40	6	9	28
11	Deep Band	In Band	30	19	22	48
		Between Bands	30	9	13	32
5	Broadcast	-	40	11	12	38
Significance level (%):				99	98	99
BLSD(.05):				7	6	8
CV(%):				29	21	11

[1]Average of three replications, 4 subsamples per plot 0-10" deep, except for trt. No. 11 In Band and Between Bands where there were only two replications.

Table 4. The effect of N and P application methods on spring wheat.

Trt. No.	Treatment Description: Placement	Fertilizer Treatment: Source[1]	N	P_2O_5	Whole Plants @ Soft Dough Stage: D.M. Yield	Phosphorus	Phosphorus Uptake	Nitrogen	Nitrogen Uptake	Grain Yield	Grain Protein
			- lb/A -		lb/A	%	lb/A	%	lb/A	Bu/A	%
1	Check	-	0	0	1990	.247	4.95	1.26	25.1	20.2	12.6
2	Dual NP, Knife	AA,APP	50	40	6196	.212	13.12	1.34	82.7	52.9	12.8
3	Dual NP, Knife	AA,APP	100	40	6792	.173	11.78	1.58	107.5	57.3	14.4
4	N Knife, P BCST	AA,TSP	50	40	5992	.198	11.88	1.30	77.9	56.2	12.8
5	N Knife, P BCST	AA,TSP	100	40	6821	.205	13.97	1.52	103.9	57.1	14.3
6	N Knife, NP1 DRILL[2]	AA,UR,TSP	50	40	5717	.200	11.39	1.45	83.7	52.9	12.8
7	N Knife, NP1 DRILL[2]	AA,UR,TSP	100	40	6466	.187	12.17	1.59	103.3	53.7	14.0
8	N Knife	AA	50	0	6050	.196	12.00	1.31	79.5	49.9	13.2
9	N Knife	AA	100	0	6719	.178	11.94	1.65	109.9	56.1	14.8
10	NP Knife, NP2 DRILL[3]	AA,APP,UR,TSP	50	40	6093	.185	11.26	1.28	78.2	53.9	12.8
11	NP Knife, NP2 DRILL[3]	AA,APP,UR,TSP	100	40	6929	.185	12.72	1.61	111.5	60.4	14.6
Significance level (%):					99	99	99	99	99	99	99
BLSD(.05):					555	.025	1.6	0.13	12.4	3.9	0.4
CV(%):					8.9	11.1	13.0	8.3	13.6	7.3	3.0

[1]AA = Anhydrous Ammonia (82-0-0), APP = Ammonium Polyphosphate (10-34-0), TSP = Triple Super-Phosphate (0-46-0), UR = Urea (46-0-0).

[2]NP1 DRILL = 10 N + 40 P_2O_5 at seeding with drill.

[3]NP2 DRILL = 10 N + 10 P_2O_5 at seeding with drill.

SOIL TEST LAB COMPARISON

West Central Experiment Station - Morris
S. D. Evans and C. A. Schrader

In the past few years the number of commercial laboratories testing soils in west central Minnesota has increased. In many cases the commercial laboratory recommendations differ greatly from those of the University of Minnesota Soil Testing Laboratory. In order to develop educational material for use by the extension soils specialists, trials were started at the West Central Experiment Station in 1980 on a corn-wheat rotation. Results from the 1980, 1981 and 1982 trials were summarized previously (Soil Series 109 and Misc. Publ. 2 - 1982 and 1983).

In the fall of 1982 soil samples of the plow layer and the 0-2' zone (corn only) were taken from each plot except the check. The soil from the four replications was combined to make two samples (plow layer and 0-2') from each treatment. The samples were dried thoroughly, mixed and subdivided and sent to the same laboratory as that treatment in 1981. Recommendations were requested for corn at a yield goal of 130 Bu/A and spring wheat at a yield goal of 65 Bu/A. Analyses requested were (1) a complete analysis on the plow layer samples and (2) a nitrate-N analysis and recommendation on the 0-2' samples on the treatments to be planted to wheat. After receiving the soil tests and recommendations (Tables 1 and 2), the fertilizer treatments were calculated with an adjustment for soil buildup with Lab C. With Lab C there was no indication that the 0-2' sample was used for the nitrogen recommendation on wheat.

General

The experiment was set up as a randomized complete block with four replications on each crop. Two blocks, each with 24 plots, are adjacent to one another and alternate between wheat and corn. The plot size is 15 feet by 40 feet. Row spacing on the corn is 30 inches.

Wheat

Zinc, manganese and copper were dissolved in water and sprayed on the plots on November 11, 1982. The N, P, K and S were applied by hand on November 11 and all plots were then plowed. In the spring the plots were field cultivated and dragged. On April 25, 1983, the plots were seeded to Era wheat @ 1 3/4 Bu/A. Bromate was applied @ 1 pt/A on June 2 and on June 9 Hoelon was applied @ 3 1/3 pts/A. The plots were harvested with a plot combine on August 2.

Corn

Zinc, manganese and copper were sprayed on the plots on November 11, 1982. N, P, K and S were hand spread on November 11 and the area was plowed. On May 10, 1983, the area was field cultivated and dragged. The plots were planted with Trojan TXS 99A on May 11, with Counter @ 8.8 lbs/A. On May 11 the plots were sprayed with Lasso (2.5 lbs/A) and Bladex (2.2 lbs/A). The plots were harvested on September 27 with a plot combine.

Results and Discussion of the Wheat Trial

As shown in Table 1, the soil tests and fertilizer recommendations varied greatly with laboratory. Two labs recommended sulfur and one copper, zinc and manganese. The N, P and K recommendations had wide variations.

There were no significant differences between labs in plant height, grain yield or grain moisture.

The fertilizer cost and economic returns are given in Table 4. The fertilizer cost differed by $26 between Lab C and Lab E. The return over fertilizer ranged from $223.40 (Lab D) to $180.17 (Lab C). The check had the lowest returns.

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Results and Discussion of the Corn Trial

Soil tests varied widely, as shown in Table 2. Recommendations for N, P, and K were different, but the range was not as great as for the wheat. One laboratory recommended sulfur, zinc, copper and manganese.

Corn grain yields from Lab B were significantly lower than from all other labs. Lab E had a significantly lower grain moisture level than Labs A, B and C.

Fertilizer costs are given in Table 4. The costs ranged from $69.94 (Lab C) to $39.07 (Lab E). The economic return over fertilizer varied about $69/acre between labs.

Four-Year Summary

The combined data for 1980-1983 (Table 5) shows quite a range in the return over check. For wheat, Lab C shows the smallest return, while Labs A and E show the greatest return. For corn, three labs are still showing negative results, while Labs A and E are now showing a positive return. The combined results show a change in ranking of the labs, with Lab D switching from a negative to a positive return. After four years of testing, it appears that the recommendations by some labs of sulfur, micronutrients and high rates of P and K are not resulting in significantly higher yields than the University of Minnesota recommendations. On the other hand, some labs give recommendations that are similar to the University of Minnesota.

Table 1. Soil test results and the suggested fertilizer program for wheat in 1983.

	Soil Test Results				
Test	Lab A	Lab B	Lab C	Lab D	Lab E (UM)
pH	7.8	7.8	7.7	7.9	7.8
P (Bray 1), ppm	-	16(M)	-	-	-
($NaHCO_3$), ppm	14(H)	43(H)	16	17(H)	12
K, ppm	136(H)	191(H)	158	146(H)	153
O.M., %	4.0	3.3(H)	5.3	M	H
Ca, ppm	3800	3050(H)	4363	4200(H)	-
Mg, ppm	565	473(VH)	605	620(H)	-
Na, ppm	9	3050(H)	19	-	-
S, ppm	8(M)	5(L)	-	11(MH)	1
Fe, ppm	16.5(VH)	20(H)	-	14(H)	-
Mn, ppm	3.8(H)	6(L)	-	5.1(ADQ)	-
Zn, ppm	1.45(H)	2.0(M)	-	1.6(H)	1.9
Cu, ppm	.55(H)	0.8(L)	-	.6(H)	-
B, ppm	-	1.4(H)	-	1.7(M)	-
ENR (lb/A)	-	96	-	-	-
Nitrate-N (lb/A)	32	22(M)	-	58	31
C.E.C. (meq/100 g)	24	19.7	30.1	-	-
Soluble salts (mmhos/cm)	.40	-	.15	-	-

	Suggested Fertilizer Program[1]				
Nutrient	Lab A	Lab B	Lab C	Lab D	Lab E (UM)
	(lb/A)				
Nitrogen	88	57	110	62	90
Phosphorus (P_2O_5)	41	55	50	15	30
Potassium (K_2O)	42	55	160[2]	30	0
Sulfur	0	12	-	20	-
Zinc	0	1.5	-	0	-
Manganese	0	3	-	-	-
Copper	0	0.5	-	-	-
Boron	-	-	-	-	-

[1]All values indicate pounds of nutrient suggested per acre for a yield goal of 65 bushels per acre for wheat.

[2]Values include maintenance plus 1/2 of suggested buildup.

Table 2. Soil test results and the suggested fertilizer program for corn in 1983.

Test	Soil Test Results				
	Lab A	Lab B	Lab C	Lab D	Lab E (UM)
pH	8.0	8.0	7.9	8.0	8.0
P (Bray 1), ppm	-	8(L)	-	-	-
($NaHCO_3$), ppm	7(L)	36(M)	15	11(M)	5.5
K, ppm	98(M)	145(M)	130	121(H)	119
O.M., %	3.4	2.8(M)	2.9	(ML)	-
Ca, ppm	4700	3270(H)	5095	4400(H)	-
Mg, ppm	2009	386(VH)	516	700(H)	-
Na, ppm	6	-	14	-	-
S, ppm	4(L)	6(L)	-	12(MH)	2
Fe, ppm	9.2(H)	14(M)	-	13(H)	-
Mn, ppm	5.8(VH)	7(L)	-	8.3(ADQ)	-
Zn, ppm	1.02(H)	1.6(M)	-	1.4(H)	1.2
Cu, ppm	.56(H)	0.8(L)	-	.58(H)	-
B, ppm	-	1.2(M)	-	1.9(M)	-
ENR (lb/A)	-	86	-	-	-
Nitrate N (lb/A)	-	-	-	4	-
C.E.C. (meq/100 g)	-	19.9	30.1	-	-
Soluble salts (mmhos/cm)	.30	-	.15	-	-

Nutrient	Suggested Fertilizer Program[1]				
	Lab A	Lab B	Lab C	Lab D	Lab E (UM)
	(lb/A)				
Nitrogen	132	160	145	150	90
Phosphorus (P_2O_5)	103	90	90	85	90
Potassium (K_2O)	73	100	240[2]	100	40
Sulfur	0	14	0	0	0
Zinc	0	2.5	0	0	0
Manganese	0	3	0	0	0
Copper	0	1	0	0	0
Boron	0	0	0	0	0

[1]All values indicate pounds of nutrient suggested per acre for a yield goal of 130 bushels of corn per acre.

[2]Values include maintenance plus 1/2 of suggested buildup.

Table 3. Effect of fertilizer recommendations on various plant measurements - 1983.

Lab	Corn				Wheat		
	Early Plant Height	Early Plants (10) Dry Weight	Grain Yield	Grain Moisture	Plant Height at Harvest	Grain Yield	Grain Moisture
	- in -	- grams -	-Bu/A-	%	- in -	-Bu/A-	%
A	29.8	78	116.4	28.2	24.2	60.4	13.1
B	29.9	82	103.5	28.2	25.0	60.2	13.4
C	29.4	77	116.6	28.1	23.8	56.6	13.3
D	31.0	89	114.1	26.6	24.2	61.0	13.4
E (UM)	31.4	92	117.6	25.4	25.5	57.7	13.5
Check	28.2	67	77.4	30.4	24.0	42.5	14.0
Signif. level (%)	97	94	99	99	77	99	84
BLSD (.05)	2.0	19	11.2	2.3	-	10.6	-
CV (%)	4.1	13.3	2.0	2.2	4.3	2.3	2.7

Table 4. Economic return over fertilizer costs - 1983.

Lab	Wheat				Corn			
	Value of crop @ $4/Bu	Fertilizer cost*	Return over fertilizer	Return over check	Value of crop @ $3/Bu	Fertilizer cost	Return over fertilizer	Return over check
	$/A							
A	241.60	27.25	214.35	44.25	349.28	51.99	297.29	65.18
B	240.80	40.10	200.70	30.60	310.43	65.20	245.20	78.32
C	226.30	46.13	180.17	10.07	349.95	69.94	280.01	117.84
D	243.80	20.32	223.40	53.38	342.30	53.35	288.95	110.19
E (UM)	230.90	20.07	210.83	40.73	352.80	39.07	313.73	120.69
Check	170.10	0	170.10	-	232.11	0	232.11	-

*Values used ($/lb) were as follows: N = $0.14, P_2O_5 = $0.24, K_2O = $0.12, S = $0.22, Zn = $0.38, Cu = $2.80.

Table 5. Four-year summary of yields and economic returns - 1980-83.

Lab	Wheat*				Corn**				Combined Average Return per Year
	Total 4-year Yield	Total 4-year Fertilizer Cost	Economic Return over Fertilizer	Return over Check	Total 4-year Yield	Total 4-year Fertilizer Cost	Economic Return over Fertilizer	Return over Check	
	Bu/A	$/A			Bu/A	$/A			$/A
A	226.9	98.98	808.62	101.82	456.7	197.63	996.79	33.54	33.84
B	236.2	155.07	789.73	82.93	451.6	231.42	941.21	-22.04	15.22
C	232.40	198.78	730.82	24.02	465.5	267.90	949.53	-13.72	2.58
D	219.40	103.85	773.75	66.95	456.6	232.85	960.27	-2.98	15.99
E (UM)	228.6	82.18	810.55	103.75	458.2	161.32	1035.70	72.45	44.05
Check	176.7	0	706.80	-	370.3	0	963.25	-	-

*Wheat valued at $4/Bu, 1980-83.

**Corn valued at $3.00, $2.40, $2.00, and $2.50/Bu in 1980, 1981, 1982, and 1983, respectively.

PROBLEMS WITH IRRIGATED CORN 1983

W. E. Fenster, Mike O'Leary and Greg Buzicky

In 1982 field experiments were initiated at two irrigated sites, the CMIDRF at Staples and Roth farm northeast of Staples. Both areas had sandy textured soils. The objective was to probe possible causes for apparent corn yield restrictions.

County Agricultural Agents and irrigator farmers in recent years have reported corn production problems where corn yields appear to be on the decline. In 1979 two farmers in Morrison County complained that yields dropped by two-thirds from the year before. In 1980 and 1981 the Wadena County Agricultural Agent reported similar problems.

Treatments of the experiment are shown in table 1 along with 1983 corn yields at Staples. The Roth farm site was not in Corn in 1983 but the study will be resumed there in 1984.

Yield data in 1982 from the Roth farm indicated a significant response to nitrogen, and a significant benefit from the use of the inhibitor "N-Serve" but no benefit from boron even though plant analysis of the corn leaf at silking time showed below sufficient levels of boron. The Staples site showed no benefit from the inhibitor, the sulfur, the boron, or from split application of N in 1982.

Data from the Staples farm in 1983 show a significant response to nitrogen. The 80 pounds per acre N treatment at the eight leaf stage plus inhibitor provided significantly higher yield than 160 pounds of N per acre added preplant, also highest yield was attained with 160 pounds per acre of N plus inhibitor added at the eight leaf stage. With no inhibitor the treatment of 160 pounds in split applications added at eight leaf, 12 leaf and tasselling stages gave similar yields. The 200 pound N with inhibitor treatment gave no further yield increase over the 160 pound treatment with inhibitor There is no significant increase in yield from magnesium or sulfur when used as starter also with NPK fertilizer.

The efforts on this project of Todd King, Negussie Berihun and Mel Wiens are acknowledged.

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

Table 1. Nutrient treatments on corn at various growth stages at the Staples irrigation farm. 1983.

Trt	Total[2/] #N/A	Broadcast Nitrogen -----Amount and time of application------ ppl[1/]	8 leaf[1/]	12 leaf	Tassel	Starter[2/] N	P	K	S	Mg	Yield Bu/A @ 15.5% moist
1	20	--	--	--	--	+	+	+	+	+	66
2	100		80+			+	+	+	+	+	124
3	180	160				+	+	+	+	+	91
4	180	160+				+	+	+	+	+	136
5	180		160+			+	+	+	+	+	149
6	180	80+	80			+	+	+	+	+	146
7	180		80	40	40	+	+	+	+	+	145
8	180		80+	40	40	+	+	+	+	+	137
9	220	200				+	+	+	+	+	139
10	220	200+				+	+	+	+	+	138
11	220		80	80	40	+	+	+	+	+	141
12	220		80+	80	40	+	+	+	+	+	141
13	220		80+	80	40	+	+	+	-	+	143
14	220		80+	80	40	+	+	+	+	-	147
15	220		80+	80	40	+	+	+	-	-	134
16	220		80+	80	40	-	-	-	-	-	132

Trts	1-12	12-16
Significant	**	ns
BLSD (.05)	12.0	--
C.V.	7.6	7.8

Soil test averages: pH - 6.4, P - 54 lb/A, K - 319 lb/A, Mg - 242 lb/A, S - 5 ppm, Zn - 4 ppm.

[1/] + associated with N rate indicates use of N-Serve (1/2 lb/A a.i.)

[2/] 20 #N, 20 #P_2O_5, 40 #K_2O
10 #S and 10 #Mg applied per acre as starter

Table 2. Plant analysis of corn of the 6th leaf. Staples farm 1983.

Treatment	P (%)	K (%)	S (%)	M (%)	B (ppm)
12	.30	2.78	.22	.16	6
13	.30	2.82	.21	.16	7
14	.29	2.28	.20	.26	6
15	.30	2.68	.20	.16	7
16	.28	2.81	.20	.16	5
Adequate levels	.25	1.75	.20	.16	6

Table 3. Nitrogen content in 6th leaf at tasselling time from various nitrogen treatment rates and methods. Staples farm 1982 and 1983.

Treatment	N rate lb./A	1982	1983
1	0	2.08	1.67
2	80	2.48	2.68
3	160	2.93	1.99
4	160+	--	2.74
5	160+	2.97	2.81
6	80+ + 80	3.29	2.70
7	80 + 40 + 40	3.03	3.04
10	200+	3.39	3.18
Adequate		2.70	

+means inhibitor added

CORN - BEAN ROTATION

H. Meredith, Melvin Wiens and Greg Buzicky

A corn-bean experiment initiated in 1981 at the Staples Station to evaluate corn yields under a regime of continuous corn and corn following soybeans or edible beans continues.

Pioneer 3978 (85-day) and 3906 (95-day) relative maturity hybrids and Seafarer Navy beans and clay soybeans are utilized as the test crops in the experiment.

Purpose of Study: This study was initiated following complaints from farmers and extension personnel of the inability to meet corn yield expectations under irrigation on the sand plain. It is recognized that consistently high yields result from the best combination of management and climate. Temperatures ranging from excessively low spring and early fall to high summer offer adequate opportunities for havoc. Rainfall, both too little and too much on these coarse textured soils creates severe management problems. Typically farmers are ill prepared to supply sufficient irrigation water during periods of severe heat stress. Excess precipitation, especially following irrigation, may result in removal of nitrate nitrogen and possibly other vital soluble nutrients as sulfur from the rooting zone.

This study attempts to apply the best cultural management practices coupled with emphasis on timely irrigation and nutrition adequacy.

Table 1. Yield and Corresponding Information

Treatment	Bu/A	Shelling %	% Moisture	Grain Yield T/A	Stover Yield T/A	Grain/Stover	Total Tons
(1) C-C 3978	135.2	90.0	23.5	3.20	1.96	1.63	5.16
(2) C-C 3906	150.4	89.4	29.2	3.56	2.50	1.42	6.06
(3) C-SB 3978	148.2	89.7	22.5	3.51	2.28	1.54	5.79
(4) C-EB 3978	147.3	90.4	23.4	3.48	1.99	1.75	5.48
(7) C-C 3906 + Zn*	155.0	89.0	28.7	3.67	2.52	1.46	6.19
Sig	NS	NS	**	NS	**		*
P-value	85	88	99	85	99		97
BLSD	--	--	1.5	--	.36		.66
C.V.	6.9	.8	4.1	6.9	10.0		7.0

*Received Zinc in 81, 82, and 83, all other plots received zinc only in 1983.

C-C Continuous corn
C-SB Corn following soybeans
C-EB Corn following edible beans

Table 2. Fertilizer Applied to Corn Plots

	Broadcast	Starter	Total
N	180	18	198
P_2O_5		46	46
K_2O	240	60	300
Zinc		12.6	12.6

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Table 3. Supplemental Information

Date of planting:	4/28	Harvest:	10/10
Seed dropped/A:	32,000	Herbicide:	Lasso 2 qts/A (4/4)
Emergence date:	May 11		2,4-D, Banvel (8/1)
Tassel began:	7/10	Irrigation:	12.2 in.
		Rainfall (May-Aug)	16.46 in.

On May 16 a minimum temperature of 24°F was recorded at the Staples Station (approximately 5½ feet above grass under a shaded canapy). Obviously the ground temperature in the field was much lower, possibly as low as 18°F or lower. The corn was approximately 1 to 2 inches tall on this date. The growing point was well below the frost area although the ground was frozen, at least on the surface. The corn leaves suffered severe burn. The damage would have been lessened had near ideal temperatures prevailed after the freeze. Contrarily, overcast cold weather followed.

On May 16 or 10 days following the freeze "buggy whipping" was observed on many plants. Stand counts on May 31, 25 days following the freeze, indicated variations due to the freeze. Although stands were not reduced considerably, skips did occur in the plots contributing to some variability. Stand counts ranged from 28.8 to 31 thousand/A.

Table 4. Additional Information on Total Nutrient Removal

Treatment	Total N Removed Pounds/A	Total P Removed	Total K Removed	Total Ca Removed	Total Mg Removed	Total Zn Removed
	Pounds/A					
1	113.1	19.3	94.7	16.8	13.9	.19
2	148.0	25.3	118.4	22.0	16.3	.22
3	127.1	21.4	107.9	19.4	14.7	.20
4	123.8	22.0	100.3	16.8	13.8	.20
7	158.4	26.4	116.6	21.9	17.3	.25
Sig	**	*	*	NS	**	**
P-value	99	98	95	93	99	99
BLSD	13.2	4.2	18.8	--	2.1	.02
C.V.	6.8	11.4	10.3	15.5	8.6	6.0

Table 5. Nutrient Content of Corn Grain

Treatment	N	P	K	Ca	Mg	Zn	Cu	B	MN	Na	Fe	Al
	Percent					PPM						
1	1.33	.25	.39	.004	.107	22.0	2.16	24	4.3	.94	16.6	.40
2	1.62	.31	.40	.005	.139	23.6	.78	3.6	6.8	.94	24.6	.40
3	1.37	.26	.38	.004	.110	21.5	1.63	2.5	4.7	.94	17.6	.40
4	1.36	.27	.40	.004	.109	22.5	1.87	2.4	4.3	1.08	17.8	.40
7	1.65	.31	.39	.005	.138	25.6	1.31	3.7	6.8	.94	25.2	.40
Sig	**	**	NS	*	**	*	*	**	**	NS	**	
P-value	99	99	20	98	99	97	98	99	99	65	99	
BLSD	.06	.04	-	.007	.015	2.6	8	.2	.77	-	2.6	
C.V.	3.1	8.7	7.3	8.8	8.4	23	30.5	5	9.9	12.4	8.8	

Table 6. Nutrient Content of Corn Stover

Treatment	N	P	K	Ca	Mg	MN	Zn	Cu	B
	- - - - - - -		%	- - - - - - - -		- - - - - - -		PPM	- - - - - -
1	.72	.08	1.8	.42	.18	60.8	13.0	2.6	7.0
2	.65	.06	1.8	.43	.13	60.2	10.0	2.5	7.1
3	.69	.07	1.8	.42	.15	55.1	11.4	2.2	6.6
4	.72	.09	1.8	.42	.16	56.4	11.5	2.4	6.3
7	.75	.08	1.7	.43	.14	58.9	13.6	2.7	7.2
Sig	NS	NS	NS	NS	**	NS	NS	NS	*
P-value	84	79	2	2	99	45	87	56	95
BLSD	-	-	-	-	.02	-	-	-	.7
C.V.	7.4	20.1	10.7	8.9	7.4	10.7	15.9	16.5	6.0

Table 7. Leaf Tissue Analyses, Sampled at Silking and at Later Intervals

Date	N	P	K	Ca	Mg	MN	Zn	Cu	B
	- - - - - - -		%	- - - - - - - -		- - - - - - -		PPM	- - - - - -
7/22 L	2.66	.31	3.0	.59	.18	60	19	4.0	5.7
8/4 L	2.90	.31	2.6	.80	.23	70	19	4.8	8.8
8/4 H	3.11	.34	2.0	.71	.22	67	33	4.4	12.6
8/15 L	2.67	.27	2.4	.87	.26	81	20	5.1	11.5
8/15 H	2.79	.27	1.8	.86	.27	76	30	5.4	14.4

7/22 L Leaf opposite and below ear
8/4 L " " " " "
8/4 H " " " above "
8/15 L " " " below "
8/15 H " " " above "

Hybrid 3978. 7/22 sampling at 90% silk stage.

Uptake of Residual Fertilizer Nitrogen by Irrigated Barley

by Gregory C. Buzicky

When nitrogen (N) fertilizer is applied to the soil a portion is immobilzed by soil microbes and comes incorporated in the soil organic matter. This nitrogen, referred to as residual fertilizer nitrogen, is slowly mineralized over a period of years. The objective of this study was to determine the amount of residual fertilizer N taken up by subsequent crops one and two years after fertilizer application and to determine if subsequent N applications would affect the uptake of the residual fertilizer nitrogen.

Experimental Procedure. The experimental site was located at the Staples Irrigation Center and Demonstration Farm on a Sverdrup sandy loam. This site recieved 300 lbs N/A in 1980. Eight microplots (10' by 3') recieved N as approximately 5 % atom enriched 15-N. Four of the eight microplots recieved 15-N as ammonium chloride (NH_4Cl) while the other four recieved 15-N as calcium nitrate ($Ca(NO_3)_2$.

The treatments applied in 1981 and 1982 were 40 or 80 lbs N/A as ammonium nitrate in split applications (2/3 planting,1/3 boot). Soil test results from the site were: O.M.-2.7, pH-7.1, P-71, K -221, S-3. The plot area recieved approximately 6 acre-inches of supplemental irrigation each year.

In 1981, following broadcast application of 40 lbs K_2O/A and 20 lbs S/A and disking, Morex barley was planted on 4/16 at a rate of 96 lbs/A with 10 lbs P_2O_5/A as starter. Bromoxynil was sprayed on 6/3 for weed control and the boot application of N was applied. Forage yields were taken at the hard dough stage on 7/2 from the 15-N microplot areas. Soil samples for 15-N analysis were taken at this time also. Plots were harvested for yield on 7/27.

In 1982, following application of 50 lbs/A Sul-Po-Mag and seedbed preparation, Morex barley was planted on 4/27 at a rate of 96 lbs/a with 10 lbs P_2O_5/A as starter. Weed control was achieved with applications of dicloflop (Hoelon) on 6/4 and Bronimal+ on 6/15. Diathane M-45 was sprayed on 6/19. Forage yields were taken from microplots on 7/20 with yield determinations made on 8/6.

The forage samples were used for maximum plant growth and 15-N determinations. The soil samples were taken at this time were analysized for 15-N atom enrichment in the 0-9" and 9-18" increments. Standard precationary procedures for 15-N determinations were observed in sampling, handling and processing of the soil and plant 15-N samples.

Results. As would be expected on a coarse textured, irrigated soil, there was a yield and N uptake response to increased N application in both years (Tables 1 and 2). Grain yields were not as high as would be desired due to severe outbreak of Helminthosporium net blotch and Alteneria. Although the plots were sprayed with fungicide in 1982, control was minimal. However, forage yields were not thought to be affected to the same extent as the grain.

The influence of rate of N application on the amount of residual fertilizer N taken up in 1981 and 1982 by barley at the hard dough stage is presented in Table 3. Residual fertilizer N contributed only a small amount of nitrogen to the plant with only 2 to 3 lbs/A of residual fertilizer N utilized by the first subsequent crop and about 1 lb/A was taken up by the barley in the second residual year. While nitrogen applications affect yield and total N uptake, the uptake of residual fertilizer N was not influenced.

Some large differences were noted in the uptake of residual fertilizer nitrogen with respect to the original source of fertilizer N. The influence of the original source of N fertilization was investigated and this data is presented in Table 4. Significant differences were noted in the total amount of residual fertilizer N taken up by the barley in both years. Also, the percent of nitrogen derived from the 1980 fertilizer is significantly different depending on the origin of the N source. If the source was ammonium, then 6% of the N in the barley was residual fertilizer N in 1981 and 2% in 1982. With the nitrate source, 3.3% of the N in the plants was due to residual fertilizer N in 1981 and 1.3% in 1982. The percent N recovered, based on the original 300 lbs N/A application, differs significantly for both years. However, in 1981 and 1982, the percent recovered based on how much was in the soil at the start of each year is not significantly different. This would indicate that the mineralization and/or availability of the residual

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fertilizer N is similiar regardless of the original source and that the amount of residual fertilizer N taken up by plants is largely dependent on the amount of fertilizer N immobilized and how recent that the immobilization occurred.

The amount of residual fertilizer N found in the upper 18" of soil at the start of the study and after each cropping year is presented in Table 5. The nitrogen from the ammonium source was immobilized to a greater degree than the nitrogen from the nitrate source. These differences remained throughout the duration of the study and resulted in the differential uptake of residual fertilizer N. Significant differences existed in the 0-9" increment but this was not the case in the 9-18" increment. With the exception of the nitrate source in 1981 to 1982, a small loss of residual fertilizer nitrogen was detected each year. This agrees with the plant uptake of residual fertilizer N discussed earlier.

Summary. A portion of applied fertilizer N is immobilized in the soil and is slowly mineralized over a period of time and can be referred to as residual fertilizer N. The uptake of residual fertilizer N, under conditions of this study, was only 1-3 lbs/A per year depending on the number of years since application. The amount of residual fertilizer N used by subsequent crops was dependent on the amount of N that was initially immobilized in the soil and was not affected by crop yield or subsequent N fertilization. Nitrogen applied in the ammonium form was immobilized to a much greater extent than the nitrogen applied in the nitrate form.

Table 1. Yield and quality parameters of barley grown under irrigation as influenced by N rates, 1981.

Rate	Grain				Forage		
	Yield	Test wt.	N	Plump	Yield	N	N Removed
lbs/A	bu/A	lbs/bu	------%	-------	lbs/A	%	--lbs/A--
0	22.8	44.4	2.03	73	2460	.98	24.1
40	41.0	43.6	1.80	76	4580	1.01	46.2
80	51.2	43.8	2.01	74	5334	1.26	67.3
Sig. Level	99	57	27	66	99	99	99
BLSD (.05)	10.1	--	--	--	618	.16	13.0
C.V.(%)	38.1	2.2	10.7	6.6	10.0	9.1	18.2

Table 2. Yield and quality parameters of barley grown under irrigation as influenced by N rates, 1982.

Rate	Grain				Forage		
	Yield	Test wt.	N	Plump	Yield	N	N Removed
lbs/A	bu/A	lbs/bu	------%	-------	lbs/A	%	--lbs/A--
0	30.7	40.4	2.00	57	2050	1.40	28.6
40	44.1	40.0	1.94	58	4248	1.09	46.2
80	58.2	40.4	2.09	56	5128	1.26	64.9
Sig. Level	99	61	34	79	99	99	99
BLSD (.05)	13.8	--	--	--	916	.12	12.3
C.V.(%)	19.2	1.6	6.5	9.1	15.5	6.3	16.8

Table 3. N uptake, residual fertilizer N uptake and % N derived from 1980 applied N fertilizer as influenced by rate.

Year	Rate	Total N Removed	1980 Fert. Removed in 1981 Crop	% N Derived from 1980 Fertilizer	% Recovered from 1980 Fertilizer	% Recovered from Amount in Soil F,1980	% Recovered from Amount in Soil F,1981
	lbs/A	lbs/A	lbs/A	%	%	%	%
1981	40	45.0	2.3	4.95	.76	7.89	--
	80	67.3	3.0	4.38	.99	7.73	--
Sig.		*	ns	ns	ns	ns	--
1982	40	46.2	0.8	1.69	.26	2.67	3.05
	80	65.7	1.0	1.56	.33	2.60	3.02
Sig.		*	ns	ns	ns	ns	ns

Table 4. N uptake, residual fertilizer N uptake and % N derived from 1980 applied N fertilizer as influenced by original N source.

Year	Fert. Source	Total N Removed	1980 Fert. Removed in 1981 Crop	% N Derived from 1980 Fertilizer	% Recovered from 1980 Fertilizer	% Recovered from Amount in Soil F,1980	% Recovered from Amount in Soil F,1981
		lbs/A	lbs/A	%	%	%	%
1981	Nitrate	50.1	1.6	3.31	.54	6.62	--
	Ammonium	62.2	3.6	6.01	1.21	8.50	--
Sig.		ns	*	+	*	ns	--
1982	Nitrate	50.4	0.6	1.28	.21	2.55	3.24
	Ammonium	60.7	1.2	1.96	.38	2.69	2.93
Sig.		ns	**	+	**	ns	ns

Table 5. Fertilizer N remaining in 0-9", 9-18" and 0-18" soil increments as influenced by the original N source.

Fertilizer Source	Fertilizer N Remaining in Soil								
	Fall, 1980			Fall, 1981			Fall,1982		
	0-9"	9-18"	0-18"	0-9"	9-18"	0-18"	0-9"	9-18"	0-18"
	lbs Residual Fertilizer N/A								
Nitrate	19.2	5.1	24.3	15.5	3.6	19.1	15.1	4.0	19.1
Ammonium	37.0	5.7	42.7	35.3	4.0	39.3	32.5	4.7	37.2
Sig.	*	ns	*	**	ns	**	*	ns	*

SOUTHERN EXPERIMENT STATION - WASECA

WEATHER DATA - 1983

Month	Period	Precipitation 1983	Precipitation Normal 1/	Avg. Air Temp. 1983	Avg. Air Temp. Normal 1/	Growing Degree Days 1983	Growing Degree Days Normal 1/
		-----inches------		-------°F--------			
January	1-31	0.87	0.84	17.0	10.0		
February	1-28	1.17	0.99	23.0	16.4		
March	1-31	4.92	1.99	30.6	27.6		
April	1-30	4.28	2.64	39.0	44.7		
May	1-10	2.39		50.6		53.5	
	11-20	1.63		53.4		69.5	
	21-31	0.92		55.3		89.0	
	Total	4.94	3.76	53.2	57.7	212.0	334
June	1-10	0.07		59.7		111.5	
	11-20	1.27		66.9		171.5	
	21-30	3.12		72.6		215.5	
	Total	4.46	4.48	66.4	67.1	498.5	518
July	1-10	4.26		71.7		211.0	
	11-20	1.03		78.2		266.0	
	21-31	0.01		76.3		273.0	
	Total	5.30	4.02	75.4	71.2	750.0	641
August	1-10	0.00		75.6		236.0	
	11-20	0.05		75.0		241.0	
	21-31	4.56		74.2		261.0	
	Total	4.61	3.99	75.0	68.8	738.0	579
September	1-30	4.23	3.36	61.4	59.8	292.5	311
October	1-31	3.15	2.08	48.2	48.9	0.0	38
November	1-30	4.73	1.43	33.8	32.5		
December	1-31	1.96	1.02	-0.1	18.0		
Year	Jan-Dec	44.62	30.60	43.6	43.6	2491.0	2421
Growing Season	May-Sep	23.54	19.61	66.3	64.9	2491.0	2383

Notes:

1) 30-year normal from 1951-1980.
2) Highest temp. on July 22 -- 96°.
3) Highest 24-hour precipitation on July 1 -- 3.45".
4) Growing degree days were 3% above normal.
5) Available soil moisture in 0-5' profile was below 60% of field capacity in mid-August.
6) Last spring frost -- April 20.
7) Frost on September 23.

ROTATION NITROGEN STUDY

Waseca, 1983

G. W. Randall and D. T. Walters

Increasing the efficiency of fertilizer N along with reducing fertilizer N recommendations by improved diagnostic techniques, symbiotic N fixation, crop rotation, etc. are goals which are gaining widespread research support throughout the United States. The adoption of crop rotations or sequences may play a vital role in the conservation of N. The purpose of this study is to determine the N needs of continuous corn (removed for grain), corn removed for silage, second year corn following soybeans, corn following soybeans and corn following wheat.

EXPERIMENTAL PROCEDURES

Four crop sequences (continuous corn, corn-soybean, corn-wheat and corn-wheat + alfalfa) were begun in 1974 on a Webster clay loam. Each N plot within each crop sequence is 15' wide (6 rows) by 50' long. Rates of N (0, 40, 80, 120, 160 and 200 lb N/A) have been applied annually to corn.

The corn-wheat + alfalfa sequence was dropped in 1981 in favor of a continuous corn system where all of the corn was removed as silage the preceding year. This gives us a comparison of the N needs between grain removal only compared to total above-ground biomass removal. In 1982, a C-C-Sb rotation was introduced to examine the N needs of second-year corn following soybeans.

In 1983, anhydrous ammonia was applied on April 29 to all corn plots. Wheat received 50 lb N/A as urea before planting. Broadcast P and K of 50 + 150 lb P_2O_5 and K_2O/A were applied in the fall of 1982 before moldboard plowing all plots. Starter fertilizer was not applied.

Each corn plot was split lengthwise and two corn hybrids (Pioneer 3732 and Pioneer 3906) were planted in 30" rows at 29900 ppA on May 4. Amaze was applied to all corn plots at 1 lb/A to control rootworms. Butte wheat was planted on May 5. Hardin soybeans were planted on May 24.

Weeds were chemically controlled along with one cultivation of the corn. A combination of 4 qt Lasso plus 3 lb Bladex/A was applied preemergence to corn. Soybeans received 4 qt Lasso plus 6 qt Amiben/A applied preemergence.

Corn leaf samples were taken at silking from rows 2 and 3 (Hybrid A) and from rows 4 and 5 (Hybrid B) of each 6-row plot. Corn yields were taken by mechanically harvesting the same rows. Grain moisture and grain N data were obtained on the harvested samples.

After the 1982 harvest, soil samples were taken in the fall to a depth of 5' from the 0 and 160-lb N treatments which were applied to the continuous corn and continuous corn (silage) rotations in 1981. The same depth soil samples were also taken from the 0-lb N treatments in the plots where soybeans and wheat were the 1982 crop. Two cores were taken/plot, divided into 1-foot increments, composited/rep, dried, crushed and analyzed for NO_3-N by the Soil Testing Laboratory.

RESULTS

Nitrate-N remaining in the soil profile after the 1982 crop which was available to the 1983 corn, is presented in Table 1. When no fertilizer N was applied in 1982 (except the blanket 50-lb rate to wheat) very little difference in residual NO_3-N appeared among the four crop sequences. Essentially no differences in residual NO_3-N existed following continuous corn (grain or silage) or soybeans. Lowest residual NO_3-N followed wheat. When 160-lb of N was applied some carryover of that N was found with continuous corn (grain and silage) with greater residual NO_3-N levels following continuous corn (silage).

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Table 1. Effect of previous crop and N rate applied to corn in the crop sequence on residual NO_3-N remaining in the 0-5' profile at the end of the 1982 growing season.

Profile depth	Corn (grain)	Corn (silage)	Soybeans	Wheat
	Previous Crop			
feet	lb NO_3-N/foot			
		0 lb N/A		
0-1	29	30	32	30
1-2	23	25	27	24
2-3	22	24	24	20
3-4	23	25	23	17
4-5	24	19	22	16
Total (lb NO_3-N/5')	121	123	128	107
		160 lb N/A		
0-1	40	58		
1-2	39	48		
2-3	33	41		
3-4	31	35		
4-5	31	31		
Total (lb NO_3-N/5')	174	213		

Grain yield, leaf N and grain N responded to fertilizer N with both hybrids regardless of the previous crop (Tables 2A-B). When averaged over all N rates, there was no difference in the grain yield between P3906 and P3732. Grain N, however, was significantly higher for P3906. As a result, more N was removed in the grain by P3906 regardless of previous crop. Grain moisture was consistently higher for P3732 across all N rates and was significantly reduced upon addition of N.

Grain yields were suboptimal for 1982 due to moisture stress conditions brought about by extremely dry weather in late July and August. When averaging the two hybrids together, corn grain yield response to 200-lb N rate over the 0-lb N rate averaged 61.1, 52.4, 56, 60.7 and 68.5 bu/A for the continuous corn (grain), continuous corn (silage), corn after soybeans, corn after wheat, and second year corn after soybeans, respectively, (Table 2).

When no N was added, yields of second year corn following soybeans were lowest and were approximately 20 bu/A lower than for continuous corn. This was probably due to higher corn yields and greater stover production in the year following soybeans which resulted in a larger amount of corn residue being plowed under. This residue then could have immobilized more of the mineralized soil N than with the smaller amount of residue with the continuous corn system. Grain yields following corn (silage) were comparable to grain yields from continuous corn.

Highest grain yields were obtained when corn followed soybeans or wheat (Table 2). In general, yields were maximized at a lower N rate with P3906 than with P3732. For hybrid P3906, yields were maximized at 120-lb N/A when the preceding crop was continuous corn (grain) or soybeans and at 160-lb N/A following continuous corn (silage), wheat, and corn following soybeans. With hybrid P3732, yields were maximized at 160-lb N/A when the previous crop was continuous corn (silage), soybeans or corn following soybeans and at 200-lb N/A following continuous corn (grain) or wheat. At the 200-lb N rate corn yields (averaged over hybrids) exhibited differences of 10, 24, 26 and -13 bu/A for corn (silage), soybeans, wheat or corn following soybeans when compared to continuous corn. These differences were much greater than previous years and attests to the advantage of rotation in a stress year.

When no N was added, leaf N was highest following wheat and slightly lower following soybeans. Leaf N for second year corn following soybeans was lower than corn (silage) which was lower than continuous corn (grain). This is closely related to the yield differences mentioned previously. No significant difference occurred in leaf N between hybrids. Leaf N associated with the optimum yield level averaged 2.62 $\pm$ .1% (Table 2).

Table 2A. Corn grain yield, leaf N, grain N, grain N removed and grain moisture as influenced by previous crop, N-rate and hybrid at Waseca, 1983.

Previous Crop	Hybrid	N-rate (lb/A) 0	40	80	120	160	200
		Yield (bu/A)					
Cont. Corn (grain)	3906	51.3	68.4	93.1	110.5	111.1	108.3
	3732	56.8	77.3	91.4	102.5	108.1	122.1
Cont. Corn (silage)	3906	52.8	69.9	99.8	107.8	113.7	107.3
	3732	52.7	77.3	90.6	103.6	106.7	102.8
Soybeans	3906	80.6	107.4	115.0	138.0	137.3	140.1
	3732	86.0	115.2	127.2	134.8	139.0	138.6
Wheat	3906	76.1	103.3	120.7	134.3	140.7	138.1
	3732	84.8	110.6	130.1	131.7	139.7	144.3
Corn after soybeans	3906	33.8	61.0	89.0	99.9	110.8	99.5
	3732	33.4	56.4	84.8	96.7	102.9	104.7
		Leaf N (%)					
Cont. Corn (grain)	3906	1.48	1.58	2.00	2.52	2.56	2.64
	3732	1.52	1.59	1.84	2.40	2.64	2.53
Cont. Corn (silage)	3906	1.50	1.70	2.12	2.51	2.69	2.57
	3732	1.45	1.67	2.14	2.53	2.66	2.63
Soybeans	3906	1.52	2.00	2.42	2.71	2.71	2.78
	3732	1.56	1.97	2.34	2.55	2.70	2.77
Wheat	3906	1.64	2.01	2.27	2.61	2.68	2.75
	3732	1.59	1.91	2.06	2.71	2.76	2.61
Corn after soybeans	3906	1.44	1.51	1.86	2.34	2.63	2.63
	3732	1.35	1.43	2.02	2.51	2.51	2.62
		Grain N (%)					
Cont. Corn (grain)	3906	1.49	1.39	1.48	1.59	1.70	1.72
	3732	1.29	1.25	1.28	1.42	1.47	1.50
Cont. Corn (silage)	3906	1.52	1.48	1.43	1.63	1.68	1.71
	3732	1.37	1.26	1.30	1.48	1.49	1.53
Soybeans	3906	1.41	1.48	1.50	1.68	1.66	1.75
	3732	1.18	1.21	1.32	1.38	1.45	1.41
Wheat	3906	1.47	1.48	1.48	1.63	1.71	1.69
	3732	1.17	1.22	1.25	1.37	1.41	1.40
Corn after soybeans	3906	1.52	1.40	1.43	1.66	1.62	1.73
	3732	1.33	1.27	1.30	1.43	1.48	1.50
		Grain N Removed (lb/A)					
Cont. Corn (grain)	3906	36.1	45.1	65.0	83.1	89.3	87.4
	3732	33.7	45.4	55.2	67.7	74.7	85.4
Cont. Corn (silage)	3906	38.0	49.1	67.6	82.7	90.5	86.7
	3732	33.3	46.7	55.9	71.3	74.8	73.0
Soybeans	3906	54.1	75.5	81.3	109.5	106.9	116.0
	3732	48.1	66.1	79.3	87.9	95.0	91.7
Wheat	3906	53.5	72.9	84.7	103.3	112.9	110.4
	3732	46.9	63.8	77.0	85.5	92.6	95.3
Corn after soybeans	3906	23.9	40.6	60.5	77.6	84.8	80.7
	3732	20.7	33.4	52.0	63.9	72.1	72.6
		Grain Moisture (%)					
Cont. Corn (grain)	3906	18.8	17.2	17.7	17.0	17.2	17.2
	3732	23.0	21.3	20.8	20.6	20.9	19.7
Cont. Corn (silage)	3906	17.8	18.0	17.7	17.7	17.0	16.9
	3732	23.2	21.4	20.9	21.2	20.4	21.2
Soybeans	3906	19.2	18.6	17.8	14.4	17.5	17.9
	3732	22.2	21.2	20.0	20.2	20.0	20.4
Wheat	3906	19.2	18.5	18.2	18.0	18.2	18.3
	3732	21.8	22.0	20.7	20.6	20.9	20.8
Corn after soybeans	3906	18.6	17.0	17.1	16.7	16.8	16.1
	3732	23.1	21.8	20.6	20.8	20.1	20.4

Table 2B. Statistical interpretation of Rotation x N data at Waseca in 1983.

Source	Yield	Grain Moisture	Grain N	Grain N removed	Leaf N
	Probability level of significance				
Main effects					
Sequence	99	34	42	99	99
N rate	99	99	99	99	99
Hybrid	72	99	99	99	86
Interactions					
Sequence x N rate	15	73	43	06	97
Sequence x Hybrid	96	96	99	86	18
N rate x Hybrid	98	77	79	99	09
Seq x NR x Hybrid	34	34	09	59	71
BLSD: Sequence (.10)	8.7			6.0	.11
(.05)	10.3			7.0	.13
N rate (.10)	4.5	.39	.03	3.0	.06
(.05)	5.2	.45	.03	3.5	.07
CV (%)	8.6	6.9	5.2	9.7	7.1

Grain N data do not follow the yield and N data closely (Table 2). Grain N ranked according to previous crop as continuous corn (silage) > corn after soybeans > continuous corn > soybeans > wheat when no N was applied. This most likely resulted from dilution and to differences in grain yield. Grain N was significantly higher for hybrid P3906 when compared to P3732. When 200-lb N/A was applied, differences in grain N did not exist among the crop sequences. Protein levels at the optimum N rates averaged about 10.4 and 9.1% with the P3906 and P3732 hybrids, respectively.

The relationship between N rates needed for the optimum yields shown in Table 2 did not show any apparent relationship to the residual NO_3-N values shown in Table 1. This effect was complicated by the differential response of hybrid to previous crop and N rate. Although the lowest residual NO_3-N was found in following wheat, yields were optimized at 160 and 200-lb N/A for P3906 and P3732, respectively.

Fodder and silage yields from the continuous corn (silage) treatment responded to fertilizer N with both hybrids (Table 3). Fodder and silage yields for both P3906 and P3732 were maximized at the 120-lb N/A rate. Pioneer 3732 yielded significantly more fodder and silage than P3906 when averaged over N rates.

To determine if N from the 1982 application to corn influenced 1983 soybean yields, soybeans from the 0 and 200-lb N/A treatments were harvested from all 5 replications. The data in Table 4 indicate no effect from the previous year's N treatment on soybean yield or seed moisture in 1983.

Table 3. Fodder and silage yield as influenced by N rate and hybrid in a silage corn rotation at Waseca, 1983.

N rate	Hybrid	Fodder Yield	Silage Yield
lb/A		T DM/A	T DM/A
0	3906	1.36	2.67
	3732	1.63	2.92
40	3906	1.75	3.64
	3732	2.32	4.31
80	3906	2.08	4.60
	3732	2.54	5.07
120	3906	2.21	5.33
	3732	2.68	5.57
160	3906	2.03	4.79
	3732	2.44	5.22
200	3906	2.17	5.12
	3732	2.42	5.33
Individual Factors			
N rate (lb/A)			
0		1.50	2.80
40		2.04	2.97
80		2.31	4.84
120		2.45	5.45
160		2.24	5.00
200		2.30	5.22
Signif. Level (%):[1/]		99	99
BLSD (.05) :		.14	.32
Hybrid			
3906		1.93	4.36
3732		2.34	4.75
Signif. Level (%):[1/]		99	99
Hybrid x N rate IA		60	63

[1/] Probability level of significance

Table 4. Influence of N applied to corn in 1982 on the yield and moisture of soybeans in 1983.

N rate (lb/A)	Yield bu/A	Moisture %
0	59.3	11.9
200	57.3	12.0

NITROGEN LOSS TO TILE LINES AS AFFECTED BY TILLAGE

Waseca, 1983

G. W. Randall and D. T. Walters

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 proposed 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 from 12 plots measuring 45' x 50' each enclosed with plastic sheeting to a 6' depth into a tile line installed in each plot. 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 7-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, the 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. A fertilizer application rate of 0 + 50 + 150 ($N+P_2O_5+K_2O$)/A was broadcast applied in October, 1982 before the moldboard plowing. Percent surface residue was measured on April 26, 1983 and averaged 10.5 and 96% for the moldboard plow and no tillage systems, respectively.

On April 30, 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 May 9 at a population of 27700 plants/A with a John Deere Max-Emerge planter equipped with 2" fluted 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#) and atrazine (3#/A). Control was excellent.

Early plant growth was determined by harvesting the above ground portion of 10 plants/plot 43 days after planting. The leaf opposite and below the ear was taken from 10 randomly selected plants per plot at silking and was analyzed for N. Silage and grain yields were taken at physiological maturity by hand harvesting 30 and 60' of row, respectively, from each plot.

Tile lines began flowing in March, 1983 and continued to flow intermittently until mid July. Conditions were extremely dry in late July, August and September and no tile flow was recorded during this period. Tile lines commenced flowing again in October through early December. When tile lines were flowing, flow rates were measured daily and samples taken on Monday, Wednesday and Friday for NO_3-N analysis. All analyses were done by the Research Analytical Lab.

Soil NO_3-N in the 0-6' profile was determined from two cores/plot taken in 1-foot increments on October 17, 1983.

RESULTS

Early plant growth with moldboard plow tillage was significantly greater than with no tillage (Table 1). This was probably due to cooler soil temperatures and slower emergence rates under no tillage. Leaf N was also significantly greater with moldboard plow tillage. Corn silking on no tillage plots was delayed approximately one week.

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No significant differences (p>95%) were found between tillage systems in silage yield, silage N uptake, grain yield, grain N or grain N uptake in 1983. A slight trend toward higher silage yield and silage N uptake was observed with moldboard plow however.

Precipitation for 1983 was 46% above the 30-year normal and resulted in high amounts of tile flow in 1983. Tile flow for the period (March-December) was approximately 9% higher with the no tillage treatment (Table 2). Nitrate-N concentration in the tile water averaged 0.82 mg/L higher with no tillage which was probably not a significant difference. Total NO_3-N loss, a function of both tile flow and NO_3-N concentration, averaged 7.4 lb NO_3-N/A higher with no tillage primarily due to the high tile flow from this treatment.

Residual NO_3-N in the 0-6' profile after harvest was not significantly affected by the two tillage treatments (Table 3).

Table 1. Influence of tillage system on corn production and N utilization at Waseca in 1983.

Tillage system	Early plant growth	Leaf N	Silage Yield	Silage N uptake	Grain Yield	Grain N	Grain N removal
	g/plant	%	T DM/A	lb N/A	bu/A	%	lb N/A
Mb. Plow	34.7	2.69	4.95	103.3	105.8	1.45	73.0
No Tillage	17.7	2.50	4.70	97.5	102.3	1.50	72.4
Signif. Level (%):	99	94	75	80	47	28	08
CV (%) :	10.5	3.4	5.2	5.0	6.8	10.8	12.5

Table 2. Influence of tillage system on tile flow, NO_3-N concentration and NO_3-N loss at Waseca in 1983.

Tillage system	Tile flow[1/]	Nitrate-N Concentration	Nitrate-N Loss
	acre-inches	mg/L	lb NO_3-N/A
Mb. Plow	20.55	7.88	36.70
No Tillage	22.39	8.70	44.10

1/ March-December, 1983

Table 3. Influence of tillage system on residual NO_3-N in the soil profile in November, 1983.

Profile depth	Tillage System: Mb. Plow	Tillage System: No Tillage
feet	-------NO_3-N (lb/A)------	
0-1	12.8	14.4
1-2	14.8	8.0
2-3	14.0	12.0
3-4	11.6	15.6
4-5	11.2	14.8
5-6	11.2	16.0
Total (lb NO_3-N/A 0-6')	75.6	80.8

NITROGEN EFFICIENCY AS AFFECTED BY RIDGE-PLANTING

Waseca, 1983

G. W. Randall

As conservation tillage systems become more popular there are numerous questions regarding proper fertilization practices. Ridge planting, a system where no preparatory tillage is done but the seeds are planted on a preformed ridge, has attracted much attention in the last few years. The purpose of this study was to determine the influence of N source, N rate and method-time of N application on the N needs of continuous corn grown in a ridge-plant system so as to improve N efficiency with conservation tillage.

EXPERIMENTAL PROCEDURES

Nineteen treatments, involving a factorial with 3 method-times of application, 3 sources of N and 2 rates of N plus a check treatment, were replicated five times and applied to a Webster clay loam. All treatments were completely randomized. Each individual plot measured 10' wide (4 rows) by 60' in length.

The plots in 1983 were planted on the same plots as in 1981 and 1982; thus, the treatments were continuous. The previous crop of corn was ridged in July of 1982. In the fall of 1980, P and K were broadcast at a rate of 30 + 120 lb P_2O_5+K_2O/A. Soil tests averaged: pH = 7.4 Bray P_1 = 41 lb/A (Very High) and exchangeable K = 325 lb/A (Very High). Response to additional fertilizer P and K would not be expected at these soil test levels; hence no P or K was applied for 1983.

Corn (Pioneer 3732) was planted with a Buffalo till-planter at 27000 plants/A with 1 lb Furadan (a.i.)/A on May 18. No starter fertilizer was used. Weeds were chemically controlled with Lasso (4 lb/A) + Bladex (3½ lb/A) applied preemergence on May 23. All plots were cultivated and ridged on July 14.

One-third of the N treatments was applied preplant on May 18. The urea was broadcast on the surface by hand while the urea-ammonium nitrate (UAN) solution (28% N) was broadcast with a motorized bicycle sprayer. The planting operation which removes the top of the ridge and deposits the soil in the interrow valleys was done within 6 hours of N application and should have incorporated most of the N. Anhydrous ammonia (AA) was knifed-in between the ridges with an anhydrous tool bar equipped with coulters ahead of the knives.

Another one-third of the treatments was applied just as the corn was emerging (June 3). Application techniques were the same as at preplanting. The last one-third of the treatments was sidedress-applied at the 10-leaf stage (July 8). This delay from the intended 8-leaf stage was due to an extended wet period from June 30 to July 7. The urea and UAN materials were banded 4-6 inches to the side of each row and covered slightly with soil. This simulated N application with a cultivator.

The percent of the soil surface covered by corn residue from the 1981 crop was measured prior to planting and again at emergence by the line-intercept method.

Leaf samples were taken at silking from 10 random plants in the center two rows of each plot. Final population was determined from 120' of row prior to harvest. Grain yield, grain moisture and grain N (protein) were determined on corn harvested from the center two rows of each plot with a modified JD 3300 plot combine on October 6.

Two separate analyses of variance statistical tests were conducted on the data. The first was a two-way ANOVA with all treatments including the check. A second analysis, with the check treatment omitted, was made to estimate the influence of each of the main factors (method-time, N source, and N rate) and the interactions among these factors.

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

RESULTS AND DISCUSSION:

Surface residue. Residue accumulation measurements across both the ridge and inter-ridge areas of all treatments showed that 70% of the soil surface was covered by residue from the previous crop prior to planting (May 18). At the emergence stage (June 3) this had dropped to 27% as a result of residue incorporation by the planter.

Plant height. Plant heights were measured at two stages: 13-14 leaf (July 20) and after tasseling (August 9). Prior to tasseling all N treatments applied at the preplant (PP) and emergence (EM) stages increased the plant height above the check (Table 1). Apparently the N from the sidedress (SD) treatments applied 12 days prior to taking the measurements had not been utilized yet. Thus, the plants were still somewhat stunted. When averaged over N source and rate, the factorial analysis indicated the PP application to have slightly taller plants than the EM application with both the PP and EM plants being substantially taller than the SD plants (Table 2). There was no significant difference among N sources when averaged over N rate and method-time. The difference in plant height between the N rates was not significant (90% level) when averaged over method-time and source. The highly significant interaction between method-time and N source (98% level) indicates that the plants were somewhat smaller with AA compared to the UAN and urea materials when applied PP and EM, while at the SD stage the largest plants were associated with the AA source. The reversal was probably due to the injection of the AA into the moist soil at the SD stage where the NH_3 could be nitrified quickly and taken up by the plants. Whereas, the UAN and urea were applied near the soil surface and probably were not moved into the rooting zone for rapid uptake.

Table 1. Plant height, final plant population, and leaf N as influenced by method-time, source, and rate of N fertilizer applied to a ridge-plant system at Waseca in 1983.

Treatments						
Method[1/] -Time	N Source[2/]	N Rate	Plant Height 7/20	Plant Height 8/9	Final population	Leaf N
		lb N/A	-----cm-----		x 10^{-3}	%
PP	UAN	75	145	225	25.8	2.25
PP	UAN	150	153	222	27.0	2.66
PP	Urea	75	142	219	26.5	2.27
PP	Urea	150	145	222	26.5	2.51
PP	AA	75	134	216	26.4	2.27
PP	AA	150	148	228	25.7	2.71
EM	UAN	75	141	219	26.4	2.11
EM	UAN	150	141	220	25.9	2.45
EM	Urea	75	137	221	25.9	2.30
EM	Urea	150	147	222	25.7	2.76
EM	AA	75	135	218	26.6	2.35
EM	AA	150	134	216	25.5	2.76
SD	UAN	75	123	208	26.1	1.64
SD	UAN	150	116	203	25.6	1.89
SD	Urea	75	119	203	25.7	1.60
SD	Urea	150	116	202	25.1	1.89
SD	AA	75	125	215	25.9	2.36
SD	AA	150	128	221	26.7	2.64
	Check		116	201	25.3	1.56
	Significance Level (%):		99	99	95	99
	BLSD (.05)	:	11.	10.	1.5	.23
	CV (%)	:	6.7	3.8	3.3	8.8

1/ PP=preplant, EM=emergence, SD=sidedress at 8-leaf stage

2/ UAN=28% N solution, AA=anhydrous ammonia

3/ Probability level of significance

Table 2. Factorial analyses of plant height, plant population and leaf N as influenced by method-time, source and rate of N fertilizer applied to a ridge-plant system at Waseca in 1983.

	Plant Height 7/20	Plant Height 8/9	Final population	Leaf N
	-----cm-----		x 10^{-3}	%
Main Treatments				
Method-Time				
PP	144	222	26.3	2.44
EM	139	219	26.0	2.46
SD	121	209	25.9	2.00
Signif. Level (%):	99	99	84	99
BLSD (.05) :	4	4		.09
N Source				
UAN	136	216	26.1	2.17
Urea	134	215	25.9	2.22
AA	134	219	26.1	2.51
Signif. Level (%):	48	85	49	99
BLSD (.05) :				.09
N Rate				
75	133	216	26.1	2.13
150	136	217	26.0	2.47
Signif. Level (%):	88	52	63	99
Interactions				
Meth-Time x Source				
PP UAN	149	224	26.4	2.45
PP Urea	143	221	26.5	2.39
PP AA	141	222	26.0	2.49
EM UAN	141	219	26.1	2.28
EM Urea	142	221	25.8	2.53
EM AA	135	217	26.0	2.56
SD UAN	119	206	25.9	1.77
SD Urea	117	203	25.4	1.74
SD AA	126	218	26.3	2.50
Signif. Level (%):	98	99	78	99
			Significance Levels (%)	
Method-Time x Rate	94	45	77	57
Source x Rate	43	80	40	11
M-T x S x R	58	45	97	24

After tasseling height measurements also showed significantly taller plants with the PP and EM applications compared to the check (Table 1). However, the SD applications of UAN and urea were not different from the check. Factorial analysis of the data (Table 2) indicate an almost identical pattern as with the pre-tassel data. No appreciable rain occurred in the 32-day period between the SD application and the post-tassel measurement. During this time it appears as though the SD-applied UAN and urea, which were placed on the soil surface and covered slightly, remained near the upper-part of the rooting profile and were positionally unavailable.

Final population. Final population was significantly different (95% level) among the treatments but no relationship could be ascribed to method-time, N source or N rate (Tables 1 and 2). This was in contrast to previous years when populations were decreased by the application of AA at the EM stage. Improved coulters which penetrated the soil ahead of the new anhydrous knives (without sealing wings) aided the 1983 application of the AA under soil conditions which were ideal.

Leaf N. Nitrogen concentration in the earleaf at silking was increased significantly over the check by all of the N treatments except the SD applied 75-lb rate of UAN and urea (Table 1). Factorial analysis showed a significant effect of method-time (PP = EM > SD) when averaged over N source and rate, N source (AA > urea = UAN) when averaged over method-time and N rate, and N rate (150 > 75) when averaged over method-time and N source (Table 2). The significant interaction (99% level) between method-time and N source is shown by the low N concentrations with the SD applied UAN and urea treatments (probably for the same reason as discussed for plant height) and the UAN applied at the EM stage. Perhaps some of the UAN was volatilized from this high pH soil (7.4) which was 27% covered with plant residues from the 1982 crop. This did not occur with urea, however.

Grain yield. Grain yields were extremely low due to the 7-week dry period (July 5-August 24) and the accompanying very hot temperatures which placed tremendous stress on the corn. However, all N treatments except the 75-lb rate of urea SD applied at the 10-leaf stage resulted in yields greater than the check (Table 1). Factorial analysis showed significant differences among method-time (PP > EM >> SD), between N rates (150 > 75) and a slight advantage for AA compared to UAN and urea (significant at the 91% level) (Table 2). The significant method-time x N source interaction is again shown by the (1) little difference among N sources when applied PP, (2) slightly lower yield with UAN when broadcast-applied to the soil surface at the EM stage, and (3) substantially lower yields obtained with UAN and urea compared to AA when SD applied at the 10-leaf stage.

Nitrogen applied prior to planting offered no problems. Apparently the UAN and urea were incorporated satisfactorily by the planter and the AA went on very easily. The residue was easily cut by the coulters and ammonia vapors were not observed. Ammonia application at the 10-leaf stage went very smoothly and resulted in higher yields than with either UAN or urea. This was probably due to positional unavailability of the UAN and urea which were only incorporated about 1 inch deep. After application to the slightly dry surface soil, rainfall totaled only 1.80" over the next 7 weeks. This did not allow for adequate movement of the N down into the soil where most of the root activity and nutrient uptake was occurring. On the other hand the AA was injected about 7" deep into the moist soil where nitrification could take place, hence, greater N uptake.

Grain moisture. With the exception of three SD treatments grain moisture was reduced significantly from the check by all of the N treatments (Table 3). Factorial analysis showed lower grain moistures to be associated with the earlier N application times (PP < EM < SD) and with the higher N rate (Table 4). Grain moisture was not significantly affected (95% level) by source of N; however, the method-time x source interaction was highly significant. This is illustrated by the slightly lower moisture levels with UAN and urea compared to AA at the PP and EM stages as contrasted to the higher moistures with UAN and urea compared to AA at the SD stage.

Protein. Protein percentage of all treatments was generally low but was increased over the check by all of the 150-lb N treatments except the SD application of UAN at the 10-leaf stage (Table 3). Factorial analysis indicated an effect of N source (AA > Urea = UAN) and N rate (150 > 75) on protein percentage (Table 4). Protein levels were not influenced by the method-time factor or the interaction between method-time and N source. However, the highly significant interaction between method-time and N rate is shown by protein being increased from 7.79% to 8.83% by the higher N rate with the PP application, from 7.79% to 8.57% with the EM application, but only from 8.00% to 8.16% with the SD application at the 10-leaf stage.

N removal. Grain N removal is the product of grain yield times grain N percentage and thus parallels the yield and protein responses very closely. All N treatments significantly improved N removal (uptake) over the check (Table 3). Factorial analyses indicated less grain N removed with delayed N application time, with UAN and urea compared to AA, and with the 75-lb N rate (Table 4).

Nitrogen efficiency. The N efficiency, as calculated from grain N removal minus that of the check and then divided by the N application rate, was extremely low in 1983 due to the low yields (Table 3). The lowest values were generally obtained with the SD applied UAN and urea materials and with UAN applied at the EM stage.

Weather conditions could have been conducive to volatilization of the surface-applied UAN and urea following the EM application as shown in Table 5. Although precipitation totaled only 0.09" in the 10-day period, measurable rainfall occurred on 3 days with trace amounts occurring on 4 other days. This amount of rain would not have been enough to move the N into the soil, but the rather humid and warm conditions may have resulted in some volatilization.

Table 3. Grain yield, moisture, protein, N removal, and N efficiency as influenced by method-time, source and rate of fertilizer N applied to a ridge-planted system at Waseca in 1983.

Treatments			Grain				
Method-Time	N Source	N Rate	Yield	Moisture	Protein	N removal 1/	N efficiency 2/
		lb N/A	bu/A	%	%	lb N/A	%
PP	UAN	75	86.3	20.8	8.05	52.7	26
PP	UAN	150	101.2	19.9	8.64	66.2	22
PP	Urea	75	86.9	21.0	7.71	50.7	24
PP	Urea	150	97.1	20.2	8.79	64.4	21
PP	AA	75	80.6	22.4	7.61	46.5	18
PP	AA	150	98.2	20.4	9.06	67.0	23
EM	UAN	75	80.5	21.7	7.71	47.0	19
EM	UAN	150	84.1	21.6	8.49	53.7	14
EM	Urea	75	86.4	21.8	7.67	50.2	23
EM	Urea	150	99.0	20.3	8.41	63.1	20
EM	AA	75	85.3	22.6	8.00	51.5	25
EM	AA	150	87.7	21.6	8.80	58.3	17
SD	UAN	75	71.5	23.3	7.77	42.2	12
SD	UAN	150	75.6	22.8	7.87	44.9	08
SD	Urea	75	64.9	23.5	7.95	39.4	09
SD	Urea	150	70.1	23.3	8.20	43.7	07
SD	AA	75	83.2	22.9	8.27	52.2	26
SD	AA	150	91.8	21.5	8.41	58.3	17
	Check		58.2	24.1	7.44	32.8	
Significance Level (%):			99	99	99	99	
BLSD(.05) :			9.7	1.1	.51	6.3	
CV(%) :			9.8	4.4	5.1	10.5	

1/ Yield times grain N

2/ (Grain N removed from trt. - Grain N removed from check) ÷ N Rate

Table 4. Factorial analyses of grain yield, moisture, protein and N removal as influenced by method-time, source and rate of N fertilizer applied to a ridge-plant system at Waseca in 1983.

	Grain			
	Yield	Moisture	Protein	N removal
	bu/A	%	%	lb N/A
Main Treatments				
Method-Time				
PP	91.7	20.8	8.31	57.9
EM	87.2	21.6	8.18	53.9
SD	76.2	22.9	8.08	46.8
Significance Level (%):	99	99	88	99
BLSD (.05) :	3.9	.4		2.6
N Source				
UAN	83.2	21.7	8.09	51.1
Urea	84.1	21.7	8.13	51.9
AA	87.8	21.9	8.36	55.6
Significance Level (%):	91	36	97	99
BLSD (.05) :			.23	2.8
N Rate				
75	80.6	22.2	7.86	48.0
150	89.4	21.3	8.52	57.7
Significance Level (%):	99	99	99	99
Interactions				
Meth-Time x Source				
PP UAN	93.7	20.3	8.34	59.4
PP Urea	92.0	20.6	8.25	57.5
PP AA	89.4	21.4	8.34	56.8
EM UAN	82.3	21.7	8.10	50.3
EM Urea	92.7	21.0	8.04	56.6
EM AA	86.5	22.1	8.40	54.9
SD UAN	73.5	23.0	7.82	43.6
SD Urea	67.5	23.4	8.09	41.6
SD AA	87.5	22.2	8.34	55.3
Significance Level (%):	99	99	67	99
		Significance Level (%)		
Meth-Time x Rate	90	39	99	99
Source x Rate	12	86	63	55
M-T x S x R	49	49	49	51

Table 5. Air temperature and precipitation in the 10-day period following the emergence stage application of N in 1983.

Day	Air Temperature Max.	Air Temperature Min.	Precipitation
	-------°F------		inches
1 (N applied)	72	47	T
2	67	46	T
3	58	39	.05
4	71	44	---
5	77	50	---
6	81	53	.01
7	78	60	---
8	87	61	T
9	82	64	.03
10	82	65	T

SUMMARY

Application of N at PP regardless of N source resulted in the highest yields, protein level, and N removal, tallest plants at both the pre and post tassel stages, and the lowest grain moisture. Application at the emergence stage to the 27% residue covered soil surface resulted in similar results as with the PP application except with UAN. Leaf N and grain yield was lower with UAN compared to urea and AA. This could have been due to volatilization loss since significant rainfall did not occur until 11 days after application. The SD applications of all materials at the 10-leaf stage gave the lowest yields. This was especially true for UAN and urea. Because of the extremely dry conditions from the time of sidedressing until late August, positional unavailability of the UAN and urea was thought to be the primary factor.

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SOIL TEST COMPARISON STUDY

Waseca, 1983

G. W. Randall and P. L. Kelly

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 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. Both sites have been cropped to continuous corn. 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. Soil analyses requested consisted of pH, OM, extractable P_1, 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.

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 allows us to follow the buildup or decline of nutrients in the soil as affected by the recommendations of a particular laboratory over a continuous, long period of time.

Soybeans were initiated into this study in 1982 after nine years continuous corn at the very high testing site and after seven years at the medium-high testing site and will again be planted in 1984.

Fertilizer amounts based on the analyses and recommendations from the summer 1982 samples were applied in the fall to the appropriate plots and incorporated by field cultivation. Lab nitrogen recommendations were spread in the following spring and also field cultivated. These fertilizer recommendations were based on a yield goal of 160 bu/A of corn following soybeans. Corn (Pioneer 3732) was planted at 27,700 ppA in 30" rows on May 9 with neither insecticide nor starter fertilizer. Chemical weed control consisted of 3½ qt. Lasso and 3½ qt. Bladex/A applied preemergence.

On July 25 the leaf opposite and below the ear at 50% silking was randomly sampled from ten plants and submitted for analyses. Final populations were determined from 70' of row. Grain yield and moisture were determined on corn harvested from the center two rows of each plot with a modified JD 3000 plot combine. Grain yields were converted to 15.5% moisture.

In August 1983, 0-7" soil samples were taken from each treatment of each of the two sites and were sent to the laboratory of the respective treatment. The recommendations obtained from these samples will be used for the 1984 soybean crop.

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

RESULTS

Very high testing site

The soil test results and the accompanying recommended fertilizer program of each laboratory are shown in Table 1 for the very high testing site. While the numeric values of the five laboratories were generally similar, the interpretations (whether the soil tests high, low, medium, deficient, etc.) varied significantly. As a result N, P and K recommendations among the laboratories were substantially different. Various micronutrients and sulfur were recommended by two of the four private labs. Three of the four private labs recommended liming the soil.

Table 1. Soil test results and the recommended fertilizer programs on the very high testing site at Waseca in 1983.

	Soil Test Results[1/]				
Test	Lab A	Lab B	Lab C	Lab D	Lab E (UM)
pH	5.9	6.0	6.2	6.0	5.9
pH (buffer)	6.7	6.6	6.7	6.5	6.2
Phosphorus	29 H	26 D	26 VH	36 H	23 VH
Potassium	178 H	162 L	130 H	175 H	125 MH
Organic Matter (%)	3.2 H	3.9 A	3.2 M	3.9	H
Calcium	1860 M	2437 A	4000	3030 M	---
Magnesium	405 VH	466 A	500	500 M	413 A
Sulfur	8 M	24 A	19 H	26 VH	10 MH
Iron	80 VH	86 E	8	5.6 VH	---
Manganese	35 VH	25 E	2	2 VH	---
Zinc	1.9 M	1.6 A	1.6 H	1.4 M	1.0 M
Copper	1.1 M	.9 A	.4	---	---
Boron	1.7 H	.8 A	1.3	---	---
ENR (lb/A)	94	---	---	50	---
C.E.C. (meq/100g)	15.8	21.5	24.8	26.9	---

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

	Recommended Fertilizer Program[2/]				
Nutrient	Lab A	Lab B	Lab C	Lab D	Lab E (UM)
Nitrogen	200	160	167	244	130
Phosphorus (P_2O_5)	50	70	12	75	---
Potassium (K_2O)	90	135[3/]	61	112	90
Sulfur	14	---	---	---	---
Iron	---	---	---	.12[4/]	---
Manganese	---	---	---	.12[4/]	---
Zinc	2.5	---	---	.62[4/]	---
Copper	---	---	---	---	---
Boron	---	---	---	---	---
Lime (T/A)	1.5	2	.8	---	---

2/ All values indicate pounds of nutrient 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.

4/ As 5 qt/A of a material weighing 9.9 lb/gal and containing 5% Zn, 1% Fe, 1% Mn.

Grain yields were significantly affected by the fertilizer treatments (Table 2). All fertilizer recommendations resulted in higher yields than the unfertilized check. There was no significant difference between grain yield, grain moisture nor final population among the five laboratory treatments.

Table 2. Effect of fertilizer recommendations on corn final population, grain yield and moisture on the very high testing site in 1983.

Lab	Fertilizer Recommendations	Final Population	Grain Yield	Grain H_2O
	lb/A[1/]	x 10^{-3}	bu/A	%
A	200N +50P + 90K +14S +2.5Zn	24.5	101.4	21.6
B	160N +70P +135K	23.9	102.9	21.6
C	167N +12P + 61K	24.2	110.3	21.7
D	244N +75P +112K +.12Fe +.12Mn +.62Zn	24.5	107.4	21.8
E(UM)	130N + 90K	23.5	104.2	21.5
Check		24.3	78.4	22.3
	Significance Level (%):	71	99	99
	BLSD (.05) :		11.2	.5
	CV (%) :	3.4	9.7	1.7

[1/] P and K expressed on oxide basis.

Earleaf P, Fe and Cu concentrations among the five laboratories were not significantly different (P=.05 level) (Table 3). The greater fertilizer N and K recommendation did result in a corresponding rise in corn leaf N and K concentrations. The Fe + Mn + Zn recommended by lab D resulted in higher leaf Mn than other labs but Fe and Zn were unaffected. Laboratory A's Zn recommendation resulted in the highest % leaf Zn of the five labs. The B and Cu concentrations among the five laboratories were not significantly different (P=.05). Leaf nutrient concentrations except Cu appeared to be adequate for optimum plant growth.

Table 3. Effect of fertilizer recommendations on corn leaf nutrient concentrations on the very high testing site in 1983.

Lab	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%					ppm				
A	3.00	.29	2.04	.44	.33	171	50	31	4.3	8.9
B	2.91	.29	2.14	.42	.32	162	45	28	3.9	8.5
C	2.87	.29	1.95	.44	.34	182	48	30	4.0	8.4
D	3.08	.30	2.06	.45	.33	174	57	28	4.3	8.8
E(UM)	2.81	.29	1.91	.42	.35	175	45	25	3.8	8.2
Check	1.90	.22	1.67	.36	.27	171	34	15	2.1	7.6
Signif.(%):	99	99	99	99	99	65	99	99	99	99
BLSD(.05) :	.1	.01	.12	.02	.02		5	2	.5	.6
CV(%) :	3.5	3.8	5.5	4.8	6.1	8.5	9.1	6.5	13.2	5.6

Medium-high testing site

The soil test results and the accompanying recommended fertilizer program of each laboratory are shown in Table 4 for the medium-high testing site. While the numeric values of the five laboratories were generally similar the corresponding interpretation (whether the soil tests high, low, medium, deficient etc.) varied substantially. Nitrogen, P and K recommendations among the labs were quite different. Also, various micronutrients and sulfur were recommended by two of the four private labs. Two of the four private labs recommended liming the soil.

The treatments that received fertilizer yielded significantly more than the check (Table 5). However, there were no significant yield differences among the fertilizer treatments. Grain moisture was reduced significantly from the control by all of the fertilizer treatments with no differences among the five laboratories. Final population was not different among the treatments.

Table 4. Soil test results and the recommended fertilizer programs on the medium-high testing site at Waseca in 1983.

Test	Soil Test Results[1/] Lab A	Lab B	Lab C	Lab D	Lab E (UM)
pH	6.4	6.7	6.4	5.8	6.2
pH (buffer)	6.7	---	6.9	6.8	---
Phosphorus	17 M	18 D	16 H	23 M	14 MH
Potassium	169 M	151 D	125 H	120 M	121 MH
Organic Matter (%)	4.2 H	5.3 A	3.4 M	3.9	H
Calcium	2870 H	4237 A	6250	4105 H	---
Magnesium	506 VH	631 A	750	600 M	552 A
Sulfur	7 L	15 A	18 H	5 L	5 LM
Iron	44.0 VH	41.4 A	8	5.6 VH	---
Manganese	29 H	21 E	2	2 VH	---
Zinc	2.3 M	1.8 A	1.3 H	1.9 M	1.0 M
Copper	1.3 H	1.1 A	.4	---	---
Boron	2.1 VH	1.1 A	1.9	---	---
ENR (lb/A)	114	---	---	50	---
C.E.C. (meq/100g)	20.9	26.8	37.9	28.7	---

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

Nutrient	Recommended Fertilizer Program[2/] Lab A	Lab B	Lab C	Lab D	Lab E (UM)
Nitrogen	185	155	167	244	130
Phosphorus (P_2O_5)	80	107[3/]	54	91	70
Potassium (K_2O)	105	200[3/]	68	155	90
Sulfur	15	---	---	---	---
Iron	---	---	---	.12[4/]	---
Manganese	---	---	---	.12[4/]	---
Zinc	2	---	---	.62[4/]	---
Copper	---	---	---	---	---
Boron	---	---	---	---	---
Lime (T/A)	1.5	---	---	2.3	---

2/ All values indicate pounds of nutrient 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.

4/ As 5 qt/A of a material weighing 9.9 lb/gal and containing 5% Zn, 1% Fe, 1% Mn.

There was no significant difference among the five laboratories for leaf nutrients P, Fe, Mn, Zn, Cu or B (Table 6). The micronutrients recommended by two of the four private labs did not result in a corresponding increase in leaf concentrations. The high rate of lab D's nitrogen recommendation resulted in higher leaf N. Leaf nutrient concentrations from the check treatment were sufficient for optimum plant growth with the exception of K and Cu. Leaf K and Cu appeared low.

Table 5. Effect of fertilizer recommendations on corn final population, grain yield and moisture on the medium-high testing site in 1983.

Lab	Fertilizer Recommendations	Final Population	Grain Yield	Grain H_2O
	lb/A[1/]	x 10^{-3}	bu/A	%
A	185N + 80P +105K +15S +2Zn	23.9	122.6	20.2
B	155N +107P +215K	23.8	127.1	20.2
C	167N + 54P + 68K	25.0	126.6	20.7
D	244N + 91P +155K +.12Fe +.12Mn +.62Zn	24.8	125.9	20.7
E(UM)	130N + 70P + 90K	23.8	124.8	20.4
Check		24.2	77.3	22.5
	Significance Level (%):	68	99	99
	BLSD (.05) :		8.8	.5
	CV (%) :	4.5	7.0	2.1

[1/] P and K expressed on oxide basis.

Table 6. Effect of fertilizer recommendations on corn leaf nutrient concentrations on the medium-high testing site in 1983.

Lab	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	Nutrient									
	%					ppm				
A	3.00	.29	1.62	.50	.39	184	51	25	4.2	9.4
B	2.91	.29	1.78	.48	.35	178	49	22	4.3	9.7
C	2.87	.29	1.43	.51	.42	178	52	22	4.1	9.8
D	3.08	.30	1.62	.50	.42	169	54	24	4.7	9.8
E(UM)	2.81	.29	1.41	.51	.41	175	49	22	3.7	9.5
Check	1.90	.29	1.22	.52	.39	168	39	19	2.6	8.9
Signif.(%):	99	2	99	99	98	44	99	94	99	33
BLSD(.05) :	.10		.15	.02	.05		9	4	1.0	
CV(%) :	3.5	10.0	9.1	3.3	8.8	9.5	14.5	13.7	20.5	10.5

SUMMARY - 1983

There were substantial differences among the laboratories' fertilizer recommendations at both sites. Nitrogen, P and K recommendations differed greatly among the laboratories. Sulfur and various micronutrient recommendations were provided by two of the four private labs. Differences among the leaf nutrient concentrations were noted but all with the exception of Ca and K (medium-high testing site only) were adequate for corn growth. Differences in grain yield, grain moisture and plant population were not observed among the five laboratories at both sites in 1983.

Fertilization resulted in only two of the five labs showing any profit on the very high testing site (Table 7). Fertilizer costs ranged from $41/A with lab E to $98/A with lab D. On the medium-high testing site a large return was gained from fertilizer ($39-88/A). Also, the laboratories' recommendations resulted in fertilizer costs ranging from $58-107/A while net return varied by $49.

Table 7. Effect of fertilizer recommendations on yield, value, fertilizer cost and the resulting economic return on both the very high testing site and medium-high testing site at Waseca in 1983.

	Very High Testing Site				Medium-High Testing Site			
Lab	Yield	Value @3.00/bu	Fert. cost[1/]	Return[2/]	Yield	Value @3.00/bu	Fert. cost[1/]	Return[2/]
	bu/A	$/A	$/A	$/A	bu/A	$/A	$/A	$/A
A	101.4	304	73	- 4	122.6	368	79	+57
B	102.9	309	70	+ 4	127.1	381	86	+63
C	110.3	331	50	+46	126.6	380	60	+88
D	107.4	322	98	-11	125.9	378	107	+39
E(UM)	104.2	313	41	+37	124.8	374	58	+84
Check	78.4	235	--	--	77.3	232	---	--

1/ Using May, 1983 prices for each nutrient expressed as dollars/lb as follows: N, 24; P_2O_5, .24; K_2O, .11; S, .22; B, .75; Zn, .38.

2/ Return yield value @ 3.00/bu - fertilizer cost - value of check trt.

Conclusions from the 1983 study can be summarized as follows:

1. Application of high rates of P & K to soils already testing high to very high is not practical.

2. No direct benefit or response was obtained with the addition of S or the micronutrients even though they were recommended by some laboratories.

FOUR-YEAR SUMMARY

Economic returns from the very high testing site showed benefit to fertilizer from two of the five laboratories. Net return from the 1980-1983 period ranged from $52/A with lab E to $76/A with lab A. Recommendations from lab D resulted in the highest fertilizer cost. Part of this negative return can be attributed to fertilizer recommendations made for a yield goal of 180 bu/A and 160 bu/A for 1980 and 1983, respectively. Due to drought-stress conditions the 1980 corn yield only averaged 100 bu/A.

On the medium-high testing site yield responses paid for the fertilizer recommendations by all five laboratories (Table 8). However, net return ranged from $60/A with lab D, whose recommendations resulted in the higher fertilizer cost, to $192/A with lab E which recommended the least amount of fertilizer.

Table 8. Effect of fertilizer recommendations on total yield, total fertilizer cost and the resulting economics on both the very high and medium-high testing site at Waseca from 1980-1983.

	Very High Testing Site 4-Year Total			Medium-High Testing Site 4-Year Total		
Lab	Crop value[1/]	Fert. cost	Return[2/]	Crop value[1/]	Fert. cost	Return[2/]
	$/A	$/A	$/A	$/A	$/A	$/A
A	1313	239	-76	1504	274	+101
B	1337	245	-58	1489	299	+ 61
C	1375	183	+42	1504	208	+167
D	1376	286	-60	1493	304	+ 60
E(UM)	1342	140	+52	1506	185	+192
Check	1150	0	--	1129	0	---

1/ 3.00, 2.40 and 3.00/bu used for corn in 1980, 1981 and 1983, respectively, and 5.50/bu for soybeans in 1982 for four-year total crop value.

2/ Return over 4-year period = crop value - fertilizer cost - value of check treatment.

LIQUID AND DRY STARTER FERTILIZERS FOR CORN IN SOUTH-CENTRAL MINNESOTA

Waseca, 1983

G. W. Randall and D. T. Walters

Row-applied starter fertilizers have been used for over 30 years in corn production. As greater amounts of P and K fertilizers have been broadcast-applied and soil tests have increased over the last decade, row applications have declined in popularity because of less direct yield response and greater time and labor required for this method of application. Within the last five years liquid starter fertilizers have become extremely competitive with dry materials and in some cases have replaced dry fertilizers; largely because of ease and speed of handling. The purpose of this study was to determine (1) the influence of starter fertilizer on early corn growth, nutrient uptake and corn yield and (2) the relative effectiveness of dry vs liquid starter fertilizer methods.

EXPERIMENTAL PROCEDURES

Four starter fertilizer treatments and a check with no starter fertilizer (Table 1) were applied in a randomized, complete-block design with eight replications on a Nicollet clay loam soil (Aquic Hapludoll). Soil test of this site averaged: pH = 5.9, Bray 1 extractable P = 38 lb/A and exchangeable K = 225 lb/A. Corn that had been moldboard plowed was the previous crop. Nitrogen as anhydrous ammonia was applied at a rate of 200 lb N/A on April 30.

Corn (Pioneer 3901) was planted on May 9 at a rate of 27700 plants/A with a 4-row John Deere 7000 Max-Emerge planter. This planter was used to apply the dry material in a 2 x 2 band and the liquid in the row with the seed. The 7-21-7, 5-12-5 and 8-20-8 were obtained from local fertilizer dealers while the 9-18-9 was obtained from Na-Churs. The 5-12-5 dry material applied at the 95-lb rate yields approximately the same amount of N + P + K as 5 gal/A of the two liquid materials. The 140-lb rate of the 8-20-8 is closer to a more conventional rate of a dry fertilizer while still using a 1:2.5:1 material. Furadan at a rate of 1 lb/A (active) was band-applied to control rootworms. Lasso (3½ qts/A) and Bladex (3 lb/A) were applied preemergence to control weeds.

Ten randomly selected plants from the outside 2 rows of these 4-row plots were sampled on June 20 for early plant growth measurements and for nutrient analysis. Plant heights were measured on July 11 (prior to tasseling) and on August 3 (shortly after tasseling). Leaf samples opposite and below the ear were taken at silking for analysis. Grain yields were determined by combine harvesting the center two rows of each plot with a JD 3300 modified plot combine. Moisture and protein analyses were determined on those samples.

RESULTS

Climatic conditions in the 3-week period after planting were much wetter and cooler than usual. These conditions resulted in rather slow germination and emergence. Early plant growth measurements taken six weeks after planting showed significant differences in plant weight (Table 1). All starter treatments showed larger plants than when no starter was applied. No difference in early plant growth was found between the two liquid materials or between the liquid products and the dry product applied at the same rate. These data indicate a primary effect related to rate of application and no effect related to placement (banded with the seed compared to 2 x 2).

Small plant P concentration was higher with the dry materials than with the liquids (Table 1). No difference in small plant P was seen between the two liquid materials. Small plant K for the 8-20-8 dry starter treatment was statistically higher than the 9-18-9 liquid treatment. There was a significantly lower small plant K concentration with liquids when compared to dry materials (at 90% probability). Small plant Ca was increased by the 8-20-8 dry material when compared to the two liquid materials.

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

Table 1. Influence of starter fertilizer on the nutrient concentration in the small whole corn plants at Waseca in 1983.

Treatment Material	Rate	Small plant weight	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
		g DM/plt.	----------%----------				----------ppm----------				
No Starter		2.0	.47	4.74	.46	.28	1496	91	56	11.0	18.5
9-18-9 (liq)	5 gal/A	2.7	.46	4.68	.44	.26	1555	94	53	10.1	15.4
7-21-7 (liq)	5 gal/A	2.6	.47	4.70	.45	.26	1693	99	54	10.2	15.0
5-12-5 (dry)	95 lb/A	2.7	.50	4.92	.47	.27	1587	96	54	10.6	17.9
8-20-8 (dry)	140 lb/A	2.6	.49	4.95	.48	.27	1446	97	56	9.9	14.9
P Level (%): 1/		99	99	95	99	93	49	33	64	92	80
BLSD(.05) :		.3	.01	.25	.02						
CV(%) :		9.7	2.7	3.9	3.3	4.5	16.2	10.4	5.0	6.8	20.1

1/ Probability levels of significant difference among treatment means.

Nutrient uptake, the product of nutrient concentration times small plant weight (dry matter), was increased by the starter treatments over the no starter treatment primarily because of the larger plants associated with the starter treatments (Table 2). Highest nutrient uptake levels were associated with the 95 lb/A 5-12-5 treatment but these levels were not always statistically higher than the 8-20-8 or liquid treatments. Uptake of P was significantly higher with the 5-12-5 dry material than the 7-21-7 liquid material. No significant difference existed between the two liquid materials.

Table 2. Influence of starter fertilizer on the nutrient uptake in the small whole corn plants at Waseca in 1983.

Treatment Material	Rate	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
		----------mg/plant----------								
No Starter		9.6	96	9.3	5.7	3.0	.18	.11	.022	.009
9-18-9 (liq)	5 gal/A	12.8	132	12.3	7.4	4.3	.26	.15	.028	.006
7-21-7 (liq)	5 gal/A	12.4	125	12.1	7.0	4.5	.26	.14	.027	.006
5-12-5 (dry)	95 lb/A	13.8	136	12.9	7.4	4.4	.26	.15	.029	.006
8-20-8 (dry)	140 lb/A	12.7	128	12.4	7.0	3.7	.25	.14	.025	.006
P Level (%):		99	99	99	99	99	99	99	99	99
BLSD(.05) :		1.2	16	1.2	.8	.8	.03	.01	.004	.002
CV(%) :		8.8	11.2	9.2	9.6	16.7	11.8	9.3	11.2	23.4

Leaf nutrient concentrations shown in Table 3 were sufficient for optimum yields. Leaf Mn from the 8-20-8 treatment was significantly lower than the other starter treatments or the no starter treatment. Leaf Cu from the dry starter treatments was significantly lower than the 9-18-9 liquid or no starter treatments.

Table 3. Influence of starter fertilizer on the nutrient concentrations in the corn ear leaf at Waseca in 1983.

Treatment Material	Rate	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
		----------%----------					----------ppm----------				
No Starter		3.2	.30	1.94	.44	.25	208	84	30	3.6	9.1
9-18-9 (liq)	5 gal/A	3.1	.31	2.01	.43	.25	220	84	30	3.6	9.6
7-21-7 (liq)	5 gal/A	3.1	.31	1.98	.43	.25	212	84	31	3.3	9.4
5-12-5 (dry)	95 lb/A	3.2	.31	1.97	.43	.24	205	81	29	3.0	9.8
8-20-8 (dry)	140 lb/A	3.1	.31	2.05	.43	.24	203	75	29	3.1	9.3
P Level (%):		25	91	53	42	75	72	98	94	97	31
BLSD(.05) :								6		.5	
CV(%) :		2.2	2.3	4.2	4.1	6.0	7.8	6.8	5.9	12.1	10.2

Plant height at approximately the 13 to 14-leaf stage was significantly improved by the starter fertilizers and reflected the differences shown in early plant growth in mid-June (Table 4). However, differences in height did not exist among the treatments once tasseling occurred.

Reductions in final plant population have been reported when applying liquid fertilizers with the seed. The data shown in Table 4 indicate no deleterious effect of any of the starter treatments on plant population. No reason can be given for the higher population with 7-21-7.

Although a trend exists toward higher grain yields with some of the starter fertilizer treatments, grain yields were not increased significantly by the starters (Table 4). In addition, an economical return to the starter fertilizer per se would not have been realized with some of the treatments and return would have been marginal with the others. Grain moisture at harvest for the 9-18-9 liquid starter was significantly lower than other starter treatments. Grain moisture for the 8-20-8 dry starter was the highest of all of the starter treatments and did not differ from the no starter treatment.

Table 4. Influence of starter fertilizer on plant height, final population, grain yield and grain moisture at Waseca in 1983.

Treatment		Plant Height		Final	Grain	
Material	Rate	7/11	8/3	population	Yield	Moisture
		-----cm-----		x 10^{-3}	bu/A	%
No Starter		154	238	24.8	103.3	22.0
9-18-9 (liq)	5 gal/A	170	237	24.7	106.0	20.7
7-21-7 (liq)	5 gal/A	168	235	25.3	106.1	21.5
5-12-5 (dry)	95 lb/A	167	239	24.7	101.4	21.2
8-20-8 (dry)	140 lb/A	167	240	24.5	106.7	21.8
P Level (%):		99	86	58	51	99
BLSD(.05) :		3				.4
CV(%) :		1.9	1.5	3.3	6.5	2.1

SUMMARY

Under these soil test P (high) and K (medium-high) conditions early plant growth was enhanced by all starter fertilizer treatments. Differences were not seen among the liquid materials. Early growth appeared to be a function of application rate rather than fertilizer placement. These differences continued to be found up until tasseling when all treatments showed the same height. Nutrient concentrations in the small plants were only affected slightly. The greatest influence was on P with the dry materials. However, nutrient concentrations among the treatments at silking were generally not different. Grain yields were not improved significantly by the starter fertilizer treatments, whereas, grain moisture was reduced by all but the 8-20-8 dry material.

CONSERVATION TILLAGE STUDY

Waseca, 1983

G.W. Randall, J.B. Swan and D.T. Walters

With increasing emphasis on controlling erosion and minimizing energy requirements (time, labor and fuel), tillage practices of the future will undoubtedly change markedly within the next decade. As a result these practices may be commonly referred to as "conservation tillage" systems.

EXPERIMENTAL PROCEDURES

To evaluate some of the conservation tillage practices on continuous corn an experiment was established in 1975 on a Webster clay loam at the Southern Experiment Station, Waseca, Minnesota. Five tillage treatments (no tillage, fall plow, fall chisel, till-plant (ridge) and till-plant (flat) were replicated four times. Each plot was 20' wide by 125' long. Beginning in 1979, all plots were split into two, 4-row plots--one with 140 lb 9-23-30/A as starter fertilizer. In 1982 and 1983, 12 gallons of 7-21-7 was used as the starter fertilizer material. Tile lines spaced 75' apart lie perpendicular to the rows on all plots.

In 1983, soybeans were planted after 8 years of continuous corn to begin a long-term corn-soybean rotation phase of this experiment. Tillage and starter fertilizer treatments remained the same except the till-plant (flat) treatment was changed to a spring-disk treatment (Table 1).

Ridges for the till-plant (ridge) treatment were built by cultivation on corn rows in 1982. After the 1982 corn harvest stalks were chopped and the moldboard and chisel plow treatments were performed. On May 25 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 on this same date. Ridges for 1984 corn were prepared in July.

Soybeans (Hardin) were planted in 30" rows at a rate of 160,000 plants/A on May 24. The no-tillage, fall plow, fall chisel and spring disk treatments were planted with a John Deere Max-Emerge planter equipped with 2" fluted coulters. A Buffalo-till planter was used for the ridge planted treatment.

Broadcast P and K were not applied for the 1983 soybean crop because of very high soil tests. Soil tests on this site averaged: pH=6.7, Bray 1 extractable P=48 lb/A and exchangeable K=358 lb/A. Chemical weed control consisted of 3 lb Amiben and 4 lb Lasso/A applied preemergence. In order to evaluate the effectiveness of the preemergence herbicide application on weed control, a plastic sheet 18" wide and 6' long was placed between the 4th and 5th rows of each plot during herbicide spraying to prevent the application of herbicide onto the soil surface. Weed counts (grass and broadleaf) were taken on June 16 from sprayed and unsprayed areas. On July 11, one-half of each replicate was treated with a postemergence application of Poast at a rate of 1/4 lb/A with 1 qt. of oil concentrate for grass control. Treatments 2, 3, 4 and 5 were cultivated on July 18.

Early plant growth was determined by harvesting the above ground portion of 40 plants in each plot 50 days after planting. Soybean leaf samples were taken on July 25 (R1 stage) by randomly sampling the uppermost fully mature trifoliate from each of the starter treatments within each tillage treatment. Yields were taken by combine harvesting the center two rows from each plot.

On June 22 soil samples were taken to a 9" depth from the ridge-planted plots which had starter fertilizer for the last nine years. These plots were sampled in 3 positions: directly down the center of the ridge, at 6" to the side of the ridge and midway between the ridges. Before compositing the 8 cores/plot they were separated into 0-2", 2-4", 4-6" and 6-9" increments. After drying at 100°F they were submitted to the University of Minnesota Soil Testing Lab for pH, Bray 1 extractable P and exchangeable K analyses.

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 real 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.

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RESULTS

Significant differences in early plant growth (EPG) and soybean yields were found among the tillage treatments (Table 1). Largest plants were associated with the moldboard plow (MP) and chisel plow (CP)

Table 1. Influence of tillage methods, starter fertilizer and Poast herbicide on soybean production at Waseca in 1983.

Treatment			Early plant growth	Seed	
Tillage	Starter[1] fert.	Poast[2] herb.		Moisture	Yield
			g/plant	%	bu/A
No tillage	S	P		16.6	37.5
"	S	NP	1.45	16.4	27.4
"	NS	P		16.8	37.3
"	NS	NP	1.55	16.5	24.1
Fall plow, f. cult.	S	P		16.8	41.6
" "	S	NP	2.23	16.4	47.0
" "	NS	P		17.1	43.2
" "	NS	NP	2.65	17.1	47.1
Fall chisel, d., f. cult.	S	P		16.5	44.2
" "	S	NP	2.41	16.6	40.5
" "	NS	P		17.1	41.7
" "	NS	NP	2.38	16.7	39.9
Till plant (ridge)	S	P		16.8	41.5
"	S	NP	2.03	16.7	46.6
"	NS	P		17.0	41.4
"	NS	NP	1.95	17.2	41.0
Spring disk (2x)[3]	S	P		16.4	40.9
"	S	NP	1.85	16.8	43.4
"	NS	P		16.9	41.8
"	NS	NP	2.11	16.9	45.5
Individual Factors					
Tillage					
No tillage			1.50	16.6	31.6
Fall plow			2.44	16.8	44.7
Fall chisel			2.40	16.7	41.6
Till plant (ridge)			1.99	16.9	42.6
Spring disk (2x)			1.98	16.7	42.9
Significance Level (%):[4]			99	73	99
BLSD (.05) :			.52		4.2
Starter Fertilizer					
Starter			1.99	16.6	41.1
No starter			2.13	16.9	40.3
Significance Level (%):[4]			91	99	53
Poast Herbicide					
Poast				16.8	41.1
No Poast				16.7	40.2
Significance Level (%):[4]				18	37
Interactions			Significance Levels(%)[4]		
Tillage x SF			77	13	37
Tillage x Poast				25	99
SF x Poast				14	52
Tillage x SF x Poast				35	28
CV(%)			9.6	2.8	10.3

[1] S = starter fertilizer used: NS = no starter fertilizer used.

[2] P = Poast herbicide used: NP = no Poast herbicide used.

[3] Formerly a till-plant (flat) treatment.

[4] Probability level of significant difference between means.

systems and were significantly larger than the no tillage (NT) system (P≥95). Early plant growth for the till-plant (ridge) (TP-R) and spring disk (SD) treatments were higher than EPG for the NT system at probability levels of 90 > p < 95. Starter fertilizer response averaged over tillage treatments resulted in significantly lower early plant weights (p=91%). The correlation of EPG and grain yield was not significant with starter fertilizer; however, without starter fertilizer grain yield was quadratically related to EPG (R^2 = 0.6**).

Seed moisture at harvest was unaffected by tillage treatments or Poast application. Starter fertilizer resulted in a significant reduction (0.3%) in seed moisture when averaged over tillage.

Soybean yields were highest with the MP system. Yields with the CP, TP-R and SD systems were slightly but not significantly lower than the MP treatment. Yields from the NT system averaged 10-13 bu/A less than the other tillage treatments. Starter fertilizer had no effect on yields.

Percent surface residue cover measured before spring tillage showed the highest amounts with the NT (98%) system followed by the till-plant (flat) (79%), TP-R (70%), CP (40%) and MP (6%) systems (Table 2). After planting, residue cover on the MP treatment increased 83% from 6 to 11 percent. Residue cover was reduced after planting on the TP-R, SD, CP and NT treatments by 61, 51, 7 and 3 percent respectively.

Table 2. Influence of tillage methods for soybeans after corn on surface residue before and after planting at Waseca in 1983.

Treatment	Surface Residue	
	Before planting	After planting
	%	%
No tillage	98	95
Fall plow	6	11
Fall chisel	40	37
Till-plant (ridge)	70	27
Spring disk (2x)[1/]	79	36
Significance Level (%):	99	99
BLSD (.05) :	12.3	12.7
CV (%) :	11.8	17.5

[1/] Formerly till-plant (flat) treatment.

The rate of seedling emergence was determined by counting the number of plants that had broken through the soil surface in 40' of row/plot/day from the 11th to the 20th day following planting. Emergence, as a percent of final stand, shown in Table 3 indicates the most rapid germination with the MP and TP-R treatments, followed closely (1 day) by the SD and CP systems. Slowest emergence occurred from the NT system.

Table 3. Influence of tillage methods on the emergence progress of soybeans following corn at Waseca in 1983.

Treatment	Days Post Planting								
	11	12	13	14	15	16	17	18	22
	% emerged								
No tillage	0	1	5	30	50	74	86	90	100
Fall plow	12	32	44	72	83	91	94	96	100
Fall chisel	2	19	27	63	74	87	94	96	100
Till-plant (ridge)	13	36	48	77	88	91	95	95	100
Spring disk (2x)	1	11	18	52	72	85	93	93	100

Leaf samples taken at the R1 stage were chemically analyzed (Table 4). With the exception of P, Cu, and Zn, nutrient concentrations were not significantly affected by the tillage systems. The NT, TP-R and SD treatments showed significantly higher P concentrations than the MP or CP treatments. Till-plant (ridge) and SD systems exhibited the highest Cu and Zn leaf concentrations. Starter

fertilizer showed slightly higher Fe and slightly lower Zn concentrations when averaged over tillage systems. All nutrient concentrations in the leaf were considered adequate for optimum yields.

Table 4. Influence of tillage methods and starter fertilizer for soybeans on early plant growth and leaf nutrient concentration at the R1 stage at Waseca in 1983.

Treatment		Nutrient								
Tillage	Starter fert.	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
		%				ppm				
No tillage	S	.37	2.01	1.14	.45	144	65	39	8.4	53
"	NS	.36	1.97	1.15	.46	139	64	39	8.8	53
Fall plow	S	.33	1.99	1.09	.44	147	55	38	7.2	49
"	NS	.33	2.00	1.15	.45	144	57	41	7.1	50
Fall chisel	S	.34	1.94	1.12	.45	151	63	37	7.2	52
"	NS	.35	1.91	1.17	.47	144	65	40	7.6	52
Till-plant (ridge)	S	.37	1.95	1.10	.47	153	59	43	9.4	56
" "	NS	.37	1.89	1.13	.48	148	55	43	9.6	54
Spring disk (2x)	S	.37	1.86	1.18	.51	149	58	41	10.0	53
" "	NS	.37	1.94	1.11	.49	143	54	42	9.6	54
Individual Factors										
Tillage										
No tillage		.36	1.99	1.14	.45	141	64	39	8.6	53
Fall plow		.33	2.00	1.12	.44	145	56	39	7.2	50
Fall chisel		.34	1.93	1.15	.46	147	64	38	7.4	52
Till-plant (ridge)		.37	1.91	1.12	.48	150	57	43	9.5	55
Spring disk (2x)		.37	1.90	1.14	.50	146	56	41	9.8	54
Significance Level (%):		99	70	20	89	41	64	95	97	67
BLSD (.05) :		.01						3.2	1.9	
Starter fertilizer										
Starter		.36	1.95	1.12	.46	149	60	39	8.4	53
No starter		.36	1.94	1.14	.47	143	59	41	8.5	53
Significance Level (%):		12	37	77	46	95	31	96	28	15
Interactions										
Tillage x SF										
Significance Level (%):		02	75	88	66	01	23	38	29	77
CV (%) :		4.6	3.0	3.4	3.1	4.5	9.1	4.1	7.0	2.2

Weed counts (broadleaf and grass) were taken between the 4th and 5th rows from 4 randomly placed 1 ft^2 sections/plot 23 days after preemergence herbicide application (Table 5). Weed pressure from broadleaf weeds was not great, as broadleaf weed counts were low from both herbicide treated and untreated areas. Grasses were controlled extremely well in the MP, TP-R, CP and SD systems. Grass control was inadequate in the NT system probably because the thick surface residue accumulation prevented the preemergence herbicides from fully contacting the soil. Postemergence application of Poast herbicide 47 days after planting provided excellent grass control for all tillage treatments. Seed yields were not significantly affected by Poast application when averaged over all tillage systems (Table 1). Yields were reduced slightly with the MP and TP-R systems by approximately 5 and 3 bu/A, respectively. Yield increases attributed to Poast averaged 3, 4 and 11 bu/A for the CP, SD and NT treatments, respectively. Hence, the significant (99% level) tillage x Poast interaction.

Soil samples taken from the ridge-plant treatment after planting (Table 6) showed that regardless of the position of sampling, pH, P and K levels were fairly uniform when compared within depth. Soil samples taken from these same plots in 1982 after planting and ridging showed very high levels of P and K in the top 2" within the ridge as compared to samples taken between the ridges. One might conclude from this that soil samples can be randomly taken from a ridge planted system that is relatively flat after planting but before ridging.

Table 5. Weed populations on June 24th as affected by tillage and herbicide for soybeans following corn at Waseca in 1983.

Treatment	Herbicide[1]		No Herbicide	
	Grasses	Broadleaves	Grasses	Broadleaves
	plants/10 sq. ft.[2]			
No tillage	226	5	857	3
Fall plow	2	2	8	1
Fall chisel	1	1	22	2
Till-plant (ridge)	0	3	2	2
Spring disk (2x)	2	0	43	1

[1] 3 lb Amiben and 4 lb Lasso/A preemergence

[2] Average over 4 replications

Table 6. Soil test pH, P and K after soybean planting and before ridging after 8 years continuous ridge planted corn at Waseca.

Profile depth	Position of ridge sample[1]		
	In row	6" to side of row	15" between row
inches	Soil pH		
0-2	6.5	6.4	6.2
2-4	7.0	7.0	6.7
4-6	7.1	7.1	7.0
6-9	7.1	7.2	7.1
	Soil P (ppm)		
0-2	49	51	40
2-4	21	26	24
4-6	13	15	17
6-9	8	8	9
	Soil K (ppm)		
0-2	300	293	299
2-4	190	176	221
4-6	151	138	150
6-9	123	130	139

[1] Average over 4 replications; 8 cores composited/replication

SUMMARY

A field experiment was established in 1975 to evaluate five tillage systems (no tillage, moldboard plow, chisel plow, till-plant (ridge) and till-plant (flat) on continuous corn grown on a Webster clay loam. Beginning in 1979 all plots were split to evaluate the effect of starter fertilizer with these tillage treatments. In 1983 soybeans were planted to begin a long-term corn-soybean rotation phase of this experiment. The till-plant (flat) treatment was changed to a spring disk (2x) treatment in 1983. The most rapid emergence was observed for MP and TP-R systems followed closely by the CP and SD systems. Delayed emergence and low EPG weights were associated with the NT system. P concentrations for the NT, TP-R and SD systems were significantly higher than the MP or CP systems. Soybean yields among the MP, CP, TP-R and SD systems were not significantly different but were higher than the no tillage system which was heavily infested with weeds. Postemergence application of herbicide resulted in excellent grass control and significantly improved seed yield for the NT system. Starter fertilizer did not improve yields with any of the systems. Soil sampling of the ridge-plant system in the ridge, 6" to the side of the ridge or between ridges showed no apparent differences in pH, P or K within depths when samples were taken after planting but before ridging.

SOYBEAN ROW WIDTH IN A RIDGE-PLANT TILLAGE SYSTEM

Waseca, 1983

G. W. Randall

One of the tillage systems that is rapidly gaining popularity is the ridge-plant system (sometimes referred to as till planting). With this system no primary tillage is done. Ridges are built sometime the previous year and the crop is merely planted on the ridge. Since most Corn Belt farmers are growing corn in 30" rows prior to soybeans in the crop sequence, ridges are built in a 30" row-width. Most recent studies, however, have indicated soybean yield responses of 0-20% by using 15" and narrower rows compared to 30" rows. Thus, the objective of this study was to evaluate 30" soybean rows planted on ridges compared to 30" and 10" rows planted on previously ridged areas that had been tilled lightly before planting.

EXPERIMENTAL PROCEDURES

An area of Nicollet clay loam which was planted to corn in 30" rows and ridged in June, 1982, was the site of this study. A split-plot design consisting of three row width-ridge treatments (30" row-on ridges, 30" row-with ridge disked, and 10" row-with ridge disked) and split into two varieties (Corsoy 79 and Hodgson 78) was used. A light 20" diameter blade tandem disk was used to disk the tops off of the ridges immediately prior to planting of the last two treatments. Each individual plot measured 60' long by 10' wide and was replicated six times. A Buffalo till planter was used to plant the 30"-ridge treatment, a John Deere 7000 Max-Emerge planted the 30"-disked ridge treatment, and an ALAMCO experimental planter was used for the 10" rows. Soybeans were planted on May 24 at a rate of about 160,000 seeds/A. Starter fertilizer was not used because of high soil tests. Weeds were controlled chemically with Lasso + Amiben.

Emergence rates were taken from June 3 thru June 20 by counting plants in either two 30-inch rows of four 10-inch rows per plot. Surface residue accumulation was measured with the line-transect method. All yields were determined by combine harvesting the center rows of each plot.

RESULTS AND DISCUSSION

Emergence rate of the soybeans was affected by the row width-tillage treatments and by the soybean variety (Table 1). Planting in 30" rows directly into the ridges with the till-planter resulted in soybean emergence 11 days after planting with 95% of the beans emerged 18 days after planting. Disking the tops off of the ridges and planting in 30" rows with the Max-Emerge planter delayed initial and 95% emergence by about 1 day. Rate of emergence was slowest with the soybeans planted in 10" rows on the disked ridges. The first beans emerged 13 days after planting and the rate continued to be about 1-2 days behind the 30" ridge-planted beans. The Corsoy 79 soybeans consistently emerged about 1 day earlier than the Hodgson 78 variety regardless of row width-tillage treatment. These emergence rate differences followed the same pattern as in 1982; however, the differences were not as marked. The reason for this could be attributed to the precipitation which occurred on 5 of the first 10 days following planting in 1983.

Date of canopy closure estimated subjectively showed a large difference between row widths and a slight difference between ridge treatments. Average date of closure was July 12 with the 10" rows, July 30 with the 30" rows planted on the ridge, and August 8 for the 30" rows planted on the disked ridges.

Surface residue measurements taken prior to disking of the ridges indicated that 57% of the soil surface was covered by residue from the previous corn crop. After planting, surface residues covered approximately 25% of the soil surface with the ridges that had been disked lightly compared to 17% after planting with the till-planter (Table 2). As expected no difference in residues was observed between the varieties.

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

Final plant stand varied among the row width - tillage treatments primarily because three different planters were used in the study (Table 2). The final stand was also higher with the Corsoy 79 variety; probably because of the smaller seed which rolled out faster from the soybean feed cups used with the Buffalo and John Deere planters. A known (counted) number of seeds were planted with the Alamco 10" row planter which uses a cone-type seed distribution system. These final stand differences were not thought to have a large influence on final yield.

Soybean yields were affected significantly by the treatments (Table 2). Even though emergence was delayed slightly, yields from the 10" rows averaged about 5-6 bu/A better than the 30" rows. The 30" rows planted on the ridges yielded significantly higher (2.7 bu/A) than the flat-planted 30" rows. Part of the difference may have been due to the difference in plant population, however. Significant yield differences did not occur between the Corsoy 79 and Hodgson 78 varieties. The interaction between row width-ridge treatment and variety (significant at the 95% probability level) is shown by the higher yields with the Corsoy 79 variety on the disked, flat-planted treatments compared to higher yields with the Hodgson 78 variety planted on the ridges.

Table 1. Influence of row width-ridge treatment and soybean variety on soybean rate of emergence.

Treatment		Days after planting											
Row width-ridge	Variety	11	12	13	14	15	16	17	18	20	22	24	27
		% emerged											
30", ridge	Corsoy 79	4	18	29	60	82	90	95	96	97	98	99	100
"	Hodgson 78	1	6	12	34	59	82	90	91	95	98	99	100
30", flat	Corsoy 79	1	7	15	39	67	82	91	94	96	98	98	100
"	Hodgson 78	0	3	5	22	54	72	86	91	94	96	98	100
10", flat	Corsoy 79	0	0	5	27	52	70	82	91	97	100	100	100
"	Hodgson 78	0	0	5	18	48	65	77	87	94	100	100	100

Table 2. Influence of row, plant population, width-ridge treatment and soybean variety on surface residues and soybean yields.

Treatment		Surface residue after planting	Final stand	Seed yield
Row width-ridge	Variety	%	plants/Ax10^{-3}	bu/A
30", ridge	Corsoy 79	15	205.	43.0
"	Hodgson 78	19	153.	45.7
30", flat	Corsoy 79	25	164.	42.7
"	Hodgson 78	29	112.	40.5
10", flat	Corsoy 79	25	132.	49.2
"	Hodgson 78	23	135.	47.9
Individual Factors				
Row width-ridge				
30", ridge		17	179	44.3
30", flat		27	138	41.6
10", flat		24	134	48.6
Signif. Level (%):[1/]		98		99
BLSD (.05) :		6.		1.6
Variety				
Corsoy 79		22	168	45.0
Hodgson 78		24	132	44.7
Signif. Level (%):[1/]		63		32
Row width-ridge x variety interaction				
Signif. Level (%):[1/]		55		95
CV (%) :		29.		5.

[1/] Probability of a significant difference among the treatment means.

SUMMARY

Date from the second year of this two-year study indicated that a light disking of ridges could be performed easily and satisfactorily to enable narrow row planting of soybeans in a ridge-plant corn-soybean sequence. Surface residue amounts can be maintained at satisfactory levels and yields increased with the 10" row soybeans planted in this manner. This, of course, necessitates building the ridges for corn (if one desires to do so) after the soybean crop is harvested.

ACKNOWLEDGMENT

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EFFECT OF TIME OF RIDGING SOYBEANS ON SOYBEAN PRODUCTION IN A RIDGE-PLANT SYSTEM

Waseca, 1983

G. W. Randall

The ridges in a ridge-plant system are usually considered one of the keys in making the system work. This is especially important in wet, poorly-drained soils planted to corn, which is sensitive to cold soil temperatures. The ridge warms up and dries more quickly; thus allowing earlier planting.

Construction of the ridges in soybeans for corn the next year poses some potential problems. If the ridging is done during the growing season, are the soybeans damaged to the point of yield reduction? Is pod height lowered so as to increase harvest losses? On the other hand, if narrow-row soybeans are planted, is it possible to build the ridges post-harvest? What are the effects of this late ridging treatment on surface residue cover?

The purpose of this study was to evaluate three times of ridging soybeans for corn on soybean production.

EXPERIMENTAL PROCEDURES

The experimental site (Webster clay loam) was planted to corn in 30" rows and ridged in 1982. Two varieties of soybeans (Corsoy 79 and Hodgson 78) were planted in 30" rows with a Buffalo till planter on May 18 at a rate of 160,000 seeds/A. No starter fertilizer was used. Weeds were controlled chemically with Lasso + Amiben. The ridging treatments were superimposed over varieties at three stages of soybean growth (early bloom (R1), mid-bloom (R2.5), and post harvest). A Hiniker cultivator was used to build the ridges. This split-plot design with ridge treatments as the main plot was replicated six times.

Plant height at maturity and the height of the lowest pod above the soil surface were measured from 10 randomly selected plants/plot just prior to harvest. All yields were determined by harvesting each plot with a modified JD3300 plot combine.

RESULTS AND DISCUSSION

The ridging operation at the R1 stage (July 18) presented some problems again in 1983. Since no prior cultivation had been conducted, the soil surface was hard and, consequently, slabs of soil tended to knock some of the plants over. Speed and depth of cultivation had to be watched carefully. Experiences such as these lead to the recommendation of cultivating soybeans at least 2 weeks prior to the ridging operation. All plots were cultivated on July 18 in preparation for the mid-bloom ridging treatments. At the mid-bloom stage (R2.5) on July 29, the plants were larger and were not as sensitive to cultivation speed. Also, the prior cultivation had loosened and dried the surface soil which permitted building the ridges with soil almost free of large clods and slabs.

Soil conditions were much drier for the late ridging treatment compared to the July 18 ridging. Ridge height after ridging was estimated to be about 5-6" (amplitude).

Plant height at maturity from the July ridged treatments averaged 1½-2" higher than the non-ridged treatment (Table 1). Corsoy 79 soybeans were 6" taller than the Hodgson 78 variety. A time of ridging by variety interaction was not found.

The height of the lowest pod above the soil surface was much higher than in 1982 but was affected significantly by ridging (Table 1). The ridging operations during the summer reduced the pod height by 1.5 to 1.8 cm when averaged over varieties. The pod height of the Group I variety (Hodgson 78) was significantly lower than the Group II variety (Corsoy 79).

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Table 1. Influence of time of ridging on soybean plant height, pod height, seed moisture, and seed yield.

Treatment		Plant height at maturity	Height of lowest pod	Seed	
Ridging time[1]	Variety			Moisture	Yield
		inches	cm	%	bu/A
July 18	Corsoy 79	39	12.0	12.6	50.1
"	Hodgson 78	32	10.2	11.8	41.1
July 29	Corsoy 79	38	12.6	12.6	48.6
"	Hodgson 78	31	10.2	11.9	43.2
Post Harvest	Corsoy 79	36	13.4	12.7	52.0
" "	Hodgson 78	31	12.5	11.9	45.7
Individual Factors					
Ridging time					
July 18		35.4	11.1	12.2	45.6
July 29		34.9	11.4	12.3	45.9
Post-harvest		33.5	12.9	12.3	48.9
Signif. Level (%):[2]		99	97	53	99
BLSD (.05) :		1	1.4		1.6
Variety					
Corsoy 79		37.8	12.7	12.7	50.2
Hodgson 78		31.4	11.0	11.9	43.3
Signif. Level (%):[2]		99	99	99	99
Ridge time x variety interaction					
Signif. Level (%):[2]		32	51	28	94
CV (%) :		5	12.	1.	4.

[1] Corresponds to R1 (July 18) and R2.5 (July 29) stages.

[2] Probability of a significant difference among treatment means.

Seed moisture at harvest was influenced by the variety but was not influenced by the time of ridging (Table 1).

Soybean yields when averaged over the two varieties were significantly reduced by 3.0 and 3.3 bu/A by ridging during the R2.5 and R1 stages, respectively (Table 1). When examining the harvest losses (Table 2), it does not appear that the yield reductions were due to harvest problems. Also, the height of the lowest pod was sufficiently high to permit rather easy harvesting. An explanation for this yield reduction may be that the ridge cultivation pruned some roots and/or increased the soil water loss during this very dry July-August period. Corsoy 79 significantly outyielded Hodgson 78 by 6.9 bu/A when averaged over the time of ridging. The significant (94%) interaction between time of ridging and variety is shown by the Hodgson 78 yields being decreased more when ridged at the R1 stage while the lowest Corsoy 79 yields were associated with ridging at the R2.5 stage.

Harvest losses were quite low and were not affected by the time of ridging (Table 2). Losses were greater with the Hodgson 78 variety; perhaps due to lower seed moisture and lower pod height.

Ridge heights were measured within 10 days after the fall post harvest ridging operation was conducted. At that time the post harvest ridges were approximately 1" higher than the ridges formed in July (Table 2). More significantly the percent surface covered by the residue was decreased to 32% with post harvest ridging compared to approximately 70-75% with the July ridge treatments when measured by the line-intercept method.

Slightly but significantly more residue was found on the soil surface with the Corsoy 79 variety.

Ridge heights from the 1982 experiment were measured on April 25, 1983 and are shown in Table 2. Ridge height averaged between 4-5" and significant differences among the time of ridging treatments were not apparent.

Table 2. Influence of time of ridging and soybean variety on harvest loss, ridge height, and surface residue cover.

Treatment		Harvest	Post Harvest		Spring '83
Ridging time[1/]	Variety	loss	Ridge height	Residue	ridge height
		bu/A	cm	%	cm
July 18	Corsoy 79	.4	14.3	75	11.4
"	Hodgson 78	1.4	14.2	68	10.3
July 29	Corsoy 79	.6	13.0	78	10.4
"	Hodgson 78	.9	13.1	72	10.3
Post Harvest	Corsoy 79	.3	16.8	35	10.6
" "	Hodgson 78	1.2	16.9	29	10.9
Individual Factors					
Ridging time					
July 18		.9	14.3	71	10.9
July 29		.8	13.1	75	10.4
Post-Harvest		.7	16.8	32	10.8
Signif. Level (%):	2/	91	99	99	
BLSD (.05)	:	.2	1.3	5	
Variety					
Corsoy 79		.4	14.7	62	10.8
Hodgson 78		1.2	14.7	56	10.5
Signif. Level (%):	2/	99	8	97	
Ridge time x variety interaction					
Signif. Level (%):	2/	96	8	3	
CV (%)	: 2/	38	5	13	

1/ Corresponds to R1 (July 18) and R2.5 (July 29) stages.

2/ Probability of a significant difference among treatment means.

SUMMARY

Results from the second year of this study indicate that soybean yields were depressed by approximately 3.0 bu/A when ridging was done at the R1 and R2.5 stages compared to post harvest ridging. These data agree fairly well with the previous year's and suggest a preference for post-harvest ridging in the fall for the next year's crop.

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NITROGEN AND SULFUR APPLICATIONS TO CORN IN SOUTHERN MINNESOTA

1983

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Corn yield response to varying N rates and application times in Southern Minnesota have been documented frequently. However, response by corn to sulfur (S) on these soils has not been frequently and consistently reported. Recently, ammonium sulfate as a source of both N and S has become more common as a fertilizer material in the northern Corn Belt. The purpose of this study was to evaluate preplant vs split applications of ammonium sulfate compared to preplant application of urea on corn production on two soils of Southern Minnesota.

EXPERIMENTAL PROCEDURES

Two sites which had been planted to corn in 1982 were selected for this study. One location was on a Mt. Carrol silt loam (Mollisol) on the William Quiggle farm in Goodhue County. This soil represents a large acreage of well-drained, low organic matter, loessial soils cropped to corn in Southeastern Minnesota. The other location was at the Southern Experiment Station, University of Minnesota in Waseca County. This Webster clay loam soil has inherently poor drainage, high organic matter content, and is extensively cropped to corn and soybeans. It represents a large acreage of soils in Southern Minnesota and Northern Iowa.

Tillage at the Goodhue County site consisted of fall chisel plowing and then spring disking and field cultivating prior to planting. The site in Waseca County was fall moldboard plowed and spring field cultivated. Soil tests for the Goodhue and Waseca sites follow: pH = 6.7 and 6.6; Bray extractable P_1 = 87 and 56 lb/A (both Very High); exchangeable K = 248 and 386 lb/A (High and Very High); and extractable SO_4-S = 5 and 8 ppm, respectively for the two locations.

Eight N and S treatments were replicated four times at the Goodhue site and 6 times at the Waseca site in a randomized, complete-block design. Each plot measured 15' wide (6-30" rows) x 30' long in Goodhue County and 10' wide (4-30" rows) x 55' long in Waseca County.

Corn (Pioneer 3906) was planted with a JD Max-Emerge planter on May 23 at a population of 27700 plants/A in Goodhue County and May 16 at a population of 29900 in Waseca County. Weeds were chemically controlled with a preemergence application of Lasso + atrazine at both locations. Furadan was applied with the planter to control rootworms at both locations.

The preplant applications of both N sources were applied and incorporated by secondary tillage on May 5 and 11 at the Goodhue and Waseca sites, respectively. The split application treatments were applied ½ preplant and ½ sidedressed at the 8 to 9-leaf stage on July 12 and July 6 at the Goodhue and Waseca locations, respectively. Application rates of N and S for the Goodhue and Waseca locations are shown in Tables 1 and 3, respectively.

Ten randomly selected leaves opposite and below the ear were taken at silking for total N and S analyses. Fodder and grain yields were obtained at physiological maturity by hand harvest techniques at the Goodhue location while plots were combine harvested at Waseca. All fodder and grain analyses were conducted on samples gathered at harvest. Chemical analyses were performed by the Research Analytical Laboratory, University of Minnesota.

RESULTS AND DISCUSSION

Goodhue County: Leaf N, silage yield and total N uptake in the silage were increased significantly over the check by the urea and AS treatments (Table 1). Trends toward higher fodder N concentrations and fodder yields with the urea and AS treatments were evident; however, greater experimental error negated statistically significant differences at the 95% level. Differences among the urea with and without S treatments and AS were not statistically significant for any of these parameters.

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When examining the effect of N rate averaged over N source and time of application, leaf and fodder N concentrations and total N uptake were greater with the higher N rate (Table 1). Fodder and silage yield were not influenced by N rate. The N source-method of application, when averaged over N rates, had no effect on any of the above parameters. Moreover, there was no interaction between N rate and N source-time of application.

Table 1. Influence of rate, source and time of application of N and S on leaf N, fodder N, fodder yield, silage yield, total N uptake and final population at GOODHUE in 1983.

N Rate	N Source[1/]	S Rate	S Source	Applcn method[2/]	Leaf N	Fodder N	Fodder yield	Silage yield	Total N uptake	Final population
lb/A		lb/A			%	%	----T DM/A----		lb N/A	ppA x 10^{-3}
Check					2.46	.73	2.49	5.33	111	26.4
67	Urea	-	-	PP	3.05	.82	3.13	6.41	143	26.4
67	Urea	79	Gypsum	PP	3.14	.70	3.20	6.72	145	26.5
67	AS	79	AS	PP	3.09	.78	2.94	6.11	137	26.0
67	AS	79	AS	Split	3.13	.69	2.88	6.31	136	25.4
134	Urea	-	-	PP	3.43	.83	2.77	6.17	147	26.0
134	AS	158	AS	PP	3.31	.87	3.09	6.74	159	27.3
134	AS	158	AS	Split	3.34	.85	2.73	6.40	151	25.9
Significance Level (%):[3/]					99	91	84	99	99	31
BLSD (.05)				:	.18			.72	17	
CV (%)				:	4.3	12.	12.6	7.2	8.1	5.2
Individual Factors										
N rate (lb/A)										
67					3.09	.76	2.98	6.28	139	25.9
134					3.36	.85	2.86	6.44	152	26.4
Significance Level (%):[3/]					99	94	57	57	99	62
N source-time of application										
Urea - PP					3.24	.83	2.95	6.29	145	26.2
AS - PP					3.20	.82	3.01	6.43	148	26.6
AS - Split					3.23	.77	2.80	6.35	144	25.6
Significance Level (%):[3/]					26	51	50	15	24	69
Interactions										
N rate x N source-time										
Significance Level (%):[3/]					81	64	61	78	64	59

[1/] AS = ammonium sulfate

[2/] PP = preplant, Split = ½ at PP and ½ at 8 to 9-leaf stage

[3/] Probability level of significant difference among treatment means

Grain yield, N concentration, and N removal were significantly improved by the urea and AS treatments over the check (Table 2). Grain yield for the urea + gypsum treatment was significantly higher than with comparable rates of N and S applied as AS; however, this effect was not noted for any of the other parameters. Factorial examination of the main effects showed significantly higher grain yield, N concentration, and grain N removal with the higher N rate when averaged over N source-time of application. Differences among the N source-time of application treatments were not significantly different when averaged over N rate; however, yields were 5.4 bu/A higher with the split application. In addition, no interaction between N rate and source-application time was noted.

Leaf, grain, and fodder samples from the three high N rate treatments were additionally analyzed for total S. Results shown in Table 3 indicate a significant (93% level) increase in leaf S with the PP application of AS compared to urea. Grain and fodder S concentrations, total S uptake in the silage, and grain S removal (product of grain yield times grain S concentration) were not affected by the S treatments on this low organic matter soil which showed a rather low extractable SO_4-S

level (5 ppm). However, N:S ratios were reduced from 13.6, 12.2 and 14.1 with urea to 11.0, 10.2 and 13.7 with the PP application of AS for leaf, fodder and grain, respectively.

Table 2. Influence of rate, source and time of application of N and S on grain yield, moisture, N and N removal at GOODHUE in 1983.

N Rate	N Source[1/]	S Rate	S Source	Applcn method[2/]	Ear moisture	Grain Yield	Grain N	Grain N removal
lb/A		lb/A			%	bu/A	%	lb/A
Check					48.2	104.4	1.52	75.1
67	Urea	-	-	PP	47.4	121.8	1.59	91.7
67	Urea	79	Gypsum	PP	46.9	130.4	1.60	99.0
67	AS	79	AS	PP	48.0	117.0	1.65	91.6
67	AS	79	AS	Split	47.1	126.6	1.60	95.9
134	Urea	-	-	PP	46.8	124.7	1.71	100.9
134	AS	158	AS	PP	46.7	133.7	1.66	104.8
134	AS	158	AS	Split	46.1	134.9	1.64	105.0
Significance Level (%):[3/]					87	99	99	99
BLSD (.05)						11.6	.08	9.3
CV (%)					2.1	6.4	3.2	6.8
Individual Factors								
N rate (lb/A)								
67					47.5	121.8	1.62	93.1
134					46.5	131.1	1.67	103.6
Significance Level (%):[3/]					97	99	97	99
N source-time of application								
Urea - PP					47.1	123.2	1.65	96
AS - PP					47.4	125.4	1.66	98
AS - Split					46.6	130.8	1.62	100
Significance Level (%):[3/]					63	79	62	48
Interactions								
N rate x N source-time								
Significance Level (%):[3/]					16	72	86	20

[1/] AS = ammonium sulfate

[2/] PP = preplant, Split = ½ at PP and ½ at 8 to 9-leaf stage

[3/] Probability level of significant difference among the treatment means

In summary, grain and silage yields, N concentration in the plant parts, and N uptake were improved by the urea and AS treatments. The highest N rate (134 lb/A) generally produced the highest yields and N concentrations. Evaluation of the data indicates that this N rate was close to optimum under the 1983 growing conditions. A consistent and significant advantage for the split application of AS over the PP application was not obtained. This was expected under the adequate but not excessive rainfall conditions at this site. Leaching and/or denitrification conditions apparently did not exist after the PP applications in early May. Significant and consistent differences between the urea + gypsum treatment and the AS treatment did not occur. With the exception of leaf S concentration, the S applications did not consistently improve corn production even though the SO_4-S level of this low organic matter soil was relatively low (5 ppm).

Table 3. Influence of N source and time of ammonium sulfate application on leaf S, grain S, fodder S, total S uptake and grain S removal at GOODHUE in 1983.

N source[1/]	Application method[2/]	Leaf S	Grain S	Fodder S	Total S uptake	Grain S removal
		%	%	%	lb/A	lb/A
Urea	PP	.253	.121	.068	11.0	7.1
AS	PP	.300	.121	.085	12.9	7.7
AS	Split	.276	.117	.073	11.5	7.5
Significance Level (%):[3/]		93	88	82	89	81
BLSD (.05)	:	.042				
CV (%)	:	8.4	2.0	15.2	9.6	4.7

1/ AS = ammonium sulfate; Both N sources applied at rate of 134 lb/A

2/ PP = preplant, Split = ½ at PP and ½ at 8 to 9-leaf stage

3/ Probability level of significant difference among the treatment means

Waseca County: Results from the study in Waseca County were considerably different than from Goodhue County. This was primarily due to the extremely dry and hot conditions which began immediately following the sidedress application. Rainfall totaled only 1.80" over the 7 weeks following the split application of AS at the 8-9 leaf stage (July 6).

Leaf N concentration, fodder and silage yield, and total N uptake in the silage were increased over the check by all of the urea and AS treatments (Table 4). Fodder N was increased over the check by only the 178-lb N/A treatments. Differences among the urea with and without S treatments and AS applied PP were not statistically significant for any of the parameters.

Examination of the main effect of N rate averaged over N source-time of application indicates that leaf and fodder N, silage yield, and total N uptake were increased significantly (90% level) by the high N rate (Table 4). Fodder yield was not influenced by N rate. The N source-time of application had a substantial effect on leaf N, fodder and silage yield, and total N uptake when averaged over N rates. The PP applications of urea and AS resulted in almost identical results. However, splitting the AS application into ½ at PP and ½ at the 8 to 9-leaf stage produced significantly lower leaf N concentration, fodder and silage yield, and total N uptake. Apparently the sidedress portion of the split application remained near the soil surface and was never moved down into the root system where it could have been utilized by the plants. A significant interaction between N rate and N source-time of application was not found for these parameters. Grain yield and grain N removal were increased substantially and grain moisture reduced significantly by all of the urea and AS treatments compared to the check (Table 5). Only the 178-lb N rate increased grain N over the check. The urea + gypsum treatment and the PP applied AS treatments did not improve yield, N concentration, moisture content and N removal of the grain over the standard urea treatments.

Factorial examination of the main effects showed a highly significant improvement in all of the grain parameters with the high N rate when averaged over N source-time of application (Table 5). Differences among the N source-time of application treatments were also highly significant when averaged over N rates. Corn grain yield, moisture content, N concentration and N removal were almost identical with the PP urea and AS treatments. However, the split application of AS gave significantly lower grain yield, N concentration, N removal and higher moisture content than the PP application of AS. Positional unavailability of the sidedress portion applied at the 8 to 9-leaf stage was thought to be the primary reason for the poor performance of the split AS treatments.

Table 4. Influence of rate, source and time of application of N and S on leaf N, fodder N, fodder yield, silage yield, total N uptake and final population at WASECA in 1983.

N Rate	N Source[1/]	S Rate	S Source	Applcn method[2/]	Leaf N	Fodder N	Fodder yield	Silage yield	Total N uptake	Final population
lb/A		lb/A			%	%	----T DM/A----		lb N/A	ppA x 10^{-3}
Check					1.73	.53	1.58	3.08	48	25.6
89	Urea	-	-	PP	2.74	.54	2.33	5.23	91	24.9
89	Urea	105	Gypsum	PP	2.77	.51	2.35	5.33	94	25.7
89	AS	105	AS	PP	2.79	.54	2.27	5.33	89	25.2
89	AS	105	AS	Split	2.43	.54	2.05	4.75	77	25.8
178	Urea	-	-	PP	3.24	.67	2.33	5.64	120	26.9
178	AS	210	AS	PP	3.29	.68	2.41	5.57	120	26.6
178	AS	210	AS	Split	2.94	.61	2.23	5.02	102	24.9
Significance Level (%):[3/]					99	99	99	99	99	86
BLSD (.05)				:	.12	.05	.24	.49	7	
CV (%)				:	4.3	8.5	9.7	9.2	7.1	5.4
Individual Factors										
N Rate (lb/A)										
89					2.66	.54	2.22	5.10	86	25.3
178					3.16	.65	2.32	5.41	114	26.2
Significance Level (%):[3/]					99	99	85	93	99	94
N source-time of application										
Urea - PP					2.99	.61	2.33	5.43	106	25.9
AS - PP					3.04	.61	2.34	5.45	105	25.9
AS - Split					2.69	.58	2.14	4.89	89	25.4
Significance Level (%):[3/]					99	80	95	99	99	44
BLSD (.05)				:	.08		.19	.41	5.4	
Interactions										
N rate x N source-time										
Significance Level (%):[3/]					2	77	43	9	49	97

[1/] AS = ammonium sulfate

[2/] PP = preplant, Split = ½ at PP and ½ at 8 to 9-leaf stage

[3/] Probability level of significant difference among treatment means

Table 5. Influence of rate, source and time of application of N and S on grain yield, moisture, N and N removal at WASECA in 1983.

N		S		Applcn	Grain			
Rate	Source[1/]	Rate	Source	method[2/]	Yield	Moisture	N	N removal
lb/A		lb/A			bu/A	--------%	---------	lb/A
Check					45.1	21.8	1.45	31.1
89	Urea	-	-	PP	93.3	19.5	1.49	65.6
89	Urea	105	Gypsum	PP	99.1	19.8	1.49	69.6
89	AS	105	AS	PP	93.5	19.7	1.46	64.7
89	AS	105	AS	Split	78.0	20.3	1.49	54.9
178	Urea	-	-	PP	114.3	19.3	1.65	89.5
178	AS	210	AS	PP	113.1	19.2	1.63	87.6
178	AS	210	AS	Split	103.3	19.6	1.52	74.4
Significance Level (%):					99	99	99	99
BLSD (.05)				:	6.7	.6	.07	4.7
CV (%)				:	7.0	2.6	4.4	6.7
Individual Factors								
N rate (lb/A)								
89					88	19.9	1.48	61.7
178					110	19.4	1.60	83.8
Significance Level (%):					99	99	99	99
N source-time of application								
Urea - PP					103.8	19.4	1.57	77.5
AS - PP					103.3	19.4	1.55	76.1
AS - Split					90.6	19.9	1.50	64.7
Significance Level (%):					99	98	97	99
BLSD (.05)				:	5.2	.4	.05	3.7
Interactions								
N rate x N source-time								
Significance Level (%):					44	54	99	49

1/ AS = ammonium sulfate

2/ PP = preplant, Split = ½ at PP and ½ at 8 to 9-leaf stage

3/ Probability level of significant difference among treatment means

Sulfur analysis conducted on the plant tissue from the 178-lb N rate treatments showed highly significant increases in S with both of the AS treatments compared to urea (Table 6). This resulted in significantly higher total S uptake with both AS applications and grain S removal with the PP application. Ratios of N:S for leaf, fodder, and grain were reduced from 14.1, 8.5 and 14.9 with urea to 10.1, 5.4 and 12.8 with the PP application of AS, respectively. These results were somewhat surprising on this high organic matter soil which had a moderate extractable SO_4-S level (8 ppm).

Table 6. Influence of N source and time of ammonium sulfate application on leaf S, grain S, fodder S, total S uptake and grain S removal at WASECA in 1983.

N source[1/]	Application method[2/]	Leaf S	Grain S	Fodder S	Total S uptake	Grain S removal
		%	%	%	lb/A	lb/A
Urea	PP	.229	.111	.079	9.7	6.0
AS	PP	.325	.127	.125	12.9	6.8
AS	Split	.365	.127	.141	12.5	6.2
Significance Level (%):	[3/]	99	99	99	99	96
BLSD (.05)	:	.026	.006	.014	1.2	.6
CV (%)	:	7.2	4.3	10.4	8.4	7.5

1/ AS = ammonium sulfate; Both N sources applied at rate of 178 lb N/A

2/ PP = preplant, Split = ½ at PP and ½ at 8 to 9-leaf stage

3/ Probability level of significant difference among treatment means

In summary, grain and silage yields, N concentration in the plant parts, and N uptake were improved by the urea and AS treatments. The highest N rate (178 lb N/A) produced the highest yields and N concentrations and was judged to be an optimum N rate under the growing conditions in 1983. The split application of AS consistently resulted in significantly lower yields and N uptake when compared to the PP application in early May. This was primarily due to positional unavailability of the early July N application which apparently was not moved down into the active zone of root activity during the hot and dry 7-week period in July and August. Significant and consistent differences between the urea + gypsum treatment and the AS treatment did not occur. Even though S concentrations in the plant parts were significantly improved, yield response to the added S was not obtained.

CONCLUSION

Under the hot, dry conditions of 1983 corn yields and N uptake were significantly improved by the urea and AS treatments at both locations. Yields were not improved by the S treatments, although S concentrations in the plant parts were increased significantly at the Waseca location. Corn production was not improved with the split application of AS at the Goodhue location. Yields and N uptake were reduced significantly with the split application of AS at Waseca.

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PLACEMENT OF NITROGEN SOLUTIONS UNDER DIFFERING TILLAGE SYSTEMS

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The use of 28% N solution for corn production has increased over the last several years in Minnesota. The popularity of this product stems at least partially because of its handling characteristics and its convenience as a carrier for herbicide applications. With the increasing emphasis on conservation tillage increased concerns are being expressed related to placement and/or management of 28% N solution. These concerns are related to the potential volitalization losses or immobilization of N that may take place if applied to soils with high surface residues (conservation tillage). The objectives of these experiments were therefore to: (1) evaluate surface vs. injected applications of 28% N solution under different tillage systems, and (2) with surface applications of 28% N solution compare uniform broadcast applications to surface dribble applications under different tillage systems.

MATERIALS, METHODS, AND OBSERVATIONS

Experimental sites - In 1983 experiments were established at two locations. One location was in East Central (EC) Minnesota at the University of Minnesota Sand Plains Research Farm near Becker, Minnesota. The second location was in South Eastern (SE) Minnesota on a producers field in Goodhue County. The soils at the EC location are formed from glacial outwash and are deep, coarse textured, and contain medium to high levels of organic matter. The soils are typically classified as a Hubbard loamy sand (Udorthentic Haploboroll) and because of their coarse texture and low water holding capacity must be irrigated to attain high production levels. The soils at the SE location are loess derived silt loam soils typically classified as either Seaton (Typic Hapludalf) or Mt. Carroll (Mollic Hapludalf).

Experimental treatments - The treatment combinations at each location were incomplete factorial arrangements of either four (EC) or three (SE) tillage treatments at three nitrogen rates (84, 168, and 336 kgN/ha - 75, 150, 300 #N/a), with three methods of 28% N solution application (broadcast, injected, or surface dribble). The 28 treatments established at the EC location consisted of four tillage systems (no till, ridge till, chisel, and moldboard plow) with all methods of 28% N application at the low N rate (84 kgN/ha), plus all application methods at two additional N rate (168 and 336 kgN/ha) on two tillage systems (no till and chisel), plus control treatments (zero N) for each tillage system (12 + 12 + 4 = 28). The 24 treatments established at the SE location were set up in an identical manner except that only three tillage systems were included (9 + 12 + 3). No moldboard plow treatment was included because this is no longer a standard practice in this area. All treatments were replicated four times utilizing a split-split plot design. The main plots were tillage with the first sub-plots being N rate and the second sub-plot being method of application. The smallest experimental sub-units were four rows wide (4m) and 15m long.

Cultural practices - A summary of the management practices utilized at each location are summarized in Table 1.

Table 1. Management practices utilized at the EC and SE experimental locations.

Management Practice	EC (Becker)	Date	SE (Goodhue)	Date
Tillage	Moldboard plow & plowpacker	4/20		
	Chisel & disc	4/21-4/25		5/10-1/10
	Ridge Till Cultivation	6/28		7/6
Planting date[1]	No till	5/3		5/10
	Other tillage	5/4		5/10
Corn variety	Pioneer 3906		Pioneer 3906	
Seeding rate	7.74 seeds/m^2		6.92 seed/m^2	
Row spacing	76 cm		97 cm	
Fertilizer treatment application	5/9		5/11	
Starter fertilizer	170 kg/ha, 8-10-30		1601/ha, 7-21-7	
Other fertilizer	250 kg/ha, 0-0-22		225kg/ha$CaSO_4$ $2H_2O$	6/6
			1 kg/ha, Zn	7/8
Insectidice	Lorsban 7 kg/ha	5/3-5/4	Dyfonate, 6 kg/ha	5/10
Herbicide[2]	Atrazine 2 kg/ha	5/6	2 kg/ha	5/10
	Metolachlor 1.5 kg/ha	5/6	2 kg/ha	5/10
	Glyphosphate 2.3 kg/ha (no till)	5/10	2.3 kg/ha	5/24
	2,4-D amine 0.5 kg/ha	6/6	2,4-D amine + 0.3 kg/ha	
	Atrazine + oil 2 kg/ha+ 10 l/ha	6/7	dicamba 0.15 kg/ha	6/9
Irrigation	17.4 cm 8.8 cm	July August		

1 At the EC location the ridge till treatments were planted with a Buffalo till planter (disc trash cleaners) and a white (5 cm fluted coulter). At the SE location a Hinéker planter was used for all treatments (trash discs were raised for no till and chisel treatments).

2 Excellent weed control was obtained at the EC location but giant foxtail was a problem on the no till treatments at the SE location.

Tillage treatment characterizations - A number of parameters including surface residue (cover), soil temperature, and crop emergence were collected to determine the impact of tillage. The factors can be important in assessing the interaction of nitrogen application method and its impact on crop production.

Surface Residue

Location	Tillage	Percent cover * In Row	Between
Becker (5/20)	Moldboard	5.3 (2.8)	7.3 (3.4)
	Chisel	46 (13)	46 (7.7)
	Ridge till	47 (17)	66 (15)
	No till	80 (13)	82 (13)
Goodhue Co. (5/31)	Chisel	50 (6.0)	46 (7.0)
	Ridge till	23 (13)	54 (7.6)
	No till	67 (11)	76 (6.0)

* In the row = A 20 cm area centered over the row and between is the remainder. The number in parentheses is the standard deviation, N=8.

With moldboard tillage there was very little residue remaining on the soil surfaces. The chisel plow treatment resulted in similar cover at both locations with about one half of the soil surface covered with crop residue. Both the modlboard and chisel treatments showed no difference in cover due to position relative to the row. The ridge till treatment resulted in more cover at the Becker site (probably due to higher levels of residue and planter differences), and large differences in and between the row. Differences relative to the row were less at the Becker site. This was probably due to planter differences and a higher moisture content of the corn residue at the time of planting.

Temperature: Becker site only

Tillage	Date and Time* 5/20 1400	6/1 1445	6/27 1315	6/30 1330	Average
Moldboard	14.7(.61)	24.8(78)	24.2(.57)	27.4(1.09)	22.8
Chisel	13.3(.38)	22.0(.31)	24.2(20)	26.7(.72)	22.0
Ridge till	12.9(.64)	20.5(1.25)	24.3(.18)	23.8(.87)	20.3
No till	12.7(.99)	19.9(1.88)	23.8(.91)	26.3(88)	20.7

* Temperatures are a mean of 12 observations (4 thermocouples with three gangs each) at a 5 cm depth in the row. The number in parenthesis is the standard deviation of the four thermocouple gangs.

The ridge till and no till treatments exhibited similar temperatures. The chisel plow treatment resulted in temperatures slightly cooler than moldboard plow tillage. Although average differences in soil temperatures due to tillage appear small, relatively small difference can result in large differences in early growth. The temperature with ridge till on 6/30 is much cooler because of the additional soil moved into the row at cultivation (6/28).

Location	Tillage	Percent Emergence* 5/17	5/20	6/1	Final* Population plants/m²
Becker	Moldboard	81(15)	95(3.8)	99(2.4)	7.45(.63)
	Chisel	40(22)	73(23)	97(3.4)	7.56(.71)
	Ridge till	3.4(5.3)	26(27)	97(7.2)	7.55(.43)
	No till	9.2(16)	22(12)	91(12)	7.32(.66)
		5/26	5/31		
	Chisel	51(23)	96(3.3)		6.74(.31)
	Ridge till	50(26)	97(3.8)		6.37(.43)
	No till	17(21)	77(16)		6.52(.20)

* The number in parenthesis is the standard deviation, N = 16.

There was no difference in final stand to tillage at either site. There was a dramatic difference in rate of emergence due to tillage at both sites. The differecne in cover in the row between sites with ridge tillage is reflected in the emergence rates. The rate of emergence with ridge till at the Becker site was similar to the no till treatment. At the Goodhue County site corn emerged much sooner with ridge till and reflects the cleaner row area at this site. Emergence at the Goodhue site was similar with the ridge till and chisel treatments even though there was half the cover with ridge till.

Crain yields and N utilization - Leaf samples from opposite and below the ear at mid-silking were collected on July 27th and August 2nd (no till) at the Becker location. Similar samples were obtained at the Goodhue location on July 28th and August 1st (no till). All leaf samples were dried, ground, and analyzed for Kjeldahl nitrogen. Total dry matter production was determined on September 22 and 23 at the Becker location and September 27-29 at the Goodhue location. At each location ears were separated from 12.2 m of row. Field weights of both ears and stalks from the above area were measured and subsamples of each collected for moisture and nitrogen determination. Grain yields were adjusted to 15.5% moisture.

RESULTS AND DISCUSSION - BECKER LOCATION (EC)

The results from the corn production components (grain, stover, and total) are presented in Table 2. Parameters used to evaluate the nitrogen status (concentration) of the crop and nitrogen uptake of the measured yield components are presented in Table 3. Treatment variables were evaluated utilizing analysis of variance. Since the experimental treatment combination was an incomplete factorial, two separate analysis of variance tables were conducted. The first procedure compared four tillage systems (no till, ridge till, and chisel, and moldboard plow) with three methods of 28% N solution application (broadcast, injected and dribble) at the low rate of N application (84 kgN/ha - 75 #N/A). The second method of analysis compared two tillage systems (no till and chisel) with all methods of 28% N application at three nitrogen rates. The analysis was conducted using models for a split plot and split-split plot experimental designs.

This location has a coarse textured soil with a low water holding capacity. With irrigation and proper N management these soils can be highly productive. In addition to the cool spring and hot summer the growing season at this location was also characterized by a large precipitation event (17 cm) on June 20th. Nitrogen applications were made approximately seven weeks prior to this large precipitation event. During that time substantial quantities of applied ammonium nitrogen (approximately 75% of 28% N solution) were converted to nitrate nitrogen. Since nitrate - N is susceptible to leaching, relatively large yield reductions were encountered at this location due to N leaching losses. This tended to lower yields across the entire experimental area, but may have had more of an influence on some treatment combinations than others. Although yields were significantly reduced due to leaching, relative comparisons can still be made concerning the effectiveness of treatment application.

With the first method of treatment comparisons experimental parameters are evaluated across four tillage systems and three methods of 28% N solution at the low rate of nitrogen. With grain yields the trends in the main effect would suggest that injection of 28% N solution was superior to either broadcast or dribble applications. A significant interaction suggests that the injection technique was only advantageous on the no till and till plant tillage treatments. Total dry matter production along with stover production also indicated a tillage X method of application interaction. The main effects would suggest that the till plant technique was inferior to the other methods and that injection of 28% was superior to the other application methods. The significant interaction with stover and total dry matter production would suggest that injection was the best technique for no till and chisel and with till plant all methods of application were inferior.

The nitrogen utilization characteristics are presented in Table 2. At the low N rate averaged over tillage and method of application there was no significant interactions with N concentrations in plant tissue. Leaf N concentrations were significantly influenced by both tillage and method of application. Moldboard plow treatments had a significanlty lower leaf N concentration than the other three tillage systems. Likewise injected treatments of 28% N solution resulted in higher leaf N concentration than either broadcast or dribble application. Concentration of N in the grain were significantly lower in no till than ridge till. Concentrations of N in the stover were highest on no till and ridge till followed by chisel and then moldboard plow with the lowest N concentration. Removal of N with the grain was substantially improved when 28% N was injected with no till but

provided no advantage with the other tillage systems. Removal of N with the stover was highest in the no till plots followed by chisel and then moldboard plow and till plant. Corn stover contained more total N when treatments of 28% N solution were injected. The significant interaction observed with total N removal appears to be associated with the superiority of the injected treatment with no till conditions.

The second method of treatment comparisons evaluated two tillage systems over three methods of application and three N rates. Not only were there sizeable differences in the main effects for the production parameters but a number of highly significant interactions. The trends established with the main effects of the production parameter would suggest that chisel was superior to no till, injected application of 28% solution were the best followed by dribble and then broadcast applications, and positive N responses up through the highest rate of N application. The significant interaction terms would suggest that regardless of tillage or N rate yields obtained with broadcast applications of 28% N solution were all extremely poor. Within no till treatments yields increased if N was injected or dribbled, but only when the highest rate of N had been applied. Injected and dribbled applications at the high N rate resulted in similar yields. Within the chisel treatments all broadcast treatments were poor, and injected treatments appeared superior to dribble applications. This was apparent with the sizeable yield increase that was obtained at the moderate N rate when it was injected but was not present with the dribble application.

Nitrogen concentration and N uptake in the different plant parts also exhibited a number of significant interactions. General trends appeared to follow similar relationships that were experienced with the production parameters.

GENERAL CONCLUSIONS

The results from this experiment support the fact that the management of 28% N solution is very important especially as we change tillage systems. In general, injected applications were better than dribble which were better than broadcast. The degree of improvement, however, varied with tillage and nitrogen rate.

Care should be exercised in the evaluation of this data. Original ideas were to characterize losses which may occur due to different methods of application when tillage systems change. The major N concerns with the original format are volitalization losses of ammonia and immobiliation of N due to surface residues. The significant rainfall in mid-June provided an additional major loss of N through leaching. Although differences between treatments were obtained, at least a portion of these differences may be due to differential leaching of N created from differential nitrification. For example, conservation tillage systems are designed to to leave plant residue on the soil surface. This residue tends to delay soil warming in the spring, thus slowing nitrification of ammonium N. Placement of N may also be important in this nitrification process. Those treatments which reflect reduced nitrification (more residue, deeper placement) would probably have more available N for crop use following the major leaching event.

RESULTS AND DISCUSSION - GOODHUE LOCATION (SE)

The results from the corn production components (grain, stover, and total) are presented in Table 4. Parameters used to evaluate the nitrogen status (concentration) of the crop and nitrogen uptake of the measured yield components are presented in Table 5. Treatment variables were evaluated utilizing analysis of variance. Interpretation and statistical procedures were conducted in a similar manner to the Becker location.

The growing season experienced in SE Minnesota during 1983 was characterized by being relatively cool and wet early and warm and dry the latter portion. The stress conditions experienced during the entire growing season were probably responsible for grain yields lower than what would be normally expected. In addition to this a rainfall (2 cm) occurred approximately 48 hours after treatment application. It is anticipated that this rainfall could have adversely influenced treatment difference obtained between methods of N application.

If comparisons of yield are made across tillage system and method of N application at the lower N rate a significant tillage X method interaction is observed. The trends established within the main effects would suggest that dribble applications were inferior to broadcast or injected applications across all tillage systems. The significant interaction however suggest that at low N rate injected

28% was the best method for till plant and the broadcast applications were better on the no till and chisel treatments. Stover yields were not significantly influenced by treatments, but total dry matter production was influenced in much the same manner as grain yields.

At the low rate of N across tillage and method of N application the concentration of N in the leaf opposite and below the ear at silking and stover samples at physiological maturity were not significantly (.05) influenced by treatment. The N concentration in the grain as well as grain N removal and total N removal were significantly influenced by treatment. The N concentration of the grain was significantly higher with the injected treatment than with either broadcast or dribble applications. This trend was also observed with the grain N removal and Total N removal, but a significant tillage X method interaction would suggest that injection was superior with ridge till and dribble application was inferior on the chisel treatment.

With the second method of analysis of variance two tillage systems (no till and chisel) are evaluated across the same three methods of application utilizing three N rates rather than one. The tillage system did not influence yield and the significant main effects of methods of application and N rate were confounded with a three way interaction. The main effects would suggest that broadcast applications of 28% were better than either injected or dribble and that maximum yield was obtained at the moderate N rate. The three way interaction would indicate that with no till at the moderate rate of N application the best method of application was injection followed by broadcast and dribble. With the chisel treatment at moderate N rate the best method was a dribble followed by injected and broadcast. Stover yields were significantly increased when the N rate was increased with increasing N rate up to the moderate rate and the broadcast applications were superior to dribble applications.

When the N concentrations and N uptake parameters are evaluated for the two tillage systems and three application methods across N rate, N rate appears to have the only significant effect. Concentrations in the leaf opposite and below the ear at silking were significantly increased up to the moderate N rate. Concentration of N in the grain and stover were significantly increased up through the highest rate of N application. Total N removal both in the grain, stover and total tended to follow similar pattern as was observed with the dry matter production.

GENERAL CONCLUSIONS

It becomes very obvious when interpreting the data that the method of 28% N application is very important as we evaluate different tillage systems. The large number of two-way and three-way interactions attest to this fact. These interactions although interesting, also prove to be difficult to interpret and explain. The crop stress induced by the type of growing season experienced in 1983 along with the interaction that the rainfall shortly after treatment application should be considered seriously before broad spectrum conclusion and/or recommendations should be made for the producer.

Table 2: Influence of nitrogen rates, tillage systems, and methods of 28% N application on grain yields and dry matter production on irrigated corn. Becker, MN - 1983

Treatments			Grain			Dry Matter Production			
N-Rate	Tillage System	Method Applied	Yields		DM	Grain	Cob	Stover	Total
Kg/ha			Bu/A	Mg/ha	%	----------Mg/ha----------			
Control	No Till	------	37.4	2.3	54.0	1.83	0.35	1.61	3.83
Control	Ridge Till	------	43.6	2.7	62.0	2.31	0.44	1.32	4.10
Control	Chisel	------	46.7	2.9	66.8	2.46	0.49	2.03	5.08
Control	Moldboard	------	46.7	2.9	68.2	2.46	0.42	1.79	4.70
84	No Till	Broadcast	38.1	2.4	54.5	2.01	0.42	1.88	4.34
84	No Till	Injected	65.6	4.1	57.2	3.47	0.60	3.11	7.21
84	No Till	Dribble	41.8	2.6	52.2	2.19	0.38	2.24	4.86
84	Ridge Till	Broadcast	42.7	2.7	62.8	2.26	0.47	1.79	4.54
84	Ridge Till	Injected	48.3	3.0	61.8	2.55	0.49	1.90	4.99
84	Ridge Till	Dribble	42.5	2.7	64.5	2.24	0.38	1.61	4.27
84	Chisel	Broadcast	54.3	3.4	72.8	2.86	0.49	2.26	5.64
84	Chisel	Injected	53.6	3.4	71.0	2.82	0.51	2.93	6.65
84	Chisel	Dribble	57.1	3.6	71.8	3.02	0.53	2.13	5.71
84	Moldboard	Broadcast	49.6	3.1	70.2	2.62	0.49	2.68	5.80
84	Moldboard	Injected	49.7	3.1	70.5	2.62	0.49	2.41	5.57
84	Moldboard	Dribble	47.3	3.0	70.8	2.50	0.47	2.17	5.17
168	No Till	Broadcast	42.6	2.7	54.2	2.24	0.53	2.21	5.04
168	No Till	Injected	57.7	3.6	53.5	3.04	0.56	3.36	6.85
168	No Till	Dribble	46.9	2.9	58.2	2.48	0.53	2.77	6.05
168	Chisel	Broadcast	65.0	4.1	65.5	3.42	0.47	2.77	6.72
168	Chisel	Injected	122.0	7.7	66.8	6.45	0.78	3.98	11.62
168	Chisel	Dribble	73.2	4.6	66.2	3.87	0.53	3.60	8.04
336	No Till	Broadcast	53.3	3.3	53.8	2.82	0.51	2.82	6.18
336	No Till	Injected	114.3	7.2	57.2	6.04	0.85	3.74	10.93
336	No Till	Dribble	114.7	7.2	57.8	6.07	0.91	4.05	11.06
336	Chisel	Broadcast	78.4	4.9	69.8	4.14	0.64	3.42	8.22
336	Chisel	Injected	147.1	9.2	67.8	7.79	1.03	4.59	13.44
336	Chisel	Dribble	139.7	8.8	69.2	7.39	0.91	4.61	12.94

Factorial Arrangement (Excludes Control, 168 and 336 Kg/ha N-Rate treatments)

Tillage							
No Till	48.5	3.1	54.7	2.55	0.47	2.42	5.46
Ridge Till	44.5	2.9	63.0	2.35	0.44	1.79	4.61
Chisel	55.0	3.5	71.8	2.91	0.51	2.44	6.00
Moldboard	48.9	3.1	70.5	2.57	0.47	2.42	5.51
P-Value (%)	89	89	99	89	86	99	99
BLSD (.05)							
Method Applied							
Broadcast	46.2	3.0	65.0	2.44	0.47	2.15	5.08
Injected	54.3	3.5	65.1	2.86	0.51	2.59	6.11
Dribble	47.2	3.0	64.8	2.48	0.44	2.03	4.99
P-Value (%)	98	98	6	98	94	99	99
BLSD (.05)							
Tillage X Method Applied							
P-Value (%)	98	98	87	98	75	98	99
BLSD (.05)							

Table 2: Continued

Treatments			Grain			Dry Matter Production			
N-Rate	Tillage System	Method Applied	Yields		DM	Grain	Cob	Stover	Total
Kg/ha			Bu/A	Mg/ha	%	----------Mg/ha----------			
Factorial Arrangement (Excludes Control, till plant and moldboard treatments)									
Tillage									
No Till			63.9	4.1	55.4	3.36	0.60	2.91	6.94
Chisel			87.8	5.6	69.0	4.63	0.67	3.36	8.74
P-Value (%)			97	97	99	97	91	99	99
BLSD (.05)									
Method Applied									
Broadcast			55.3	3.5	61.8	2.91	0.51	2.55	6.02
Injected			93.4	6.0	62.2	4.93	0.71	3.62	9.45
Dribble			78.9	5.1	62.6	4.17	0.63	3.22	8.11
P-Value (%)			99	99	39	99	99	99	99
BLSD (.05)									
N-Rate									
84			51.7	3.3	63.2	2.73	0.49	2.41	5.73
168			67.9	4.4	60.8	3.58	0.58	3.11	7.39
336			107.9	7.0	62.6	5.71	0.80	3.87	10.46
P-Value (%)			99	99	95	99	99	99	99
BLSD (.05)									
Tillage X Method Applied			46	46	75	46	36	7	56
Tillage X N-Rate			99	99	98	99	19	78	97
Method Applied X N-Rate			99	99	78	99	99	99	99
Tillage X Method X N-Rate			99	99	91	99	98	50	98

Table 3: Influence of nitrogen rates, tillage systems and methods of 28% N application, on leaf N, grain N and nitrogen removal by irrigated corn. Becker, MN - 1983

Treatments			N-Concentration			N-Removal		
N-Rate	Tillage System	Method Applied	Leaf	Grain	Stover	Grain	Stover[1]	Total
Kg/ha			----------%----------			----------Kg/ha----------		
Control	No Till	------	1.45	1.19	0.57	22.2	11.7	33.9
Control	Ridge Till	------	1.46	1.28	0.55	29.8	9.8	39.6
Control	Chisel	------	1.33	1.26	0.50	31.2	12.5	43.7
Control	Moldboard	------	1.16	1.18	0.46	29.2	10.4	39.6
84	No Till	Broadcast	1.41	1.11	0.57	22.7	13.2	36.0
84	No Till	Injected	1.85	1.16	0.50	40.6	18.7	59.3
84	No Till	Dribble	1.56	1.15	0.60	25.9	16.2	42.1
84	Ridge Till	Broadcast	1.29	1.33	0.54	30.0	12.5	42.5
84	Ridge Till	Injected	1.53	1.24	0.55	31.9	13.1	45.0
84	Ridge Till	Dribble	1.41	1.22	0.50	27.7	10.2	37.9
84	Chisel	Broadcast	1.30	1.26	0.46	36.3	12.8	49.1
84	Chisel	Injected	1.72	1.19	0.47	34.4	16.0	50.4
84	Chisel	Dribble	1.40	1.27	0.51	38.4	13.7	52.1
84	Moldboard	Broadcast	1.17	1.18	0.42	30.9	13.4	44.3
84	Moldboard	Injected	1.28	1.15	0.42	30.4	12.3	42.7
84	Moldboard	Dribble	1.13	1.20	0.44	30.3	11.8	42.1
168	No Till	Broadcast	1.50	1.34	0.55	29.9	15.3	45.2
168	No Till	Injected	2.55	1.20	0.59	36.7	23.3	60.0
168	No Till	Dribble	1.70	1.21	0.45	30.4	14.8	45.2
168	Chisel	Broadcast	1.67	1.26	0.49	43.8	16.1	59.9
168	Chisel	Injected	2.63	1.34	0.53	88.2	25.6	113.8
168	Chisel	Dribble	2.22	1.30	0.43	51.1	17.8	68.9
336	No Till	Broadcast	1.88	1.18	0.52	33.6	17.2	50.8
336	No Till	Injected	3.14	1.42	0.78	86.0	36.7	122.7
336	No Till	Dribble	3.02	1.47	0.72	90.3	35.8	126.1
336	Chisel	Broadcast	1.99	1.28	0.50	53.8	20.4	74.2
336	Chisel	Injected	3.14	1.59	0.66	124.6	37.6	162.2
336	Chisel	Broadcast	2.86	1.42	0.59	105.6	32.7	138.3
Factorial Arrangement (Excludes control, 168 and 336 Kg/ha N-rate treatments)								
Tillage								
No Till			1.61	1.14	0.56	29.8	16.0	45.8
Ridge Till			1.41	1.26	0.53	29.8	11.8	41.6
Chisel			1.47	1.24	0.48	36.3	14.1	50.5
Moldboard			1.19	1.18	0.43	30.5	12.4	43.1
P-Value (%)			99	97	99	89	99	92
BLSD (.05)			0.12	0.12	0.05		1.7	
Method Applied								
Broadcast			1.29	1.22	0.50	30.0	13.0	43.0
Injected			1.59	1.19	0.48	34.4	15.8	49.4
Dribble			1.37	1.21	0.51	30.5	13.6	43.5
P-Value (%)			99	76	51	93	97	98
BLSD (.05)			0.10				1.8	
Tillage X Method Applied								
P-Value (%)			67	92	50	98	86	98

Table 3: continued on next page.

Table 3: Continued

Treatments			N-Concentration			N-Removal		
N-Rate	Tillage System	Method Applied	Leaf	Grain	Stover	Grain	Stover[1]	Total
Kg/ha			----------%----------			----------Kg/ha----------		
Factorial Arrangement (Excludes control, till plant and moldboard treatments)								
Tillage								
No Till			2.07	1.25	0.58	44.0	21.2	65.2
Chisel			2.10	1.32	0.51	64.0	21.4	85.4
P-Value (%)			33	88	99	98	10	99
Method Applied								
Broadcast			1.62	1.24	0.51	36.7	15.8	52.7
Injected			2.50	1.32	0.59	68.4	26.3	94.7
Dribble			2.12	1.30	0.55	57.0	21.8	78.8
P-Value (%)			99	90	98	99	99	99
BLSD (.05)								
N-Rate								
84			1.54	1.19	0.52	33.4	15.1	48.5
168			2.04	1.27	0.50	46.7	18.8	65.7
336			2.67	1.39	0.63	82.3	30.1	112.4
P-Value (%)			99	99	99	99	99	99
BLSD (.05)								
Tillage X Method Applied			19	99	99	88	22	78
Tillage X N-Rate			95	31	49	95	60	96
Method Applied X N-Rate			99	98	99	99	99	99
Tillage X Method X N-Rate			63	77	45	99	17	97

1 = Stover includes cob + Stover N-Removal

Table 4: Influence of nitrogen rates, tillage systems and methods of 28% N application on grain yield and dry matter production on corn. Goodhue Co. MN - 1983

Treatments			Grain			Dry Matter Production			
N-Rate	Tillage System	Method Applied	Yields		DM	Grain	Cob	Stover	Total
Kg/ha			Bu/A	Mg/ha	%	----------Mg/ha----------			
Control	No Till	-	77.5	4.87	64.8	4.09	0.67	4.43	9.23
Control	Ridge Till	-	69.8	4.38	67.0	3.69	0.60	3.69	7.99
Control	Chisel	-	77.2	4.85	65.2	4.07	0.58	3.47	8.18
84	No Till	Broadcast	121.4	7.63	67.1	6.42	0.94	4.70	12.10
84	No Till	Injected	112.2	7.05	65.8	5.94	0.92	4.77	11.64
84	No Till	Dribble	116.7	7.34	65.6	6.18	0.94	4.52	11.64
84	Ridge Till	Broadcast	123.2	7.75	69.5	6.54	0.92	4.64	12.10
84	Ridge Till	Injected	138.6	8.71	68.6	7.35	0.98	5.24	13.57
84	Ridge Till	Dribble	108.2	6.80	68.0	5.73	0.85	4.55	11.15
84	Chisel	Broadcast	124.2	7.81	69.9	6.58	0.94	4.99	12.54
84	Chisel	Injected	114.2	7.18	70.0	6.05	0.92	4.95	11.94
84	Chisel	Dribble	109.6	6.89	66.2	5.80	0.89	5.13	11.82
168	No Till	Broadcast	136.2	8.56	66.2	7.21	1.12	5.73	14.09
168	No Till	Injected	145.7	9.16	66.8	7.73	1.20	5.31	14.38
168	No Till	Dribble	125.6	7.90	64.8	6.65	1.09	5.33	13.10
168	Chisel	Broadcast	139.0	8.74	67.6	7.35	1.12	6.11	14.63
168	Chisel	Injected	139.7	8.78	66.9	7.39	1.12	5.46	14.02
168	Chisel	Dribble	145.5	9.15	67.0	7.71	1.21	5.67	14.78
336	No Till	Broadcast	138.0	8.68	65.8	7.32	1.14	5.82	14.27
336	No Till	Injected	125.9	7.92	65.7	6.67	1.12	5.58	13.78
336	No Till	Dribble	133.2	8.37	65.5	7.06	1.14	5.31	13.53
336	Chisel	Broadcast	138.2	8.69	68.0	7.32	1.16	5.60	14.09
336	Chisel	Injected	131.7	8.28	68.1	6.97	1.09	5.24	13.30
336	Chisel	Dribble	127.9	8.04	67.8	6.76	1.07	5.23	13.08

Factorial Arrangement (Excludes control, 168 and 336 Kg/ha N-rate treatments)

Tillage							
No Till	116.8	7.34	66.1	6.18	0.94	4.66	11.80
Ridge Till	123.3	7.75	68.7	6.54	0.92	4.82	12.27
Chisel	116.0	7.29	67.7	6.14	0.92	5.02	12.09
P-Values (%)	61	61	46	61	4	71	39
BLSD (.05)							
Method Applied							
Broadcast	122.9	7.72	68.8	6.52	0.94	4.77	12.23
Injected	121.7	7.65	67.1	6.45	0.94	4.97	12.38
Dribble	111.5	7.23	66.6	5.89	0.89	4.72	11.53
P-Values (%)	98	98	94	98	64	61	97
BLSD (.05)							
Tillage X Method Applied							
P-Values (%)	98	98	17	98	34	57	97

Table 4 continued on next page.

Table 4: Continued

Treatments			Grain			Dry Matter Production			
N-Rate	Tillage System	Method Applied	Yields		DM	Grain	Cob	Stover	Total
Kg/ha			Bu/A	Mg/ha	%	----------Mg/ha----------			
Factorial Arrangement (Excludes control and till plant treatments)									
Tillage									
No Till			128.3	8.07	65.9	6.78	1.05	5.22	13.00
Chisel			130.0	8.17	67.6	6.87	1.05	5.34	13.26
P-Values (%)			45	45	67	45	7	38	32
BLSD (.05)									
Method Applied									
Broadcast			132.8	8.35	67.4	7.03	1.07	5.48	13.62
Injected			128.2	8.06	66.7	6.78	1.05	5.22	13.19
Dribble			126.4	7.95	66.1	6.69	1.05	5.19	13.00
P-Values (%)			96	96	93	96	14	93	97
BLSD (.05)									0.47
N-Rate									
84			116.4	7.32	66.9	6.16	0.94	4.84	11.94
168			138.6	8.72	66.6	7.34	1.14	5.60	14.15
336			132.5	8.33	66.8	7.01	1.12	5.44	13.66
P-Values (%)			99	99	10	99	99	99	99
BLSD (.05)							0.08	0.40	0.74
Tillage X Method Applied			7	7	25	7	34	38	64
Tillage X N-Rate			29	29	19	29	9	70	59
Method Applied X N-Rate			88	88	65	88	46	49	11
Tillage X Method X N-Rate			97	97	27	97	43	1	67

Table 5: Influence of nitrogen rates, tillage systems and methods of 28% N application, on leaf N content, grain N content and nitrogen removal by corn. Goodhue Co., MN - 1983

Treatments			N-Concentration			N-Removal		
N-Rate	Tillage System	Method Applied	Leaf	Grain	Stover	Grain	Stover[1]	Total
Kg/ha			----------%----------			----------Kg/ha----------		
Control	No Till	------	1.95	1.48	0.59	61.1	30.7	91.8
Control	Ridge Till	------	1.87	1.40	0.55	52.0	23.7	75.7
Control	Chisel	------	1.77	1.33	0.57	54.8	23.5	78.3
84	No Till	Broadcast	2.62	1.39	0.67	89.8	37.7	127.6
84	No Till	Injected	2.70	1.47	0.65	87.4	37.4	124.8
84	No Till	Dribble	2.67	1.46	0.69	90.6	38.0	128.6
84	Ridge Till	Broadcast	2.74	1.29	0.57	84.3	31.9	116.2
84	Ridge Till	Injected	2.73	1.51	0.65	111.3	40.9	152.2
84	Ridge Till	Dribble	2.44	1.37	0.65	78.8	35.0	113.9
84	Chisel	Broadcast	2.55	1.50	0.63	99.4	38.1	137.5
84	Chisel	Injected	2.84	1.58	0.63	96.0	37.2	133.2
84	Chisel	Dribble	2.70	1.40	0.62	81.8	37.4	119.2
168	No Till	Broadcast	2.96	1.57	0.88	113.7	60.9	174.6
168	No Till	Injected	3.02	1.62	0.85	125.7	55.4	181.1
168	No Till	Dribble	2.89	1.59	0.83	106.1	53.6	159.7
168	Chisel	Broadcast	3.06	1.65	0.82	121.7	59.9	181.8
168	Chisel	Injected	3.01	1.60	0.81	118.7	53.6	172.4
168	Chisel	Dribble	3.13	1.72	0.81	132.6	55.5	188.0
336	No Till	Broadcast	3.14	1.64	0.92	120.4	64.7	185.1
336	No Till	Injected	3.09	1.69	0.92	112.6	61.7	174.2
336	No Till	Dribble	2.88	1.67	0.83	117.8	54.1	171.7
336	Chisel	Broadcast	3.19	1.64	0.93	120.7	63.4	184.1
336	Chisel	Injected	2.98	1.64	0.95	114.7	60.1	174.9
336	Chisel	Dribble	2.98	1.69	0.85	115.4	54.1	169.4

Factorial Arrangement (Excludes Control, 168 and 336 Kg/ha N-rate treatments)

Tillage						
No Till	2.66	1.44	0.67	8.92	37.7	127.0
Ridge Till	2.63	1.39	0.62	91.5	35.9	127.4
Chisel	2.69	1.49	0.63	92.4	37.5	129.9
P-Values (%)	36	92	31	16	10	8
BLSD (.05)						
Method Applied						
Broadcast	2.63	1.39	0.62	91.1	35.8	127.1
Injected	2.75	1.52	0.64	98.2	38.5	136.7
Dribble	2.60	1.41	0.65	83.8	36.8	120.6
P-Value (%)	83	98	37	98	50	96
BLSD (.05)		0.08				
Tillage X Method Applied						
P-Values (%)	77	84	49	98	62	98

Table 5 continued on next page.

Table 5: Continued

Treatments			N-Concentration			N-Removal		
N-Rate	Tillage System	Method Applied	Leaf	Grain	Stover	Grain	Stover[1]	Total
Kg/ha			----------%----------			----------Kg/ha----------		
Factorial Arrangement (Excludes control and till plant treatments)								
Tillage								
No Till			2.88	1.56	0.80	107.0	51.5	158.6
Chisel			2.94	1.60	0.78	111.2	51.1	162.3
P-Values (%)			53	84	25	78	5	30
BLSD (.05)								
Method Applied								
Broadcast			2.92	1.56	0.81	110.9	54.1	165.0
Injected			2.94	1.60	0.80	109.0	50.8	160.0
Dribble			2.87	1.58	0.77	107.4	48.6	156.0
P-Values (%)			39	54	67	49	91	84
BLSD (.05)								
N-Rate								
84			2.68	1.46	0.65	90.8	37.6	128.4
168			3.01	1.62	0.83	119.7	56.4	176.2
336			3.04	1.66	0.90	116.9	59.7	176.6
P-Values (%)			99	99	99	99	99	99
BLSD (.05)			0.12	0.03	0.06		4.9	8.5
Tillage X Method Applied			34	44	9	28	6	20
Tillage X N-Rate			30	88	44	51	1	47
Method Applied X N-Rate			76	67	65	46	55	45
Tillage X Method X N-Rate			25	86	1	98	1	8

1 = Stover includes cob + stover N-Removal

CORN TILLAGE RESIDUE MANAGEMENT, LANCASTER, 1983

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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; will permit the maximization of the crop production benefits of the tillage systems; and will permit them to be more effectively incorporated into the overall farming system of the region.

EXPERIMENTAL PROCEDURES

The experimental site is located on the Lancaster Experimental Farm. Five tillage treatments are replicated four times (table 1) the first replication is located on Palsgrove silt loam; the other three replications are located on Rozetta silt loam. Each treatment is split into normal and mulched subtreatments. On the no-till (slot plant) and ridge-plant plots an additional subtreatment (bare) is established by removing all residue prior to planting; the residue is then placed on the adjacent mulched plots of the same tillage treatment. On mulched subtreatments, corn residue additions are made after tillage but before planting to obtain approximately 60 percent surface cover. Plots are approximately 90 to 100 feet in width and 80 feet in length. Row width is 36 inches in 1983. In 1983 corn (Pioneer 3747) was planted (at 29,800 seeds/acre) on May 9. The moldboard treatments (conventional and wheeltrack plant) were plowed May 5 and secondary tillage with a disk was also done on May 5 for the conventional and chisel treatments. The chisel plots were chiseled in the fall of 1982. On the ridge-plant plots a 2-row Buffalo-till cultivator, with lister shovels mounted on the front rank replacing disks, was used to remove the ridge top prior to planting on May 9. All plots were planted with a 4-row John Deere 7000 Max-Emerge planter equipped with fluted coulters. A Ford 6610 tractor was used to make wheel tracks prior to planting on the wheeltrack treatment.

Nitrogen (270 lbs/A as anhydrous ammonia) was injected on April 26, 1983. The starter fertilizer at planting was 200 lbs. of 6-24-24. The insecticide was Counter at 10 lb/A. Chemical weed control used was 1 qt. Dual and 2 lbs/A Atrazine applied preemerge. One pound Atrazine and 1 quart oil were applied post-emergence.

Percent cover was determined from slides made soon after planting. Planting depth, rate of emergence, plant height, silking date, and early growth measurements were made on designated portions of each plot. Random roughness measurements were made on all tillage treatments in Rep. 3 on May 10 and 11 and again on June 9.

Nine plot frames (45-3/4 x 45-3/4 inches) were emplaced on May 9 and covered to protect the surfaces. Infiltration measurements were made on the wheeltrack mulch, wheeltrack bare, no-till mulch, conventional mulch and conventional bare treatments on June 6-9. Random roughness measurements were made before and after each run. Residue amounts were measured for the mulch treatments.

Neutron probe measurements were made weekly on each plot starting June 13 through August 22. Bulk density of the surface layer was measured periodically. Hourly spring soil temperatures were measured on chisel, conventional and no-till treatments in Rep. 3 for both mulch added and bare treatments (chisel normal) at depths of 1, 5, 10, 15, 50, 100 cm. Runoff measurement subplots were installed on June 30 on Rep. 3 on conventional and no-till bare and mulch plots and on the chisel normal plot. Yields were determined by hand harvesting 60 foot samples (two 30-ft. subsamples) from each plot on September 29 and 30, 1983.

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

RESULTS

In 1983, corn yields were reduced on all treatments by water stress due to a severe drought during pollination and grain filling; only 1.13 inches of rain fell between July 3 and August 25; while air temperatures were well above normal (Table 5). Corn yields were not significantly different between treatments; however, the effect of replicates (reps) was highly significant. Average corn yields for each rep were closely related to average depth of rooting (depth to chert (Table 9); rep average corn yields increased nearly 40 bu/a as average depth to chert increased from 24 to 57 inches. In 1981 and 1982 with greater July and August precipitation, average yields in Rep 1 (24 inches to chert) equalled or exceeded yields in Rep. 4 (57 inches to chert); i.e., in years when water was adequate there was no relationship between depth to chert and average yield for a rep. The effect of rooting depth on yield thus depends greatly on the climatic conditions in the individual year as well as on the crop grown. Under water stress conditions such as 1983 at Lancaster, yield decreased consistently as rooting depth decreased.

SEEDBED CONDITIONS

Significant differences in planting depth were measured (Table 2). Even though all treatments were planted with the same planter (with fluted coulter attached) planting depth on the wheeltrack plant treatment was significantly shallower than the chisel normal treatment. No other treatments were significantly different with respect to planting depth. The standard error associated with planting depth was greater in all treatments where mulch was present in the row at planting except for the conventional treatment which had the greatest range in planting depth of any treatment. Following plowing on May 5, the soil dried sufficiently to produce a hard cloddy condition on the bare plot while the mulched plot remained at a higher water content which improved penetration of the planter unit.

Rate of emergence (Table 3) initially showed more rapid emergence on bare plots, however, severe crust formation on bare or low residue plots slowed emergence allowing the emergence rates on mulched plots to generally equal or surpass the bare plots. The crust also appeared to affect early growth and treatments were not significantly different with respect to early growth (Table 1). However, for average plant height and date of silking, significant differences were measured. The no-till mulch treatment had the shortest height and silked latest, while chisel normal was tallest and no-till bare silked first. The no-till bare and mulch treatments were significantly different with respect to date of silking and plant height; however, the individual mulch treatments for ridge plant were not significantly different from each other with respect to plant height or silking date. For the conventional treatment, mulch significantly delayed silking date.

Average population at harvest was significantly higher on the mulch ridge plant and mulch conventional tillage treatments than on the respective bare treatments. Plant population was approximately 21,000 plants/A where 20 percent or more surface residue was present on no-till, conventional and chisel normal treatments. Population was lower on both wheeltrack treatments, bare conventional and bare ridge plant treatments. As discussed earlier, soil movement and crusting appeared to selectively affect treatments without residue cover and may have reduced population. When subplots with population less than 18,000 plants/A in Reps II, III and IV were omitted, average populations ranged from 19,400 to 21,900 plants/A and yields were not significantly different between treatments.

Relative early growth (REG) and relative yield (RY) results are given in Table 4 and are in general agreement with the past two years. The ridge plant treatment differed from the general relationship with virtually no difference in Ry even though REG ranged between 0.76 to 1.06.

Large differences in final (55-minute) infiltration rates were measured between treatments (Tables 6 and 8). On both the wheeltrack and conventional tillage treatments, when mulch was present the final infiltration rates were consistently greater. The final infiltration rate for the no-till mulch treatment in 1983 exceeded all other treatments by at least 1.0 inch/hour. Table 8 contains a 3-year summary of infiltration measurements at Lancaster. The effect of mulch in maintaining a greater infiltration rate can be seen for both plowed treatments (conventional and wheeltrack plant). For the bare plowed treatments, the final infiltration rate on the rougher wheeltrack plant treatment averaged about 1.5 times that for the smooth conventionally tilled treatment. The rough surface provided some temporary benefit, but was much less effective than the mulch in maintaining a

high infiltration rate and preventing surface sealing. In 1983, two passes with the anhydrous injector knives produced 9-10 inch deep slots about 18 inches apart. When protected by mulch these deep injection marks and their fracture planes were highly effective in increasing the infiltration rate. In contrast, in 1981 and '82 the dense no-till surface was broken only in the narrow planter slot and the infiltration rate averaged about the same as the bare conventional treatments's infiltration rate. Thus when the no-till surface is sealed, mulch cover is of little benefit in increasing the infiltration rate compared to conventional tillage, however, when the no-till surface has channels through which water can move readily, the heavy mulch cover is very effective in maintaining a high infiltration rate. These results illustrate the dual requirement of 1) a porous surface with high saturated hydraulic conductivity and, 2) a protective mulch cover which are necessary in order to have rapid sustained infiltration. Residue cover by itself is not sufficient to produce a high infiltration rate.

SUMMARY

Five year results with continuous corn at Lancaster show nearly equal average yields from conventional, chisel, and ridge plant treatments with no-till (slot plant) slightly lower in some years (Table 7).

Thus farmers in the driftless soil area can choose between a variety of tillage options which have yields comparable with conventional tillage, but which are superior in soil and water conservation and also offer savings in time, labor, and fuel compared to conventional moldboard plow tillage methods.

Table 1. Effect of tillage and mulch treatments on percent cover, planting depth, corn early growth, plant height, silking date, population and yield

Treatments		Percent Cover		Avg. Planting Depth Inches	Avg. Early Growth gms DM/ 10 Plants	Avg. Height July 5 Inches	Date 50% Plants Silked July	All Subplots		Selected Subplots *(No.)	
Tillage	Residue	Row	Entire Area					Avg. Population at Harvest	Avg. Yield Bu/A	Avg. Population at Harvest	Avg. Yield Bu/A
Ridge Plant	Bare (0)	2	3	1.6 ab	31.8	33.5 ab	24 ef	18,500 c	91.7	19,500 *	94.6 *(2)
	Normal (1X)	0	10	1.4 ab	24.3	33.8 ab	24.5 cdef	20,100 abc	99.9		99.9
	Mulch (2X)	22	23	1.5 ab	33.8	31.8 abc	24.8 bcdef	21,000 a	93.1		93.1
No Till (slot plant)	Bare (0)	12	15	1.6 ab	45.0	35.8 a	23.8 f	20,700 ab	92.4	21,400 *	94.5 *(1)
	Normal (1X)	34	68	1.5 ab	29.8	34.0 ab	24.5 cdef	21,900 a	85.2		85.2
	Mulch (2X)	95	92	1.4 ab	21.0	28.5 c	26.8 a	20,800 ab	77.1	20,900 *	79.2 *(1)
Conventional	Normal (0)	1	2	1.6 ab	18.3	31.8 abc	24.5 cdef	18,600 c	88.3	19,421 *	88.8 *(1)
	Mulch (1X)	85	92	1.3 ab	23.3	30.25 bc	26 ab	21,100 a	95.9		95.9
Fall Chisel	Normal (N)	18	20	1.8 a	29.5	36.0 a	24.3 def	21,500 a	95.0		95.0
	Mulch (1X+N)	73	86	1.6 ab	21.8	32.8 abc	25.5 abcd	21,200 a	90.7		90.7
Wheeltrack Plant	Normal (N)	0	2	1.3 b	25.0	32.3 abc	25.8 abc	18,900 bc	91.4	19,500 *	92.3 *(1)
	Mulch (1X)	70	76	1.2 b	25.0	30.5 bc	25.3 bcde	18,500 c	86.6	19,500 *	87.8 *(3)
Significance Level				0.01	NS	0.05	0.01	0.01			NS

*(No.) In Reps II, III, IV omit single subplot population less than 18,000 PPA

Table 2. Planting depth measurements, Lancaster 1983.

Treatment		Planting Depth			2/3 of Seeds Between
		----------mm----------			
Tillage	Residue	Avg.	Sx	Range	Depths (mm) of:
Ridge Plant	Bare	40 ab*	8.2	20-60	32-48
	Normal	36 ab	12.4	20-60	24-48
	Mulch	39 ab	8.0	30-60	31-47
No Till (slot plant)	Bare	41 ab	6.2	30-60	35-47
	Normal	38 ab	7.6	30-60	30-46
	Mulch	37 ab	9.4	15-60	28-46
Conventional	Normal	40 ab	11.0	10-60	29-51
	Mulch	34 ab	8.8	15-50	25-43
Fall Chisel	Normal	45 a	5.4	35-50	40-50
	Mulch	40 ab	7.3	30-60	33-47
Wheeltrack Plant	Normal	33 b	9.7	15-50	23-43
	Mulch	30 b	12.9	10-60	17-43

*5 Percent level of significance Duncans new multiple range test.

Table 3. Influence of tillage method and mulch rate on percent emergence.

Treatment		Days After Planting Date of May 9					
		---------- Percent Emerged ----------					
Tillage	Residue	15	17	20	22	26	30
Ridge Plant	Bare	27	47	76	81	95	100
	Normal	21	45	74	78	97	100
	Mulch	16	44	76	91	99	100
No Till	Bare	11	40	79	85	95	100
	Normal	8	39	85	88	100	100
	Mulch	2	24	62	75	100	100
Conventional	Normal	7	31	79	79	99	100
	Mulch	5	26	74	86	99	100
Fall Chisel	Normal	12	33	74	78	98	100
	Mulch	4	35	71	80	92	100
Wheeltrack Plant	Normal	10	49	71	83	97	100
	Mulch	5	28	77	85	97	100

Day 15 = May 25

Table 4. Effect of mulch on relative early growth (Reg.) and relative yield (Ry)[1/].

Tillage	Mulch Level	Percent Cover in Row	Reg[2/]	Ry[3/]
Ridge	1X	10	0.764	1.060
	2X	23	1.063	0.971
No Till (slot plant)	1X	68	0.661	0.897
	2X	92	0.467	0.846
Conventional	1X	92	1.274	1.009
Chisel	1X + N	86	0.737	0.957
Wheeltrack Plant	1X	76	1.00	0.964

[1/] Yield adjusted to equal population for each Ry comparison in Reps II, III, IV.

[2/] $Reg = \frac{\text{Early growth with mulch}}{\text{Early growth without multh}}$

[3/] $Ry = \frac{\text{Yield with mulch}}{\text{Yield without mulch}}$

Table 5. 1983 Weather summary, Lancaster Experiment Station.

Month	Precipitation Inches Total	Precipitation Inches Departure	Growing Degree Days 1983	Growing Degree Days Departure	Temperature Avg. Max.	Temperature Avg. Min.	Temperature Avg.	Temperature Departure
					----------of----------			
April	2.34	-0.83	(59)	--	52.2	33.2	42.7	-3.8
May	5.18	1.73	186	-114	64.8	44.0	54.4	-3.4
June	3.28	-1.27	570	+55	80.6	57.4	69.0	2.0
July	3.34	-0.95	748	+88	86.5	63.8	75.2	3.8
August	3.12	-1.50	751	+156	88.3	63.2	75.7	6.8
September	3.81	0.37	414	+62	74.4	51.0	62.7	1.8

NOTE: 1.13 inches of rain between July 3 and August 25 - a period of 53 days

Table 6. 1983 Lancaster infiltration rate measurements

Tillage	Residue	Application Rate In/Hr.	Water Applied Before Runoff Inches	Infiltration Rate X Minutes After Runoff Commences In/Hr.							
				2.5	7.5	12.5	17.5	25	35	45	55
Wheeltrack	Bare (E)	4.64	1.19	2.24	1.52	1.04	1.16	1.58	0.74	0.86	0.80
	(W)	4.32	1.35	2.88	2.52	1.80	1.68	1.56	1.08	1.08	1.32
	Mulch	5.12	1.58	3.80	3.32	3.20	2.36	2.66	2.72	2.36	2.24
Conventional	Bare (E)	4.32	1.12	2.88	2.52	2.04	1.68	1.62	1.14	0.48	0.36
	(W)	4.56	1.06	2.04	1.56	1.44	0.96	0.78	0.66	0.72	0.72
	Mulch (E)	4.88	1.28	2.96	2.36	1.64	2.24	2.06	2.06	1.64	1.88
	(W)	4.93	1.15	2.05	1.09	1.33	1.21	1.27	0.79	1.39	1.09
No Till (slot plant)	Mulch (E)	4.80	1.24	3.96	3.60	2.88	2.76	3.00	2.88	3.00	3.24
	(W)	4.48	1.81	4.24	4.24	3.92	3.80	3.68	3.34	3.70	3.82

Table 7. Continuous corn tillage yield results at Lancaster, Wisconsin 1979-1983.

Tillage	1979	1980	1981	1982	1983	Average
	Bu/Ac					
Ridge plant*	162	157	157	147	100	145
Slot plant	163	146	151	141	85	137
Chisel	160	150	167	154	95	145
Conventional	169	159	168	151	89	147

*Planted flat in 1979 and 1981 - corn not cultivated to form ridges in 1980 and 1983.

Table 8. Infiltration rate* 55 minutes after runnoff begins.

Treatment		1981	1982	1983	Avg.
Tillage	Residue	Inches/Hour			
No Till	Mulch	1.46	1.10	3.53*	
	(No till mulch) / (Conv. Bare)	(1.51)	(0.72)	(6.53)	
Conventional	Bare	0.97	1.52	0.54	1.01
	Mulch	2.72	2.34	1.49	2.18
	(Bare/mulch)	(0.36)	(0.65)	(0.36)	(0.46)
Wheeltrack Plant	Bare	0.97	2.44	1.06	1.49 (81+83 only 1.02)
	Mulch	1.44		2.24	1.84
	(Bare/mulch)	(0.67)		(0.47)	(0.55)

*Soil disturbed prior to planting by anhydrous ammonia injection.

Table 9. Average yields by replicate and precipitation for 1981, 1982 and 1983 and depth to chert Lancaster, Wisconsin.

Year	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*
Avg. depth to chert in inches	24	29	37	57				

* 1983 - 1.13 inches precipitation from July 3 to Aug. 25 (53 days).

1981 - Subplots with population < 17,000 omitted.
1983 - Subplots with population < 18,000 omitted Rep II, III, IV.
1982 - Missing values estimated for 8 plots out of a total of 48 plots.

The Effect of Tillage and Potassium Placement on the Availability of Potassium to Corn

James Swan, John Moncrief, Pat Burford, and Brian Schrieber

With conservation tillage practices now becoming more popular it is important to know if different fertilizer management techniques are necessary. Placement of fertilizers may be more important. Changes in soil physical properties associated with extreme reduction in tillage can effect the spacial distribution of both roots and applied K, as well as root metabolism. These as well as other changes in soil and plant properties can affect the availability of soil K.

The main objectives of this study are:

1. To determine the effects of tillage on K availability to corn.
2. To determine the effect of row applied K and tillage on availability and growth of corn over a range of soil test K levels resulting from broadcast treatments.
3. And to characterize the effect of tillage on the spacial distribution of broadcast K, and determine how this relates to soil test interpretation.

Although,this study was initiated in 1982 only the 1983 results will be discussed.

Methods and Materials:

Cropping History and Residue Management:

The following table shows the cropping history at the experimental site.

Year	Crop Grown
1978	oats
1979	alfalfa
1980	alflafa
1981	corn as silage
1982	corn as grain
1983	corn as grain

Hybrid Corn Used:

1982-105 day single cross hybrid(Pioneer 3732) planted 5/20/82.
1983-95 day single cross hybrid(Pioneer 3906) planted 5/23/83.
Both hybrids were planted at a rate of 7.26 seeds/m^2, at a row spacing of 96 cm.

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

Pesticide Application:

1982:
- -Terbufos(Counter) was used at a rate of 7.8 kg/ha.
- -Fall application of Glyphosate(Roundup) to control quack grass at a rate of 4.6 l/ha.
- -Atrazine/Alachlor(Atrazine/Lasso) mixture applied at 4-5 leaf stage at the rate of 2.2 kg/ha atrazine and 2.2 kg/ha alachlor.

1983:

- -Atrazine/Alachlor(Atrazine/Lasso) mixture applied pre-emergence at a rate of 2.2 kg/ha atrazine and 2.2 kg/ha alachlor.
- -Fonofos(Dyphonate) for root worm control at a rate of 11.2 kg/ha.

Equipment:

- -Chisel plow(Glencoe Soil Saver) chisels 9 cm wide and spaced 33.3 cm apart with twisted shovels
- -Field Cultivator(Bushog)
- -Planters:1982 John Deere maxemerge, 1983 Hinicker, both equipped with 5 cm fluted coulters

Experimental Design:

This study was designed as a randomized complete block with six replications. Tillage treatments used were, spring chisel plowing(20-23 cm deep) followed by a field cultivator (10-13 cm deep)and no-till. Broadcast K applications were made in the spring prior to tillage. Because of preexisting variability in soil K, regression was used to characterize treatment differences.

Row applied potassium was applied as 0-0-7 to every other row and nitrogen-phosphorus starter as 7-21-0 to all the rows.

Statistical Analysis:

The analysis was done using the Statistical Package for the Social Sciences.

Treatment Summary:

Tillage:
- -No Till
- -Spring chisel plowing followed by a field cultivation

Potassium Application:

- -Broadcast application rate of 0, 225, and 450 kg/ha K_2O.
- -Row application rate of 190 l/ha 7-21-0 and 190 l/ha 7-21-0 plus 95 l/ha of 0-0-7.

Fertilizer Application Schedule:

Type	Date Applied	Method	Rate Applied
KCl	4/26/83	Broadcast	0,225 and 450 kg/ha
ammonium polyphosphate+ urea (7-21-0)	5/23/83	Row	190 l/ha
ammonium polyphosphate+ urea (7-21-0)+ KCl (0-0-7)	5/23/83	Row	190 l/ha +95 l/ha
Ammonium Nitrate	5/18/83	Broadcast	335 kg/ha
Calcium sulfate	6/8/83	Braodcast	225 kg/h
Zinc Chelate (Na_2 Zn EDTA)	7/12/83	Broadcast	1.0 kg/ha (actual Zn)

Because of borderline soil test levels, sulfur as calcium sulfate and zinc as zinc chelate were applied to eliminate the effect of these nutrients.

Soil Sampling Techniques:

Ten samples per plot were composited for 0-5, 5-10, 10-15, and 15-30 cm depths. A seperate 0-15 cm sample was taken at each of the ten sampling spots to compare with the incremented 0-15 cm sample average. Soil samples were taken on two dates: before fertilizer application(4/26/83), and after fertilizer application(6/16/83).

The samples were dried at 50 degrees centigrade, and ground to pass a 2 mm sieve.

Deep samples were taken (6/12/83) to a depth of 2 meters. The first 15 cm were discarded and the 15 to 30 cm depth retained. Then samples were incremented every 30 cm to the 2 m depth. The samples were placed in plastic bags to retain moisture, for moist soil K analysis, and bulk density determinations. After these moist samples were taken the remaining sample was dried at 50 degrees centigrade, and ground to pass a 2 mm sieve.

Plant Samples:

Whole plant samples were taken at approximately the 6 leaf stage of development(7/5/83). Plants were cut at ground level(10 plants/plot). These samples were dried at 60 degrees centigrade and ground to pass a 1 mm sieve.

At harvest grain and stover samples were taken. Grain was dried at 60 degrees centigrade, and stover at 60 degrees centigrade, both to constant weight. Both samples were ground for tissue analysis.

Soil Analysis:

The K levels in the soil tested were determined using ammonium acetate extraction. Phosphorus levels were determined by the Bray-1 method.

Residue Measurements:

Residue was measured by the line intersect method.

Results and Discussion

Site Characterization:

The effect of tillage, and distribution of residue on rate of emergence of corn and final stand count.*

Tillage	1983 Soil Cover In Row	between Row	Emergence 6/8/83	Final Stand 6/24/83
	----------percent----------			plants/m^2
No-till	50.8 (15.2)	72.3 (11.1)	66(22)	6.68(.73)
Chisel	16.7 (5.5)	21.0 (5.5)	82(11)	6.40(.40)

*Numbers in parenthesis are the standard deviations, n=12 and 6 for cover and emergence respectively. In and between the row are defined as the 20 cm area centered over the row, and the remainder respectively.

There was approximately three times the level of cover without tillage than with chisel plowing reguardless of position relative to the row. The cover without tillage was more variable due to poor distribution by the combine. Although there is a considerable difference in residue distribution and emergence due to tillage, there was no effect on final stand.

Characterization of pH, Potassium and Phosphorus

The effect of tillage and nitrogen application(ammonium nitrate applied 5/18) on soil pH, N=18, value in parenthesis is standard deviation.

depth (cm)	No-till 4/26	6/16	Chisel 4/26	6/16
	----------pH----------			
0-5	6.6 (0.3)	5.4 (0.3)	6.7 (0.2)	5.9 (0.2)
5-10	6.8 (0.2)	6.3 (0.2)	6.8 (0.2)	6.4 (0.2)
10-15	6.9 (0.2)	6.6 (0.2)	6.8 (0.1)	6.6 (0.2)
0-15	6.7 (0.2)	6.0 (0.3)	6.8 (0.1)	6.3 (0.2)
15-30	6.7 (0.2)	6.5 (0.2)	6.8 (0.1)	6.6 (0.2)

The effects of tillage on the spatial distribution and soil buffering of broadcast K(applied 6/16), N=6, standard deviation is the value in parenthesis.

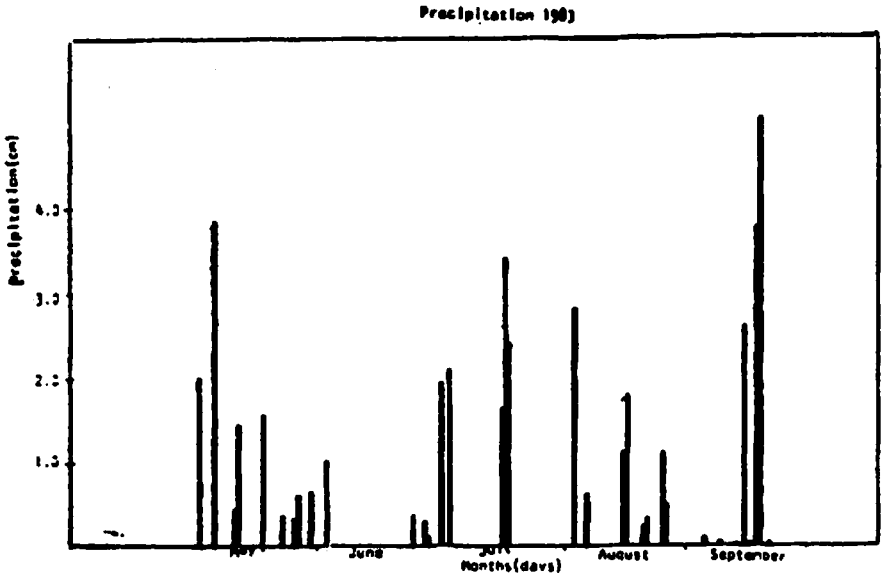
Rate of K kg K_2O/ha	Depth (cm)	No-till 4/26	No-till 6/16	Chisel 4/26	Chisel 6/16
		K(ppm)			
0	0-5	87.3 (15.2)	90.2 (21.0) 40	90.8 (15.5)	96.5 (32.6)
	5-10	65.8 (11.0)	69.4 (10.6) 40	70.5 (12.1)	76.8 (20.1)
	10-15	63.5 (14.4)	62.4 (11.6) 42	75.3 (25.0)	69.0 (19.4)
	0-15	70.5 (12.7)	69.8 (8.9)	68.5 (15.3)	72.0 (18.0)
	15-30	54.0 (19.6)	56.8 (24.5)	55.8 (10.0)	54.8 (12.4)
225	0-5	112.2 (34.3)	272.8 (55.4)	108.4 (21.9)	167.2 (39.8)
	5-10	71.0 (23.2)	91.5 (31.5)	77.5 (21.0)	123.2 (35.9)
	10-15	59.5 (13.5)	63.0 (16.0)	62.8 (18.3)	70.2 (16.8)
	0-15	79.8 (20.4)	128.8 (33.6)	75.8 (18.8)	111.5 (30.9)
	15-30	57.2 (27.1)	54.3 (17.2)	47.6 (6.9)	55.3 (15.3)
450	0-5	164.5 (17.8)	424.6 (60.0)	160.2 (71.1)	249.0 (51.5)
	5-10	70.8 (25.1)	126.6 (21.6)	112.2 (41.5)	179.2 (30.0)
	10-15	61.2 (7.1)	79.8 (10.4)	74.0 (19.9)	102.3 (32.1)
	0-15	101.7 (11.0)	172.4 (32.4)	108.3 (34.7)	152.7 (36.3)
	15-30	55.8 (17.6)	57.2 (6.5)	56.7 (24.9)	59.5 (24.8)

It is interesting to note the interaction of tillage with change in soil test. The change is 30-60 percent higher with the no-till treatment in the 0-15 cm depth. This may partially account for the higher soil K levels necessary with this system.

The spacial distribution of phosphorus. The values in parenthesis are the standard deviations, N=18.

Depth (cm)	No-till	Chisel
	P (ppm)	
0-5	25.9 (8.1)	28.2 (7.8)
5-10	23.1 (9.1)	25.9 (8.6)
10-15	21.4 (7.8)	21.5 (4.4)
0-15	25.9 (8.1)	24.6 (7.1)
15-30	13.7 (2.3)	12.7 (2.6)

Phosphorus distribution is a result of the previous tillage history at this site. The cooperator had been using chisel plow tillage prior to the establishment of the tillage treatments of this study. This is reflected in the preexisting vertical gradient in P.



Subsoil potassium, pH, bulk density, and volumetric moisture percentage, as effected by tillage(6/2/83). The value in parenthesis is the standard deviation, N=9.

Variable Type	Depth (cm)	No-till	Chisel
Moist soil K (ppm)	15-30	31.6(8.3)	42.4(14.5)
	30-60	23.0(4.4)	25.6(7.7)
	60-90	22.5(6.9)	20.5(5.0)
	90-120	28.8(7.5)	23.9(4.4)
	120-150	30.0(6.5)	26.4(4.0)
Dry soil K (ppm)	15-30	52.0(20.3)	53.2(10.9)
	30-60	76.1(16.5)	58.6(17.8)
	60-90	69.3(11.9)	59.3(17.5)
	90-120	72.9(13.8)	60.0(24.0)
	120-150	62.8(23.9)	67.8(24.1)
pH	15-30	6.8(.5)	6.9(.3)
	30-60	6.4(.4)	6.5(.4)
	60-90	6.2(.6)	6.4(.7)
	90-120	6.3(.5)	6.1(.8)
	120-150	7.0(.6)	6.6(1.1)
Bulk Density (g/cm^3)	15-30	1.41(.06)	1.46(.09)
	30-60	1.43(.07)	1.41(.05)
	60-90	1.38(.04)	1.38(.09)
	90-120	1.33(.07)	1.36(.13)
	120-150	1.30(.08)	1.27(.11)
Moisture (% by vol.)	15-30	23.7(0.89)	23.3(1.18)
	30-60	25.0(1.12)	23.5(0.92)
	60-90	25.4(0.90)	23.0(1.25)
	90-120	28.1(1.39)	26.9(3.93)
	120-150	26.5(4.48)	25.1(4.37)

There is a low level of subsoil K. Soil samples run moist had about one fourth the soil test as those allowed to dry. Subsoil moisture was higher in the no-till treatment going into the season.

The effect of tillage, broadcast K, and row applied K on early dry matter production(7/5/83). The values in parenthesis are standard deviations, N=6.

K Applied (kg K O/ha)	Row Fertilizer	Tillage No-till	Chisel
0	N-P-K	9.3(1.1)	10.7(1.4)
	N-P	6.4(3.5)	8.3(1.0)
225	N-P-K	8.1(0.9)	10.6(1.9)
	N-P	8.1(0.6)	9.3(0.9)
450	N-P-K	8.5(0.4)	9.7(2.8)
	N-P	7.6(0.9)	9.0(1.6)

Early growth is increased with the use of row applied potassium. This is expected since the plant takes up large quantities of K in its early stages of development. Chisel plow treatments had greater early whole plant growth than no-till treatments. This is most likely the result of more favorable soil temperatures, allowing earlier emergence. The effect of row applied K is greatest at the 0 kg/ha rate of broadcast K, especially in the no-till treatment.

The effect of tillage on leaf water potential readings taken on selected days as effected by tillage. The values in parenthesis are standard deviations,N=18.

Date	No-till	Chisel
	----------(-bars)---------	
7/26/83	8.0(2.0)	7.1(1.7)
7/28/83	6.2(1.2)	6.8(1.1)
8/1/83	10.0(2.0)	9.9(1.1)
8/8/83	7.8(2.2)	8.2(2.3)
8/12/83	6.7(1.5)	7.5(1.8)

There is no measured difference in moisture stress due to tillage. This is likely due to near sufficient rain during the monitoring period. Extremely hot weather late season may have had a detrimental affect on yields.

The effect of tillage and traffic on the bulk density, and moisture in the surface 20 cm on 7/22/83. The value in parenthesis is the standard deviation, N=6.

Sample Position	No-till		Chisel	
and Depth(cm)	B.D(g/cm^3)	% Water(by vol)	B.D.(g/cm^3)	% Water(by vol.)
With traffic				
2-10 cm	1.48(0.09)	31.7(2.22)	1.39(0.04)	28.7(1.98)
12-20 cm	1.43(0.86)	30.9(0.98)	1.38(0.05)	29.3(2.07)
No traffic				
2-10 cm	1.44(0.10)	30.5(1.37)	1.36(0.09)	28.0(3.85)
12-20 cm	1.39(0.10)	28.0(4.96)	1.40(0.04)	28.4(1.20)
In row				
2-10 cm	1.25(0.12)	24.1(3.14)	1.19(0.09)	22.8(4.13)
12-20 cm	1.37(0.06)	28.5(2.08)	1.31(0.04)	25.1(3.89)

Significant differences in soil density due to tillage are present in the 2-10 cm soil depth regardless of traffic or position relative to the row. A similar trend is apparent with soil moistrue. There does not seem to be appreciable increase in soil density due to traffic. This is probably the result of dry conditions at planting. Soil density in the row is lower as a result of tillage by disc openers and a fluted coulter on the planter.

Grain yields and K uptake

The effects of row K, tillage, and soil K on yields are shown in figures 1 and 2. The advantage to row K at lower soil K levels on grain yields is apparent. The advantage is greater without tillage. The starter NPK and NP lines also cross at a higher soil test with this treatment. It is difficult to tell why there was an apparent advantage to the absence of row K at higher soil K levels for both tillage treatments. This effect did not occur with stover yields suggesting an interaction of row K with crop phenology, physiology, and climate. Increases in K concentration in the grain more than compensated for yield differences resulting in convergence of starter treatments at a higher soil test(figure 2). The slope of yield and uptake curves may in part be due to the changes in soil buffering due to tillage discussed earlier.

Regression equations to characterize treatment differences of yields and K-uptake(yields on dry matter basis). n=9, see figure 1. and 2.

The equation used: $y=e^{a} K^{b}$

Variable	Tillage	Values in equation a	b	R^2	α-level
Stover(Mg/ha) Row N-P-K	No-till	1.3863	.10961	.168	.19
	Chisel	.87718	.21615	.332	.03
Stover(Mg/ha) Row N-P	No-till	1.1024	.15732	.341	.04
	Chisel	.59299	.27132	.738	.00
Grain(Mg/ha) Row N-P-K	No-till	-.74139	(1.1633-.130191nK)	.254	.27
	Chisel	-1.5412	(1.4671-.156621nK)	.122	.49
Grain(Mg/ha) Row N-P	No-till	1.1133	.14930	.572	.00
	Chisel	.87265	.21957	.824	.00
Total(Mg/ha) Row N-P-K	No-till	2.3628	.04157	.071	.40
	Chisel	2.0403	.11441	.223	.09
Total(Mg/ha) Row N-P	No-till	1.7999	.15366	.459	.02
	Chisel	1.4246	.24512	.932	.00
K-uptake(kg/ha) Row N-P-K	No-till	-.24033	(1.4570-.155271nK)	.098	.63
	Chisel	-2.3452	(2.3569-.245421nK)	.432	.05
K-uptake(kg/ha) Row N-P	No-till	2.3758	.15031	.350	.04
	Chisel	1.6023	.34363	.589	.00
K-uptake Stover(kg/ha) Row N-P-K	No-till	1.2811	.62470	.791	.00
	Chisel	-.37897	1.0004	.675	.00
K-uptake Stover(kg/ha) Row N-P	No-till	.57302	.75485	.636	.00
	Chisel	-1.4893	1.2294	.772	.00
K-uptake Total(kg/ha) Row N-P-K	No-till	2.2853	.47577	.786	.00
	Chisel	1.2250	.72669	.671	.00
K-uptake Total(kg/ha) Row N-P	No-till	1.6742	.58795	.658	.00
	Chisel	.00367	.97519	.813	.00

Summary

1. The advantage of row K on early growth occurred at lower soil K levels and was greater with no tillage.

2. The chisel plow treatment resulted in higher early growth and total corn yields.

3. The vertical gradient in soil K was steeper without tillage.

4. Changes in soil K with a given application were higher with no tillage.

5. The corn grown with no tillage required higher levels of soil K(this is mitigated by the soil buffering aspects of tillage).

6. At high soil K levels row K had a detrimental effect on grain yields.

THE EFFECT OF TILLAGE AND N MANAGEMENT ON CORN YIELDS - 1983

J. F. Moncrief, G. L. Malzer, G. W. Rehm, J. A. True, and J. Chaplin

As farmers adopt conservation tillage systems to control erosion and reduce production inputs, N management becomes more important. Research has shown reductions in N availability to be associated with extreme reductions in tillage. If N losses are the result of denitrification or increased leaching, there may be an advantage with nitrification inhibitors or delayed N application when conservation tillage extremes are used. The purpose of this study is to: assess the effect of tillage, time of N application, and use of nitrification inhibitors on N availability.

The experimental sites are located at the Sand Plains Experiment Station, Becker, Minnesota and on a cooperator's farm in Goodhue County, Minnesota. The soils are loamy sand under irrigation (Udorthentic Haploborolls) and a silt loam soil (Typic Hapludalf) at the east central (Becker) and southeast (Goodhue County) sites, respectively. Nitrogen was applied as anhydrous ammonia on May 6 at the east central site and May 12 and July 6 at the southeast site. Two nitrification inhibitors were evaluated at both sites (N-Serve and Dwell). For a detailed description of tillage treatments and characterization, cultural practices, and methods see "Placement of nitrogen solutions under differing tillage systems" in this publication. The experimental design is a split-split plot.

Results and Discussion - Southeast Minnesota Location

The probability values of treatment effects are shown in Table 1. The smaller this number is the higher the probability that the treatment effects are real and not due to chance. Grain and stover yields are shown in Tables 2 and 3, respectively. Grain yields with spring applied N generally are higher with a till plant (ridge till) system, but stover yields appear higher with corn grown under chisel plow tillage. With sidedressed N, corn yields appear to be slightly higher with chisel tillage over the till plant system. The no-till system resulted in slightly lower corn yields and appeared to be at a disadvantage with sidedressed N. The soil moisture advantage provided by this approach to residue management is maximum after a rain when soil moisture levels are relatively high. During a prolonged drought, advantages of residue due to moisture conservation would be much less or absent. Lower yields may also be due to less infiltration with this system if spotty rain is intense, resulting in more runoff. In 1983, the early season was cool and wet and the remainder extremely dry. This favored the ridge till and chisel treatments. This is supported by the data in Table 4. These measurements were made after a prolonged drought, Figure 1. Although the ridge system had lower moisture in the row, the trend shows larger moisture levels for this system and the chisel treatment over that with no tillage.

There is no consistent trend in yield response of nitrification inhibitor treatments. This would be expected in a dry year and when there is no effect of applied N past the first rate. This trend is also true of N uptake and ear leaf N concentrations (Tables 5, 6, 7, and 8).

It is interesting to note that the till plant system with spring N had more N uptake in the grain than the other two systems, but less in the stover. This is consistent with the grain and stover trends. Sidedressed N resulted in less N uptake by grain than spring applied N with this system. Less stover N uptake with spring applied N also occurred with this tillage treatment over the other two. Tillage effects on total N uptake were not significant as a result of reverse grain and stover uptake trends. In summary it appears that spring applied N resulted in more efficient partitioning of carbon and nitrogen assimilates into grain with the till plant system.

Results and Discussion - Becker (east central) Minnesota Location

Results on a loamy sand under irrigation were much different. Probability values, yields and N uptake data are shown in Tables 9, 10 and 11, respectively for this site. Significant inhibitor responses occurred at the first rate of applied N independent of tillage. This was the result of a major leaching event in June (Figure 2). In several cases, Dwell appeared to have an advantage over N-Serve.

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

Across inhibitor treatments and N rates, the till plant and chisel treatments had slightly higher grain yields. The stover yields were lower with the till plant treatment over those of the chisel treatment, similar to the trend at the other location. This resulted in total dry matter yields to be greatest with chisel plow.

Responses to the nitrification inhibitor treatments were similar with N uptake. Grain N uptake appeared to be higher with chisel plow tillage.

Table 1. Probability of treatment effects for selected variables at the Southeast Minnesota site, 1983.

Source	Variable						
	Grain Yield	Stoves Yield	Total Dry Matter	Grain N Uptake	Stoves N Uptake	Total N Uptake	Ear Leaf N
Rep	.1926	.0010	.0157	.0013	.0187	.0009	.0867
Tillage	.0488	.0330	.1294	.0168	.3915	.3581	.4149
N	.9408	.6173	.4444	.4642	.0028	.0431	.0012
Till x N	.0951	.5458	.1530	.0420	.0349	.0670	.9672
Time	.0001	.0001	.0001	.0068	.0001	.0001	.0001
Inhibitor	.1284	.2471	.0560	.7637	.5326	.5334	.3524
Till x Time	.0166	.6734	.3795	.0478	.0293	.0639	.4366
Till x Inhib.	.7936	.8880	.8506	.6812	.5997	.6275	.0209
N x Time	.0252	.0590	.0071	.0090	.1983	.0050	.7362
N x Inhib.	.1240	.1292	.3103	.0457	.8828	.1210	.1222
Time x Inhib.	.7405	.3994	.6842	.8112	.3495	.6124	.6544
Till x N x Time x Inhib.	.1813	.1798	.7745	.1432	.6992	.1258	.0073

Table 2. The effect of tillage, N rate, and nitrification inhibitor on grain yields in Southeast Minnesota, 1983*

N Rate	No-Till			Till Plant			Chisel		
	None	N-Serve	Dwell	None	N-Serve	Dwell	None	N-Serve	Dwell
Kg/ha	Mg/ha 0% moisture								
Spring									
0	4.1			3.7			3.8		
95	6.9a	6.5a	6.5a	7.4a	7.5a	7.9b	7.4a	7.0a	7.2a
195	7.0a	7.2a	6.8a	7.5a	7.7a	6.8a	7.4a	7.6a	7.3a
390	7.3a	7.0a	6.7a	7.8a	7.9a	7.6a	7.1a	7.2a	7.6b
Sidedress									
0	3.8			4.2			4.1		
95	5.8a	6.6a	6.7a	7.3a	7.5a	7.4a	7.9a	7.1b	7.0b
195	6.7a	6.6a	6.6a	7.0a	6.7a	6.8a	7.3a	5.6a	6.9b
390	6.1a	7.0b	6.7b	6.7a	7.0a	6.8a	7.1a	7.2a	6.8a

*Means for a tillage treatment in the same row followed by different letters are significant at x=.10, N=4.

Table 3. The effect of tillage, N rate, and nitrification inhibitor on stover yields in Southeast Minnesota, 1983.*

N Rate	No Till			Till Plant			Chisel		
	None	N-Serve	Dwell	None	N-Serve	Dwell	None	N-Serve	Dwell
Kg/ha	Mg/ha								
Spring									
0	5.1			4.3			4.5		
95	6.7a	6.6a	6.1a	6.1a	6.3a	6.6b	7.0a	6.6a	6.7a
195	6.7a	6.5a	6.3a	6.2a	6.2a	5.6b	7.1a	7.1a	6.7a
390	6.5a	6.3a	6.4a	6.6ab	6.7a	6.4b	6.8a	6.8a	6.9a
Sidedress									
0	4.2			4.4			4.1		
95	5.8a	6.3b	6.0a	5.1a	5.7a	6.1a	6.3a	6.1a	6.3a
195	6.5a	5.9a	5.5a	6.0a	5.5b	6.0a	6.3a	6.3a	6.5a
390	5.4a	6.0a	6.1a	5.4a	6.1b	5.3a	5.9ab	6.6b	5.5a

*Means for a tillage treatment in the same row followed by different letters are significant at x = .10, N = 4.

Table 4. The effect of tillage on soil density and moisture in Southeast Minnesota, Aug 23, 1983.*

Depth (cm)	Position Relative to row	No Till	Till Plant	Chisel
		Soil Density gm/cm^3		
2-10	In row	1.19 (.0841)	1.05 (.144)	1.10 (.061)
	Between no traffic	1.30 (.141)	1.33 (.121)	1.30 (.138)
	Between traffic	1.43 (.082)	1.43 (.136)	1.36 (.113)
12-20	In row	1.33 (.150)	1.28 (.093)	1.32 (.079)
	Between no traffic	1.32 (.142)	1.37 (.061)	1.35 (.010)
	Between traffic	1.44 (.111)	1.40 (.046)	1.44 (.101)
		Soil moisture cm^3/cm^3		
2-10	In row	24.1 (3.5)	22.0 (3.4)	25.3 (3.3)
	Between no traffic	24.6 (2.0)	27.1 (1.3)	28.4 (2.9)
	Between traffic	28.0 (1.2)	29.5 (1.5)	29.8 (2.2)
12-20	In row	22.2 (3.2)	23.8 (1.7)	26.3 (4.1)
	Between no traffic	23.0 (3.2)	24.6 (3.1)	25.6 (1.1)
	Between traffic	25.5 (3.0)	24.3 (2.1)	27.1 (2.7)

*The number on parenthesis is the standard deviation, N = 4.

Table 5. Effect of tillage, N rate, and nitrification inhibitor on grain N uptake in Southeast Minnesota, 1983.*

	No Till			Till Plant			Chisel		
N Rate	None	N-Serve	Dwell	None	N-Serve	Dwell	None	N-Serve	Dwell
Kg/ha	Kg/ha								
Spring									
0	61.2			52.0			51.0		
95	96.9a	91.8a	100.4a	117 a	117a	121a	114 a	111a	104a
195	118 a	106 b	107 b	112 a	120a	105a	116 a	117a	109a
390	111 a	116 a	106 a	123 a	120a	122a	107 a	120a	123a
Sidedress									
0	49.8			51.8			53.0		
95	94.1a	91.3a	103.0b	119 a	115a	116a	126 a	111a	113a
195	102 a	104 a	101 a	110 a	105a	109a	113 a	118a	112a
390	92.2a	116 b	111 b	101 a	110b	102a	118 a	108a	108a

*Means for a tillage treatment in the same row followed by different letters are significant at x = .10, N = 4.

Table 6. The effect of tillage, N rate, and nitrification inhibitor on stover N uptake in Southeast Minnesota, 1983.*

	No Till			Till Plant			Chisel		
N Rate	None	N-Serve	Dwell	None	N-Serve	Dwell	None	N-Serve	Dwell
Kg/ha	Kg/ha								
Spring									
0	30.7			23.4			25.7		
95	53.1a	47.5a	46.9a	44.0a	45.7a	48.3a	51.1a	43.8a	47.5a
195	51.6a	52.1a	49.0a	48.5a	46.6b	44.8b	57.6a	54.4a	54.1a
390	53.9a	55.3a	51.1a	49.5a	51.6a	49.6a	60.0a	58.3a	58.3a
Sidedress									
0	22.8			21.4			20.4		
95	47.6a	51.9a	48.3a	40.9a	42.4a	41.4a	44.1a	43.5a	43.9a
195	50.6a	54.6a	48.3a	44.6a	40.2a	45.6a	41.6a	48.7a	49.7b
390	45.9a	52.5a	53.2a	38.6a	40.4a	37.8a	59.6a	53.7a	46.5b

*Means for a tillage treatment in the same row followed by different letters are significant at x = .10, N = 4.

Table 7. The effect of tillage, N rate, and nitrification inhibitor on total N uptake in Southeast Minnesota, 1983.*

N Rate	No Till			Till Plant			Chisel		
	None	N-Serve	Dwell	None	N-Serve	Dwell	None	N-Serve	Dwell
Kg/ha	Kg/ha								
Spring									
0	91.9			75.4			76.7		
95	150 a	139b	147a	161 a	163a	170a	165 a	155a	152a
195	170 a	158a	156a	161 a	167a	150a	174 a	172a	162a
390	164 a	171a	157a	173 a	171a	172a	167 a	178a	182a
Sidedress									
0	72.6			73.2			73.4		
95	142 a	143a	151a	160 a	157a	157a	170 a	154a	157a
195	152 a	159a	149a	154 a	146a	154a	155 a	166b	162ab
390	138 a	168b	164b	140 a	150a	140a	178 a	162a	155a

*Means for a tillage treatment in the same row followed by different letters are significant at x = .10, N = 4.

Table 8. The effect of tillage, N rate, and nitrification inhibitor on leaf N concentration in Southeast Minnesota, 1983.*

N Rate	No Till			Till Plant			Chisel		
	None	N-Serve	Dwell	None	N-Serve	Dwell	None	N-Serve	Dwell
Kg/ha	%								
Spring									
0	2.03			1.88			1.77		
95	2.75a	2.70a	2.69a	2.92a	2.92a	2.82a	2.75a	2.90a	3.03a
195	2.80a	2.96b	2.81a	3.09ab	3.14a	2.54b	3.18a	2.27b	3.01a
390	2.72a	2.92a	3.11a	3.08a	2.94a	3.01a	2.96a	2.98a	3.23a
Sidedress									
0	1.97			2.04			1.84		
95	2.74a	2.73a	2.58b	2.76a	2.62a	2.70a	2.64a	2.59a	2.72a
195	2.60a	2.55a	2.74b	2.58a	2.74a	2.77a	2.73a	2.64b	2.67ab
390	2.73a	2.84a	2.92b	2.93a	2.92a	3.00a	2.69a	2.81a	2.86a

*Means for a tillage treatment in the same row followed by different letters are significant at x = .10, N = 4.

Table 9. Probability of treatment effects for selected variables at Becker, Minnesota, 1983.

Source	Variable						
	Grain Yield	Stoves Yield	Total Dry Matter	Grain N Uptake	Stoves N Uptake	Total N Uptake	Ear Leaf N
Rep	.0221	.0916	.0043	.1949	.0070	.0390	.6919
Tillage	.0238	.0974	.0299	.0297	.4245	.1280	.0387
N	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Till x N	.2514	.3431	.1288	.3693	.6172	.4807	.1763
Inhibitor	.0001	.0949	.0001	.0001	.0017	.0001	.0001
Till x Inhibitor	.3499	.2129	.0733	.3422	.0561	.2038	.3501
N x Inhibitor	.0001	.0067	.0001	.0001	.0738	.0001	.0001
Till x N x Inhibitor	.0657	.8389	.1591	.1685	.9733	.5801	.0850

Table 10. The effect of tillage, N rate, and nitrification inhibitor on yields at Becker, Minnesota, 1983.*

	No Till			Till Plant			Chisel			Moldboard		
N Rate	None	N-Serve	Dwell	None	N-Serve	Dwell	None	N-Serve	Dwell	None	N-Serve	Dwell
Kg/ha	Grain Mg/ha											
0	2.0			2.3			2.5			2.4		
85	3.3a	5.5b	5.4b	3.0a	4.7b	4.8b	3.6a	5.0b	6.7c	2.9a	4.6b	4.8b
170	5.5a	5.6a	6.7b	6.0a	6.5a	7.0a	7.4ab	6.9a	7.5b	6.3a	6.5a	6.5a
340	7.5a	7.0a	7.4a	8.4a	6.6b	7.5ab	8.0ab	7.9a	8.3b	7.7a	7.9a	8.2a
	Stover Mg/ha											
0	2.1			2.0			2.4			2.3		
85	4.2a	5.2ab	5.0b	3.3a	3.6a	3.4a	3.6a	4.2a	4.7a	3.5a	3.9a	3.6a
170	5.0a	4.6a	5.1a	4.1a	4.3ab	5.0b	5.2a	5.1a	6.3b	4.7a	4.7a	5.0a
340	6.0a	6.2a	5.9a	6.2a	5.1b	5.5ab	5.7a	5.9a	5.9a	6.2a	6.0a	5.7a
	Total Mg/ha											
0	4.1			4.3			4.9			4.7		
85	7.5a	10.6b	10.4b	6.3a	8.0ab	8.3b	7.2a	9.1b	11.9c	6.1a	8.6b	8.1b
170	10.5a	10.9ab	11.7b	10.2a	10.8ab	12.5b	13.0ab	12.5a	14.0b	11.0a	11.1a	11.6a
340	.2a .5a	13.0b	13.2ab	14.6a	11.4b	13.0ab	13.7a	13.7a	14.3a	13.9a	13.7a	13.9a

*Means for a tillage treatment in the same row followed by different letters are significant at X = .10, N = 4.

Table 11. The effect of tillage, N rate, and nitrification inhibitor on N uptake at Becker, Minnesota, 1983.*

	No Till			Till Plant			Chisel			Moldboard		
N Rate	None	N-Serve	Dwell	None	N-Serve	Dwell	None	N-Serve	Dwell	None	N-Serve	Dwell
Kg/ha	Grain N Uptake (Kg/ha)											
0	24.9			30.1			29.4			31.9		
85	40.9a	70.8b	74.7b	36.1a	61.0b	68.3b	48.5a	64.5b	87.1c	36.6a	60.5b	62.8b
170	70.5a	77.0a	96.7b	83.0a	91.6a	109 b	103 a	102 a	109 a	81.9a	87.1a	87.9a
340	116 a	116 a	118 a	128 a	104 b	111 ab	123 a	121 a	140 b	116 a	124 a	124 a
	Stover N uptake (Kg/ha)											
0	11.4			10.4			11.6			10.3		
85	17.9a	26.4b	25.4b	14.1a	17.4a	19.0a	16.1a	21.2a	25.5a	13.7a	19.2b	15.4a
170	27.9a	31.6a	31.5a	21.8a	27.1b	30.8a	25.7a	30.0a	40.0b	25.7a	26.7a	27.2a
340	38.5a	43.0a	39.6a	41.8a	36.7a	41.1a	36.4a	38.2a	42.3a	44.3a	37.4a	39.4a
	Total N uptake (Kg/ha)											
0	36.2			40.6			41.0			42.2		
85	58.8a	97.2b	100 b	50.2a	78.4b	87.3b	64.5a	85.7b	113 b	50.3a	79.8b	78.2b
170	98.3a	109 b	128 b	105 a	119 a	140 b	129 ab	132 a	149 b	108 a	114 a	115 a
340	156 a	159 a	158 a	170 a	141 b	152 ab	159 ab	159 a	182 b	160 a	161 a	164 a
	Ear leaf (% N)											
0	1.29			1.36			1.21			1.13		
85	1.60a	2.85b	3.01b	1.56a	2.28b	2.81b	1.80a	2.65b	2.81b	1.53a	2.29b	2.53b
170	2.51a	3.06b	3.07b	2.80a	2.95b	3.05b	2.90a	3.10a	3.05a	2.45a	2.71a	2.81b
340	3.17a	2.98a	2.98a	2.95a	3.11a	3.15b	2.89a	3.16a	3.04a	2.93a	3.02a	3.01a

*Means for a tillage treatment in the same row followed by different letters are significant at x - = .10, N = 4.

Figure 1. 1983 Precipitation at the Southeastern Minnesota site.

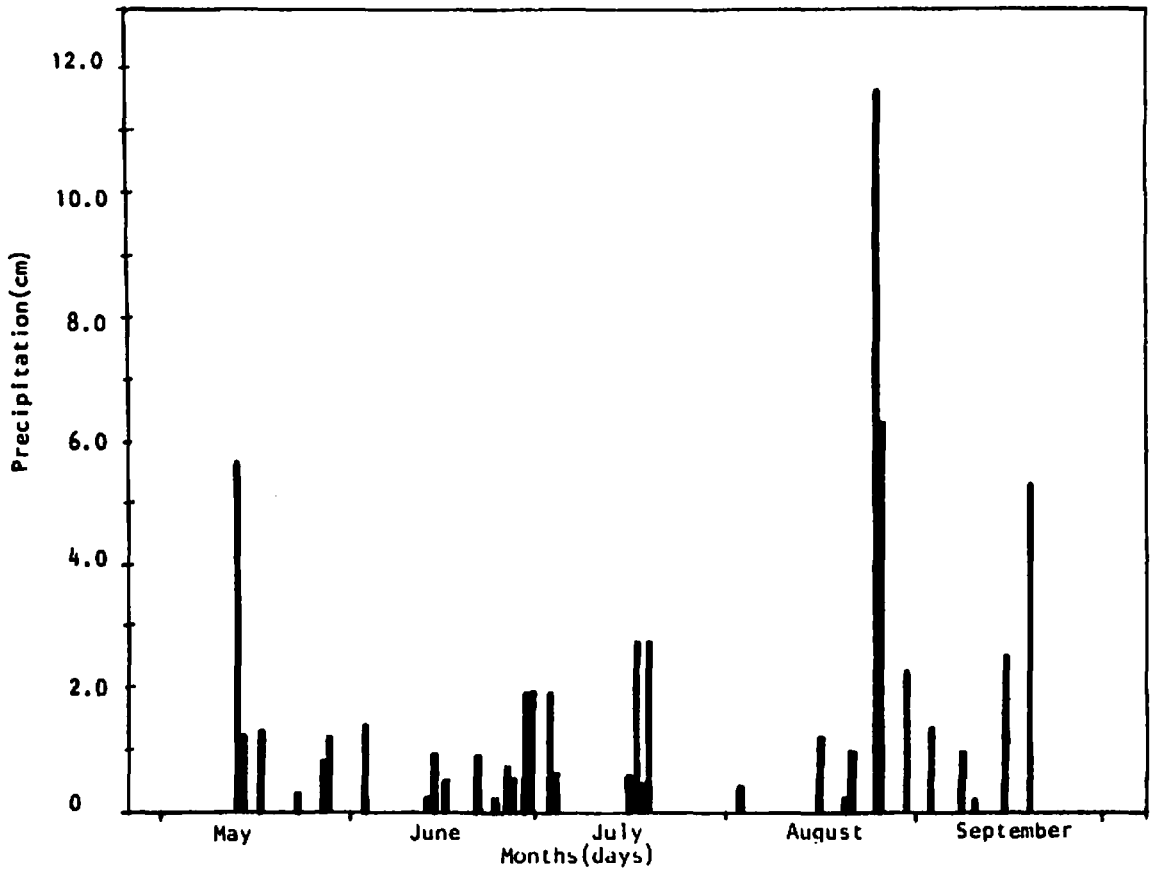
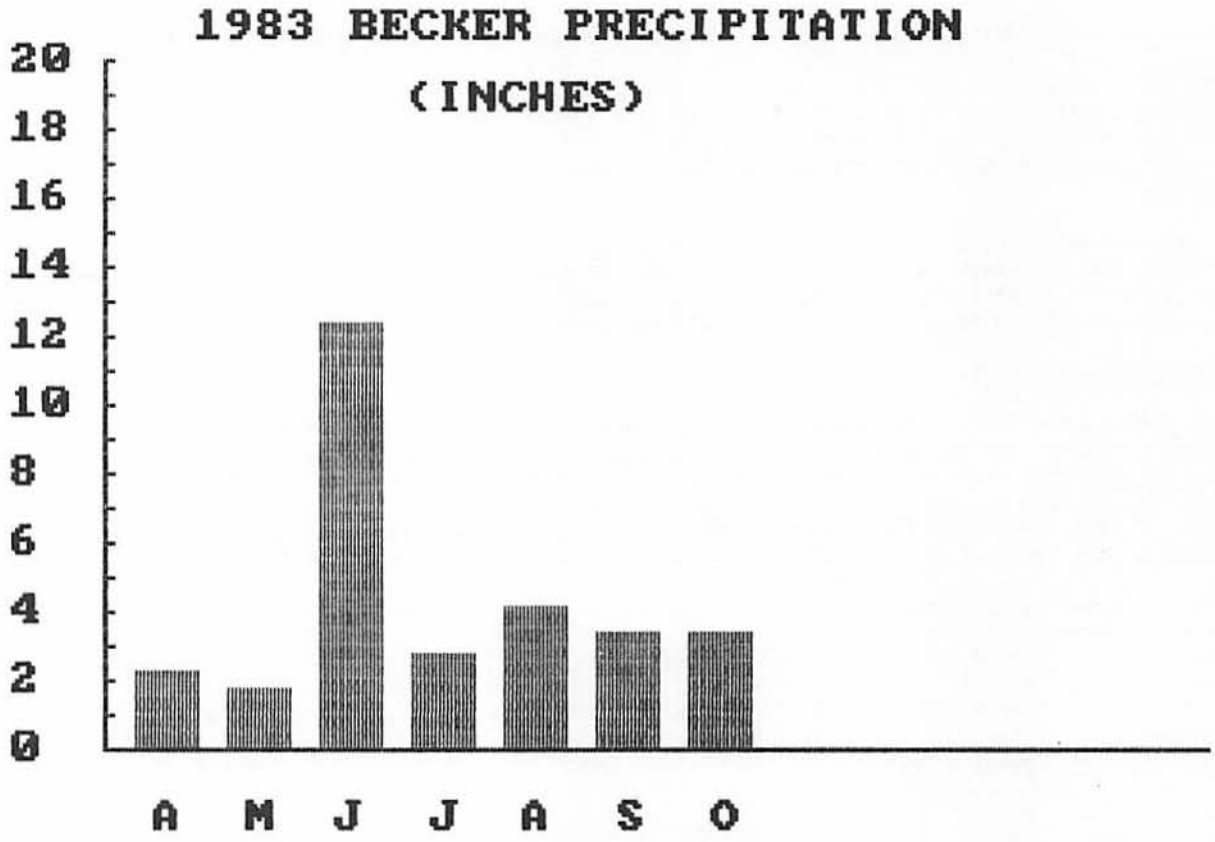


Figure 2.


1983 BECKER PRECIPITATION
(INCHES)
20
18
16
14
12
10
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2
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COMPARISON OF THREE PHOSPHORUS SOIL TEST PROCEDURES TO CROP YIELDS AND PLANT ANALYSIS DATA

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Several soil test methods for extractable phosphorus have evolved over the years. The Bray P-1 method, used at a 1:10 soil-solution ratio, was adopted by the University of Minnesota Soil Testing Laboratory for routine analysis in 1954. This method is especially well suited for assessing phosphorus availability in acid to neutral soils. The reliability of the P soil test on calcareous soils was greatly improved in 1975 by changing the soil-solution ratio from 1:10 to 1:50. In 1982 the Olsen sodium bicarbonate method of extracting soil phosphorus was introduced for soils having pH over 7.4.

The primary objective of this study was to determine the relationship between crop yield and plant tissue P, and the amounts of phosphorus extracted by the various soil testing methods. These experiments to establish guidelines for making fertilizer recommendations from soil tests have been conducted on private farms and at the Branch Experiment Stations since 1981.

EXPERIMENTAL PROCEDURE

Seven field experiments were established on calcareous soils in western Minnesota in 1981 to evaluate three P soil tests and their relationship to crop response from P additions. Wheat was grown on six sites and soybeans on the other. There were three additional sites in 1982, six in wheat, two in corn and one in soybeans. One additional trial from 1981 was lost due to flooding in 1982. In 1983 there were three wheat trials, one each of barley, corn and soybeans. Information on location, soil type, crop, and soil test levels of 1983 trials is given in Table 1.

Table 1. Cooperator, county, soil type, crop, and initial soil test results for 1983 trials.

Cooperator:	Crookston Stn.		Dahl Farm	Klassen Farm	Klenz Farm	Morris Stn.
County:	W. Polk		Norman	Swift	Martin	Stevens
Soil Series:	Hegne	Wheatville	Vallers	Colvin	Webster	Doland
Texture:	Sicl	Sil	Sil	Sicl	Cl	Sil
Crop:	Wheat	Wheat	Barley	Corn	Soybeans	Wheat
Soil pH:	8.0	8.2	8.3	8.0	7.7	7.8
Olsen P, lb/A:	20	15	17	6	10	6
Exch. K, lb/A:	314	322	302	387	295	263

The three soil tests compared were the Bray P-1 method using either 1:10 or 1:50 ratio of soil to extracting solution, and the Olsen bicarbonate method. The Bray P-1 tests are affected by high soil pH while the Olsen test is largely independent of pH. During 1981 and 1982 at several locations starter and no starter comparisons were made in addition to the four broadcast P treatments. In the 1983 trials, phosphorus fertilizer was broadcast except at the Morris Station where the broadcast P effects were compared with and without the starter fertilizer.

RESULTS AND DISCUSSION

Table 2a gives wheat and barley yields for 1982 and 1983, Table 2b gives plant tissue and soil test results for 1981, 1982 and 1983. Similar results for corn and soybeans are reported in Tables 3a and 3b. Plant analysis data for small grain, and for corn and soybeans are given in Tables 4 and 5, respectively.

Wheat

Hegne sicl, Crookston Stn., Olsen P 16 lb/A (fall 1982). The yield was increased by 5 bu/A with 30 lb. P_2O_5/A over the check. Very high P relative levels were indicated by the Bray P-1 method (1:10 and 1:50) on this soil. Extractable P levels by all three methods and plant tissue P were increased by broadcast fertilizer. Some infection from scab was observed.

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

Wheatville sil, Crookston Stn., Olsen P 10 lb/A (fall 1982). Phosphorus fertilization resulted in increased P soil test levels by the three methods but neither the yield nor tissue P of wheat were affected. Early dying of the head caused by the fungal disease scab was a problem on this field.

Doland sil, Morris Stn., Olsen P 5 lb/A (fall 1982). The yield was increased by 4 bu/A with starter fertilizer. Broadcast rates of phosphorus applied in 1982 were reflected in increased P% of plant tissue and higher soil test levels by all three methods. Although only main effects of phosphorus are reported in Table 2a, broadcast P increased the yield of wheat considerably. The yield of the true check (0 P, no starter, Olsen P 5 lb/A), for example, was 44 bu/A. On plots where the Olsen P level had been built up to 12 or 15 lb/A, the corresponding wheat yield was 58 bu/A.

Barley

Vallers sil, Dahl Farm, Olsen P 14 lb/A (spring 1983). Barley response to P fertilization was noted at heading. Increased phosphorus rates appeared to hasten plant development and resulted in increased growth and lodging. The yields of different treatments were not significantly different because of variability due to severe lodging. The percentage of plump kernels was increased by 13 with 30 lb. P_2O_5/A over the check. Plant tissue P and soil test P levels of the three methods were increased by P fertilization.

Corn

Colvin sicl, Klassen Farm, Olsen P 11 lb/A (fall 1982). Corn yield was increased in 1983 by 11 bu/A with 30 lb. P_2O_5/A applied in 1982 and 1983 and by 14 to 20 bu/A from carryover of 60 or 90 lb. P_2O_5/A applied in 1982. Olsen P test levels of samples collected in fall of 1982 were increased from 11 to 20 lb/A by the application of 60 or 90 lb. P_2O_5/A applied in the spring.

Bray P-1, 1:10 test levels were extremely low and were not changed by fertilization. It is suspected that this Colvin sicl has a relatively high total carbonate content, predominantly as calcite ($CaCO_3$); carbonates of the other soil in this study probably are mainly dolomitic ($CaCO_3$ and $MgCO_3$). These assumptions are based mainly on the trends observed in Bray P-1, 1:10 and 1:50 test levels as affected by P fertilization. The Bray P-1, 1:50 test results were considerably higher than those obtained by using 1:10 ratio, and at higher rates reflected the carryover of P fertilizer.

Soybeans

Webster cl, Klenz Farm, Olsen P 13 lb/A (spring 1983). Phosphorus fertilization increased soybean yield by 5 bu/A and increased P levels of all three soil tests but did not significantly affect the P% of leaf tissue. No yield increase beyond the 30 lb. P_2O_5/A rate occurred.

In some instances the concentrations of Cu, Fe, Mn and Zn were significantly lowered by fertilization with phosphorus (Tables 4 and 5). But for Zn, Mn and Fe they were above the critical level even at the lowest concentration. Copper concentration of plant tissue from several locations was below 5 ppm, considered to be the critical level for small grain and corn. This may not be of practical significance, however, because copper deficiencies have not been observed on mineral soils of Minnesota.

Table 2a. Wheat and barley yields at 13% moisture and plumpness of barley kernels as affected by phosphorus fertilization in 1982 and 1983.

Treatment	Location									
Broadcast	Crookston Stn.				Morris Stn.			Dahl Farm		
P_2O_5	Hegne Wheat		Wheatville Wheat		Wheat			Wheat	Barley	
	1982	1983	1982	1983	1981	1982	1983	1982	1983	
Lb/acre	Bu/acre									plump kernels %
0	51	54	53	43	63	61	51	58	57	45.2
30[1/]	46	58	55	49	64	65	57	62	65	58.2
60	48	51	57	42	64	68	59	61	69	57.5
90	46	54	55	46	64	69	59	59	64	60.5
Significance	ns	+	ns	ns	ns	*	**	ns	ns	+
BLSD (0.05)		5								13.1
Starter	-	-	-	-	64	68	58			
No Starter	-	-	-	-	64	64	54			
Significance					ns	*	*			

[1/] P rates as indicated were broadcast in 1982; at Morris Station only 30 lb. rate was spread in 1983, yields from P carryover on 60 and 90 treatment plots.

Table 2b. Phosphorus concentration of entire wheat and barley plant at boot stage and relationship to P treatment and soil test.[1/]

Treatment	Location								
Broadcast	Crookston Stn.				Morris Stn.[2/]			Dahl Farm	
P_2O_5	Hegne Wheat		Wheatville Wheat		Wheat			Wheat	Barley
	1982	1983	1982	1983	1981	1982	1983	1982	1983
Lb/acre	Plant Tissue P %								
0	.30	.32	.28	.30	.16	.22	.27	.27	.27
30	.30	.33	.26	.30	.18	.26	.32	.28	.31
60	.30	.33	.28	.32	.18	.29	.32	.29	.33
90	.31	.34	.28	.33	.20	.31	.34	.29	.36
Significance	ns	*	+	ns	ns	**	*	ns	*
BLSD (0.05)		.01					.04		.06
	Bray 1 1:10 P lb/A								
0	54	34	16	10	15	10	7	23	12
30	-	45	-	13		18	12	-	16
60	-	46	-	22		23	17	-	22
90	-	52	-	28		33	19	-	22
	Bray 1 1:50 P lb/A								
0	84	81	60	54	21	12	38	57	45
30	-	96	-	54		23	34	-	46
60	-	101	-	72		25	42	-	64
90	-	111	-	70		33	48	-	66
	Olsen P lb/A								
0	20	16	15	10	11	6	5	17	14
30	-	22	-	10		13	9	-	15
60	-	24	-	16		15	12	-	19
90	-	30	-	18		23	15	-	21

1/ 1982 Crookston and Dahl trials were sampled in spring of 1982 prior to treatment, Morris sampled fall 1981.

1983 Crookston and Morris trials were sampled in fall of 1982, Dahl sampled in spring of 1983 prior to fertilization.

All soil test results are means of four replications.

2/ Plant and soil samples of Morris trial were collected from no starter plots.

Table 3a. Corn and soybean yields as affected by broadcast phosphorus fertilization in 1982 and 1983.

Treatment	Location				
Broadcast	Klassen		Klenz		
P_2O_5	Corn 1982	Corn 1983	Soybeans 1981	Corn 1982	Soybeans 1983
Lb/acre	Bu/acre				
0	164	98	49	162	43
30[1/]	160	109	51	172	48
60	165	112	51	172	48
90	173	118	52	167	48
Significance	ns	*	ns	ns	+
BLSD (0.05)		12			5

[1/] P rates as indicated were broadcast in 1982; in 1983, only the 30 lb. rate was spread, yields from P carryover on others.

Table 3b. Phosphorus concentration of ear leaf of corn at silking and upper mature trifoliate leaves of soybeans at initial flowering and relationship to P treatment and soil test.[1/]

Treatment	Location				
Broadcast	Klassen		Klenz		
P_2O_5	Corn 1982	Corn 1983	Soybeans 1981	Corn 1982	Soybeans 1983
Lb/acre	Plant Tissue P %				
0	.27	.20	.35	.26	.37
30[2/]	.27	.21	.41	.29	.42
60	.29	.22	.40	.30	.45
90	.30	.22	.40	.30	.43
Significance	ns	*	+	**	ns
BLSD (0.05)		.01		.01	
	Bray 1 1:10 P lb/A				
0	6	2	18	13	13
30[2/]	4	2		18	19
60	7	4		21	24
90	5	2		27	24
	Bray 1 1:50 P lb/A				
0	15	31	36	33	49
30[2/]	14	22		36	61
60	15	38		39	78
90	15	44		46	84
	Olsen P lb/A				
0	16	11	15	10	13
30[2/]	17	12		12	17
60	17	20		14	22
90	18	20		19	24

[1/] 1982 trials were sampled in fall of 1981.

1983 Klassen trial was sampled in fall of 1982, Klenz trial was sampled in spring of 1983 prior to fertilizer application.

All soil test results are means of four replications.

[2/] P rates as indicated were broadcast in 1982; in 1983, only the 30 lb. rate was spread, results from P carryover on others.

Table 4. Plant analysis data for wheat at Crookston Stn. and Morris Stn., and barley at Dahl Farm, 1983.

Treatment		Plant Nutrient								
P_2O_5	Yield	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
Lb/A	Bu/A	----------%----------				----------ppm----------				
		Crookston Stn., Hegne, Wheat - whole plant at boot stage								
0	54	.32	3.08	.28	.24	68	44	24	7	4
30	58	.33	3.01	.30	.26	67	49	21	7	4
60	51	.33	3.05	.31	.24	72	44	19	7	4
90	54	.34	2.87	.29	.24	64	45	18	6	4
Significance	+	*	ns	ns	ns	ns	ns	*	ns	ns
BLSD (0.05)	5	.01						3		
		Crookston Stn., Wheatville, Wheat - whole plant at boot stage								
0	43	.30	3.15	.27	.23	67	52	33	3	6
30	49	.30	3.03	.24	.21	60	48	29	3	5
60	42	.32	2.83	.21	.20	53	46	23	2	5
90	46	.33	2.86	.23	.18	52	42	21	2	4
Significance	ns	ns	ns	ns	ns	**	+	**	*	*
BLSD (0.05)						8	8	3	.8	.1
		Morris Stn., Wheat - whole plant at boot stage								
0	51	.27	2.78	.32	.21	102	59	28	3	4
30	57	.32	2.59	.32	.22	75	64	21	2	4
60	59	.32	2.63	.34	.23	92	63	21	2	4
90	59	.34	2.66	.38	.24	94	70	20	2	4
Significance		*	ns	ns	ns	ns	ns	*	ns	ns
BLSD (0.05)		.04						5		
		Dahl Farm, Barley - whole plant at boot stage								
0	57	.27	3.32	.44	.29	48	48	29	6	6
30	65	.31	3.13	.51	.27	104	46	28	5	6
60	69	.33	2.85	.48	.33	55	44	22	4	6
90	64	.36	2.83	.49	.31	60	39	25	4	6
Significance	ns	*	ns	ns	ns	+	ns	*	*	ns
BLSD (0.05)		.06						4	2	

Table 5. Plant analysis data for corn at Klassen Farm, and soybeans at Klenz Farm, 1983.

Treatment		Plant Nutrient								
P_2O_5	Yield	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
Lb/A	Bu/A	----------%----------				----------ppm----------				
		Klassen Farm, Corn, whole plant - 8th leaf stage								
0		.28	3.52	1.20	.70	1705	136	42	10	12
30[1/]		.26	3.37	1.36	.75	1783	137	38	9	13
60		.28	3.46	1.28	.73	1688	136	40	10	13
90		.26	3.38	1.46	.74	1861	140	40	9	12
Significance		ns	ns	ns	ns	ns	ns	ns	**	ns
BLSD (0.05)									0.7	
		Klassen Farm, Corn, ear leaf at tasseling								
0	98	.20	1.70	.35	.33	78	68	16	3	9
30[1/]	109	.21	1.81	.38	.36	74	70	16	3	8
60	112	.22	1.75	.36	.36	78	71	17	3	8
90	118	.22	1.66	.40	.34	79	68	15	3	8
Significance	*	*	ns	ns	ns	ns	ns	ns	ns	ns
BLSD (0.05)	12	.01								
		Klenz Farm, Soybeans, leaves at initial flowering								
0	43	.37	2.53	1.26	.50	208	80	34	11	49
30[1/]	48	.42	2.49	1.24	.51	180	84	31	10	50
60	48	.45	2.46	1.19	.50	174	82	34	10	49
90	48	.43	2.51	1.22	.50	193	92	31	10	50
Significance	+	ns	ns	ns	ns	ns	ns	ns	ns	ns
BLSD (0.05)	5									

[1/] Indicated P rates were broadcast in 1982; in 1983 only the 30 lb. rate was spread, results from P carryover on others.

MICRONUTRIENTS AND RELATIONSHIP TO MICRONUTRIENT SOIL TESTS

W. E. Fenster and G. W. Rehm

The micronutrient study was initiated in 1981. Three of the original 6 locations were discontinued for various reasons in 1982 and the three that were continued were planted to soybeans, in 1983 one of these was planted to snap beans the other two were in corn.

Even though micronutrients for agriculture have been in use for a long time, little or no research has been done to relate soil tests of these elements to their response in the field. Sulfur and magnesium, even though not micronutrients, were also included as a variable.

The "missing element" technique was used whereby a series of plots each having one of the nutrients omitted were compared to a treatment with all elements included. This design prevented other nutrients from being limiting factors if there was possible interaction. Only one rate of each element was used. Since most of the added nutrients were in the sulfate form the sulfur comparisons were established by themselves on an adjacent area. A boron trial, in addition to being included in the main experiment, was established on an adjacent area in order to have four levels of boron compared. Nitrogen, phosphorus and potassium were applied at or above adequate amounts. All plots were replicated four times.

Yields and Plant Analysis

Tables 1 through 5 show the 1981, 1982 and 1983 results. No significant yield increases were obtained but it is apparent that nutrient content in the leaves are increased by treatments (Tables 1 and 3).

Soil Testing

There has been fine cooperation of private laboratories in testing soils from these plots. The Harris Laboratory at Lincoln, Nebraska, the A & L Laboratories at Omaha, Nebraska and Minnesota Valley Testing at New Ulm, Minnesota, have run soil analysis from all plots which will in final summary contribute a large volume of useful data.

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The efforts of Mike O'Leary and Greg Buzicky in arranging details of securing, weighing and packaging materials is gratefully acknowledged. Also Todd King, and Negussie Berihun helped make the results shown here possible. Also thanks go to Brian Schreiber, Bob Olson, and Floyd Bellin for their efforts with farm cooperators.

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

Table 1. Corn, soybean and snap bean yields, plant boron, and soil test boron from four levels of boron applications. 1981, 1982, & 1983.

Jokela Farm - Goodhue Co. non-irrigated
Mt. Carroll silt loam

lbs B/A	yield bu/A 1/			ppm B 1/ leaf			soil test - ppm hot H_2O		
	1981 Corn	1982 Soybeans	1983 Corn	1981 Corn	1982 Soybeans	1983 Corn	1981	1982	1983
0	170	49	127	4	38	8	0.6	0.8	0.7
1	178	42	124	5	44	9		1.1	1.2
2	175	47	128	5	51	10		1.5	1.7
4 2/	174	42	131	7	61	12		2.5	2.2
significance	ns	+	ns	ns					
BLSD (.10)		5							
C.V.	3.7	7.2	7.7	9.8					

Kingston Farm - Dakota Co. - irrigated
loamy sand

lbs B/A	Yield 1/ Bu/A		lb/A	ppm B 1/ leaf			soil test - ppm hot H_2O		
	1981 Corn	1982 Soybeans	1983 Snap beans	1981 Corn	1982 Soybeans	1983 Snap beans	1981	1982	1983
0	155	36	12,440	7	43	21	0.25	0.2	0.2
1	159	34	13,855	8	52	48		0.3	0.3
2	147	32	12,472	12	67	72		0.5	0.8
4 2/	160	27	13,728	18	112	60		0.9	1.4
significance	ns	**	ns	**					
BLSD (.05)		4		3.5					
C.V.	5.0	82	33	21.9					

Geiger Farm - Morrison Co. - irrigated, discontinued after 1981.
loamy sand

lbs B/A	yield bu/A 1/	ppm B 1/ leaf	soil test - ppm hot H_2O
	1981 Corn	1981 Corn	1981
0	92	4.1	0.09
1	87	6.7	
2	90	10.9	
4	90	13.7	
significance	ns	**	
BLSD (.05)		3.4	
C.V.	11.7	28.8	

1/ Average of 4 replications, where statistics are shown.

2/ Four lb. rate not applied 1983

Table 2. Yields[1/] in three counties comparing complete treatments of micronutrients plus Magnesium to plots using missing element techniques. 1981, 1982, 1983.

Treatment [2/] omitted (-) added (+)	Martin Yield [4/] 1981	1982	1983	Goodhue Yield [4/] 1981	1982	1983	Dakota [3/] Yield [4/] 1981	1982	1983
None	179	56	143	173	47	130	156	33	12,185
-Mg	181	51	144	169	43	124	160	35	14,814
-Zn	181	52	145	175	45	129	159	33	16,044
-Fe	182	53	148	174	44	130	151	34	15,036
-Mn	180	54	148	174	43	124	159	34	12,814
-B	178	52	148	177	44	128	152	34	14,596
-Cu	178	52	146	170	45	131	157	33	16,676
+ complete includes S	184	54	141	169	47	129	156	33	16,246
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns
C.V.	4.9	5.0	6.7	5.5	6.3	4.5	5.6	7.8	27.2

[1/] average of 4 repplications

[2/] pounds per acre of nutrient added Mg=50, Zn=10, Fe=10, Mn=10, B=1, Cu=5 in 1981 and 1982, residual only in 1983.

[3/] irrigated sandy loam, other two counties fine textured non-irrigated soils.

[4/] corn in 1981 and 1983 except snap beans at Dakota Co. site. Soybeans grown in 1982 at all sites.

Table 3. Plant analysis [1/] from micronutrient and magnesium treatments in trials at three counties. 1981, 1982, 1983.

Treatment [2/] omitted (-) added (+)	Martin (ppm except Mg which is %) (-) 81	82	83	(+) 81	82	83	Goodhue [4/] (-) 81	82	83	(+) 81	82	83	Dakota [3/] (-) 81	82	83	(+) 81	82	83
Mg	.58	.48	.45	.58	.42	.53	.36	.46	.38	.38	.43	.36	.27	.43	.52	.27	.49	.50
Zn	21	42	14	24	48	20	35	42	30	40	46	37	29	45	25	34	47	27
Fe	93	113	100	97	131	99	113	104	128	109	99	126	120	84	94	117	92	94
Mn	56	61	46	61	97	57	59	44	66	60	44	62	76	63	54	77	58	60
B	5	50	8	5	50	7	6	41	6	7	44	6	5	39	24	9	54	40
Cu	3	10	3	3	11	3	11	5	5	6	0	6	10	10	8	10	10	8

[1/] average of 4 replications from leaf opposite and below ear at silking time.

[2/] symbol + is from treatment of all nutrients. Pounds of nutrients added Mg=50, Zn=10, Mn=10, B=1, Cu=5, in 1981 and 1982. Residual in 1983.

[3/] irrigated sandy loam, others textured non-irrigated soils.

[4/] corn in 1981 and 1983 except sonapbeans at Dakota Co. site. Soybeans in 1982 at all sites.

Table 4. Yields, [1/] plant sulfur and soil test sulfur with and without sulfur treatments in three counties. 1981, 1982, and 1983.

Sulfur Treatment	Yield (bu/A)			Ear Leaf (% S)			U of M Soil Test (PPM S)		
	1981	1982	1983	1981	1982	1983	1981	1982	1983
				Martin Co.					
None	183	54	144	.23	.31	.20	16	1	6
50#/A	180	53	152	.29	.31	.22	--	--	5
Significance	ns	ns	ns						
				Goodhue Co.					
None	181	44	129	.24	.32	.23	16	10	3
50#/A	179	43	130	.27	.35	.27	--	19	5
Significance	ns	ns	ns						
				Dakota [2/]					
None	151	33	15966	.24	.28	.21	6	1	6
50#/A	154	34	14493	.25	.30	.21	--	2	6
Significance	ns	ns	ns						

[1/] average of 4 replications, corn at 3 sites 1981, soybeans in 1982, corn in 1983 except snap beans in Dakota Co.

[2/] Irrigated sandy loam soil, other two counties are fine textured non-irrigated soils

Table 5. Soil test means for micronutrients. University of Minnesota Lab. 1981, 1982, and 1983.

Treatment 1/ omitted (-) added (+)	Martin					Goodhue					Dakota				
	(ppm except Mg which is lbs/A)														
		(-)		(+)			(-)		(+)			(-)		(+)	
	1981	1982	1983	1982	1983	1981	1982	1983	1982	1983	1981	1982	1983	1982	1983
Mg	881	990	1124	970	1096	579	495	641	595	722	312	295	317	364	435
Zn	1.0	1.2	2.2	2.3	5.4	2.0	4.8	3.4	8.0	8.9	1.0	1.4	1.4	4.2	6.2
Fe	21	42	25	26	24	55	76	70	90	66	41	78	56	80	48
Mn	41	40	22	40	17	31	30	18	30	17	21	19	10	18	8
B	1.20	2.1	2.2	1.8	2.4	.60	1.0	0.8	3.2	1.7	.25	2.2	0.4	2.4	0.9
Cu	1.28	1.8	1.7	2.5	3.0	0.75	1.5	1.5	4.0	3.8	0.48	0.6	0.9	3.1	3.4

1/ 1981 soil test results before treatment applied, 1982 from treatment plots in 1981 and 1983 from treatment plots in 1981 and 1982.

FIELD TRIALS WITH "BASIC-H" 1983

W. E. Fenster and G. W. Rehm

The effects of the wetting agent "Basic-H" were studied at several experimental farms and by growing various crops. This product is not marketed as a plant food but meant to improve water penetration and thus better water use efficiency.

Plots were established on fine textured, clay loam soils of high organic matter at Waseca, and Lamberton. The trials at the Morris station were on silt loam soils. The experiments conducted at Crookston were on high organic matter soils, the sugarbeet trial on a loam soil, the sunflower trial on a fine sandy loam soil. The trials at Becker were on very well drained loamy sands with low organic matter and were conducted under irrigation.

Under the weather conditions of 1983 which were below normal in rainfall in most areas no benefits were obtained by the use of the wetting agent except from one treatment on wheat at the Morris station.

Trials at the Waseca and Lamberton stations were conducted by G. W. Randall, W. W. Nelson, and W. E. Fenster. Table 1 gives results of Basic-H on corn.

Table 1. Effects of Basic-H on corn yields, moisture at harvest and plant population at Waseca and Lamberton experiment stations 1983.

	Yield (Bu/A)		Moist (%)		Pop. (x 1000)
	Waseca	Lamberton	Waseca	Lamberton	Waseca
Control	56	62	21.6	23.2	27.1
Fertilizer (U of M recommendation)*	121	85	20.5	21.7	27.0
Fertilizer + Basic-H (1 gal./A)	111	87	20.4	22.1	27.6
Fertilizer + Basic-H (2 gal./A)	117	87	20.6	21.4	26.3
Basic-H only (1 gal./A)	53	54	21.8	23.1	26.8
Significance	**	**	**	ns	ns
BLSD (.05)	9.8	13.9	.6	--	--
C.V.	7.6	9.0	.8	4.2	4.9

*Fertilizer recommended	N	P_2O_5	K_2O
Waseca lbs/A	175	50	150
Lamberton lbs/A	150	60	60

*This research partially funded by the Shaklee Corporation.

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

In table 1b results at Waseca of another wetting agent "Amway Spray Adjuvant" are shown.

Table 1b. Effects of Amway Spray Adjuvant on corn yield, moisture at harvest and plant population, Waseca, MN 1983.

	Yield (Bu/A)	Moist %	Population (1000)
Control	56	21.6	27.1
Fertilizer (U of M recommendation)*	121	20.5	27.0
Fertilizer + Amway (1 gal./A)	115	20.4	27.2
Fertilizer + Amway (2 gal./A)	114	20.4	27.6
Amway only (1 gal./A)	50	21.8	26.6
Significance	**	**	ns
BLSD (.05)	8.4	.8	--
C.V.	6.6	1.1	4.3
*Fertilizer recommended	N	P_2O_5	K_2O
lbs./A	175	50	150

Results from trials with "Basic-H" at the Morris station on wheat conducted by S. D. Evans and W. E. Fenster are shown in Table 2.

Table 2. Effects of Basic-H on wheat yields and moisture at harvest time. Morris, MN 1983.

	Yield (Bu/A)	Moist (%)
Control	41	13.2
Fertilizer (U of M recommendation)*	55	12.2
Fertilizer + Basic-H (1 gal./A)	59	13.8
Fertilizer + Basic-H (2 gal./A)	56	13.9
Basic-H only (1 gal./A)	46	13.0
Significance	**	ns
BLSD (0.5)	4.5	--
C.V.	6.1	2.8

*Fertilizer recommended	N	P_2O_5	K_2O
lbs/A	50	0	0

"Basic-H" effects on sunflower production were conducted at the Crookston station by G. E. Varvel and W. E. Fenster. Table 3 shows the sunflower yields, oil content and corresponding population to treatment.

Table 3. Effects of Basic-H on sunflower yield, oil content and plant population. Crookston, MN 1983.

	Seed Yield (lbs/A)	Oil %	Pop. (x 1000)
Control	964	37.5	20.9
Fertilizer (U of M recommendation)*	1180	38.0	21.3
Fertilizer + Basic-H (1 gal./A)	1192	37.4	22.5
Fertilizer + Basic-H (2 gal./A)	1169	37.1	22.4
Basic-H only (1 gal./A)	996	37.8	20.9
Significance	ns	ns	ns
C.V.	11.4	3.4	7.8
*Fertilizer recommendation	N	P_2O_5	K_2O
lbs/A	90	50	100

"Basic-H" effects on sugar beet production were conducted at the Northwest Experiment Station in Crookston by L. J. Smith and W. E. Fenster. "Basic-H" is sold or labeled as a concentrated soil conditioner and makes no claim to being a plant food product. Major claims made by the manufacturer are that the product, when properly applied, increases the rate at which water penetrates the soil, makes water wetter thereby overcoming water repellancy, and promotes maximum water utilization by reducing runoff and loss by evaporation.

Procedure

Great Western R-2 sugarbeet seed was planted in a Wheatville loam soil on April 29, 1983. The soil before treatment tested NO_3-N - 32 lb/A, $NaHCO_3$P - 9 lb/A, and exchangeable K - 150 lb/A. The fertilizer and "Basic-H" treatments listed in Table 1 were applied on April 29. The "Basic-H" treatments were applied with a bicycle sprayer at a volume of 44 gpa of solution and a pressure of 40 psi. All treatments were thinned to a uniform population of 32,000 plants/A on June 6. The trial was harvested September 19 and the quality factors determined at the American Crystal Sugar Co-op Quality Laboratory.

RoNeet (4.0 lb/A) and Avadex (1.5 lb/A) were used for weed control, Counter insecticide (1.0 lb. ai/A) was furrow applied for sugarbeet maggot control and Mertect plus Duter (12 oz/A + 20 oz/A) was applied for cercospora leaf spot control.

The experiment design was randomized complete block with four replications.

Results and Discussion

The treatments in this trial had nonsignificant effects on all variables measured except % sugar recovery, the impurity index, and the impurity amino nitrogen (Table 4). The % sugar recovery with the control plus "Basic-H' treatment was significantly higher than the normal fertilizer and normal fertilizer plus "Basic-H" treatments, but was not significantly different from the control. The amino nitrogen

impurities were significantly higher for all treatments involving normal fertilization and explains the differences noted in % sugar recovery and the imputiry index.

No differences in the degree of plant wilting was noted for any of the treatments during August when moisture was limited.

Table 4. Effects of "Basic-H" on sugarbeet yield

Treatment	Fertilizer lb/A	Basic-H Gal/A	Yield T/A	Sugar %	Recoverable Sugar lb/A	%	lb/T	Impurities, ppm Na	K	Amino Nitrogen	Impurity Index
Control	--	--	21.5	13.80	5228	88.1	243.1	425	2217	415	795
Normal Fert.	90 N, 80 P_2O_5 80 K_2O	--	23.1	13.67	5456	86.4	236.3	495	1962	607	907
Control + Basic-H	--	1	21.2	13.95	5255	89.0	248.2	395	2065	390	734
Normal Fert. + Basic-H	90 N, 80 P_2O_5 80 K_2O	1	23.2	13.92	5572	86.1	239.9	457	2070	642	926
Normal Fert. + 2x Basic-H	90 N, 80 P_2O_5 80 K_2O	2	23.2	13.98	5636	86.7	242.4	355	2012	642	887
Statistical Significance			ns	ns	ns	**	ns	ns	ns	**	**
B.L.S.D. (.05)			--	--	--	1.7	--	--	--	110	111

The effect of "Basic-H" was studied on potatoes at an experimental field under irrigation at Becker. Data by W. E. Fenster and Michael O'Leary are shown in table 5.

Table 5. The effect of "Basic-H" on potato yield. Becker, MN 1983.

	Yield (Wt/A)	Grading % Composition by Weight (oz.) 0-3	3-6	6-9	9-12	12-16
Control	334	18.5	39.8	33.8	8.0	--
Fertilizer (U of M recommendation)*	460	9.0	37.0	34.0	9.8	10.1
Fertilizer + Basic-H (1 gal./A)	446	12.0	32.6	37.9	11.2	6.1
Fertilizer + Basic-H (2 gal./A)	424	13.8	27.6	31.2	16.9	10.4
Basic-H only (1 gal./A)	318	10.3	45.8	35.2	8.7	--
Significance	**					
BLSD (.05)	98					
C.V.	11.0					

*Fertilizer recommendation	N	P_2O_5	K_2O	S
lbs/A	150 (split) 3 times	150	400	15

SULFUR, BORON AND MAGNESIUM TRIALS ON A PROBLEM ALFALFA FIELD 1983

W. E. Fenster, M. O'Leary and G. Buzicky

Yields of irrigated alfalfa on sandy loam soils have been unsatisfactory at some locations in Stearns County. This led to the establishment of a trial with sulfur, boron and magnesium where phosphorus and potassium were maintained at very high levels. These trials were on the Eugene Heinen farm. The plot location was changed in 1983 but still on the same field.

Tables 1 and 2 show alfalfa yields, related soil tests and plant analysis resulting from sulfur, boron, copper, and magnesium treatments.

In 1982 plant analysis shows below adequate levels of copper and magnesium. Copper was therefore added for 1983.

There was no significant effect of sulfur, magnesium or boron treatments on yield in 1982. In plant analysis, except for sulfur at the second cutting, the concentration of nutrients in the upper third of alfalfa plants was not affected by treatments.

In 1982 the alfalfa stands were good but growth appeared to be less than expected. First cutting yields in 1982 were below the other two cutting yields because irrigation was not possible for the first cutting. In 1983 alfalfa yields were reasonably good on the new location but there appeared to be no yield benefit from treatments. Additions of copper and magnesium failed to increase nutrient content in plants to adequate levels for none of the three cuttings, see table 2.

Table 1. Alfalfa yields relationship to sulfur, boron, copper and magnesium treatments. Stearns County 1982, 1983.

	lbs/A		Tons/acre Total		Soil Test		
Treatment	1982	1983	1982	1983		1982	1983
Check			3.62	5.35	Text	SL	SL
S	100	50	3.85	5.27	O.M.	M	M
B	3	3	3.71	5.11	pH	7.3	7.2
Mg	300	300	3.94	5.04	p lb/A	200+	200+
Cu	--	6	--	5.47	K lb/A	443	410
Significance			ns	ns	Mg lb/A	204	201
C.V.			4.4	4.4	S ppm	5	2
					Cu ppm	--	0.6
					B ppm	--	0.5
					Zn ppm	--	4.5

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Table 2. Plant analysis of alfalfa for three individual cuttings related to S, B, Mg and Cu treatments 1983.

First Cut		S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
Trt.	lbs/A	%					ppm				
Check		.34	.46	2.58	2.15	.24	144	72	35	4	36
S	50	.41	.46	2.62	2.22	.25	144	76	38	4	38
B	3		.47	2.59	2.13	.25	143	72	36	4	70
Mg	100		.46	2.62	2.24	.26	150	84	36	4	38
Cu	6		.47	2.62	2.12	.24	148	73	37	4	40
Adequage levels		.30	.25	2.40	1.70	.30	30	30	20	10	30
Significance		*	ns	ns	ns	ns	ns	ns	ns	ns	**
BLSD (.05)			--	--	--	--	--	--	--	--	6
C.V.			3.1	6.5	3.6	3.9	9.0	10.9	5.4	9.8	8.8
Second Cut											
Check		.35	.41	3.00	1.60	.25	111	46	26	4	43
S	50	.41	.42	3.15	1.65	.26	103	45	28	4	42
B	3		.42	3.03	1.68	.25	110	51	27	4	62
Mg	300		.41	2.88	1.68	.27	111	50	28	4	44
Cu	6		.42	3.00	1.62	.26	110	46	28	4	46
Adequate levels		.30	.25	2.40	1.70	.30	30	30	20	10	30
Significance		ns	ns	ns	ns	ns	ns	ns	ns	ns	**
BLSD (.05)		--	--	--	--	--	--	--	--	--	3
C.V.			2.8	4.5	3.8	3.6	4.8	7.2	3.3	9.3	5.2
Third Cut											
Check		.30	.36	2.74	1.65	.20	64	35	22	4	40
S	50	.29	.38	2.72	1.70	.20	67	37	22	4	40
B	3		.38	2.76	1.68	.19	64	35	22	4	53
Mg	300		.38	2.81	1.68	.20	64	35	22	4	41
Cu	6		.38	2.79	1.67	.19	68	36	23	4	44
Adequate levels		.30	.25	2.40	1.70	.30	30	30	20	10	30
Significance		ns	ns	ns	ns	ns	**	ns	ns	ns	**
BLSD (.05)		--	--	--	--	--	3	--	--	--	2
C.V.			5.1	4.6	2.9	5.2	2.5	5.2	7.2	15.2	3.9

HIGH PHOSPHORUS AND POTASSIUM RATES IN A CORN-SOYBEAN ROTATION

Waseca, 1983

G.W. Randall, S.D. Evans, W.W. Nelson and D.T. Walters

EXPERIMENTAL PROCEDURES

Ten P and K treatments (Table 1) were applied at three branch experiment stations (Southern Experiment Station, Waseca; Southwest Experiment Station, Lamberton; and West Central Experiment Station, Morris) in Minnesota. A randomized, complete-block design with four replications was used. The 50-pound rates were estimated to be "maintenance" rates, and the 0, 100 and 150-pound rates provide the response curves for each element. Treatments 5 and 8 receive P and K, respectively, every third year for the duration of the experiment. Treatments 9 and 10, applied in the fall of 1973, did not receive P and K again until the fall of 1978 when the treatments were resumed at Waseca because P appeared to be limiting. These two treatments were resumed at Morris in 1979 for the same reason. All other treatments have been applied annually. In 1982, soybeans were planted at Morris and Waseca after 8 years of continuous corn to begin a long-term corn-soybean rotation phase of this experiment.

Table 1. Phosphorus and potassium treatments applied in the high P and K rate study in Minnesota.

Trt. No.	Application Year (Fall) 1973,'76,'79,'82	1974,'75,'77,'78,'80,'81
	lb P_2O_5 + K_2O/A	
1	0 + 0	0 + 0
2	0 + 100	0 + 100
3	50 + 100	50 + 100
4	100 + 100	100 + 100
5	150 + 100	0 + 100
6	100 + 0	100 + 0
7	100 + 50	100 + 50
8	100 + 150	100 + 0
9 1/	150 2/ + 100	0 + 100 3/ 5/
10 1/	100 + 150 2/	100 + 0 4/ 6/

1/ Neither P nor K was applied in 1976.

2/ The 150-lb rate was not applied at Lamberton or Waseca in 1979 but was applied at Morris.

3/ 150 + 100 applied at Waseca in 1978.

4/ 100 + 150 applied at Waseca in 1978.

5/ 0 + 100 was applied at all locations in 1980, 1981 and 1982.

6/ 100 + 0 was applied at all locations in 1980, 1981 and 1982.

The P and K materials were broadcast on soybean residue and plowed down at all locations in the fall of 1982. Phosphorus was applied as CSP (0-46-0) and K as muriate of potash (0-0-60). Starter fertilizer was not used.

Specific experimental procedures used at each of the stations are presented in Table 2. Management practices providing for optimum yields were employed at each location. Nitrogen rates were slightly higher than optimum.

At Lamberton each of the plots were split with the west half planted to corn and the east half to soybeans. Corsoy 79 soybeans were planted in 30-inch rows on May 10 at a rate of 9 seeds/foot. Weeds were controlled with a ppi application of Lasso (3 lb) and Amiben (2½ lb). Plant tissue samples were not taken. Soybeans were combine harvested on September 27.

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Planting in 1983 was delayed by late snow in April and yields were reduced by a hot and dry July and August. Grain yields at Lamberton were severely reduced by herbicide carryover (Trifluralin) from the previous year's soybeans, dry weather and severe lodging at the ear later in the season.

Table 2. Experimental procedures for the high P and K rate study on continuous corn at the three branch stations in 1983.

Variable	Lamberton	Morris	Waseca
Planting date	5/10	5/10	5/9
Row spacing	30"	30"	30"
Planting rate	26,000	27,800	32,000
Hybrid	Pioneer 3732	Pioneer 3901	Pioneer 3732
Nitrogen rate	150#	120#	160#
Herbicide	3# Lasso + 2# Bladex/A ppi	2½# Lasso + 2½# Bladex/A preemerge	3½# Lasso + 3½# Bladex/A preemerge
Insecticide	None	None	None
Harvest date	9/16	9/22	10/7

RESULTS AND DISCUSSION

Soil samples taken at the end of the 1983 growing season indicate significant differences in Bray P1 extractable P and exchangeable K at all locations (Tables 3 and 4).

There appeared to be a good linear response between extractable Bray P1 and P application rate. Soil test P was always lowest with treatments 1 and 2, which received no P. Intermediate P levels were found with treatment 3 (50-lb P_2O_5 annually) and treatment 5 (150-lb P_2O_5 every third year). Highest soil test P values were associated with the annual 100-lb P_2O_5 treatments at all locations. Soil test P values at Lamberton and Waseca were quite similar to those obtained in 1982. Soil test P values at Morris, however, averaged approximately 40 percent higher than 1982. The application of 150-lb P_2O_5 (treatment 5) and 100-lb P_2O_5 + K_2O (treatment 10) at Morris resulted in P values more than twice as high as in 1982.

Table 3. Soil test values as influenced by ten year's application of P and K treatments at Morris and Waseca.[1/]

Treatment No.	Treatment Description	pH Mo	pH Wa	P M_{10}	P M_{50}	P M_{01}	P W_{10}	K Mo	K Wa
	lb P_2O_5+K_2O/A[2/]			lb/A					
1	0 + 0	7.7	6.5	9	27	8	20	336	251
2	0 + 100	7.8	6.4	11	31	9	18	476	327
3	50 + 100	7.7	6.1	44	99	38	49	430	291
4	100 + 100	7.7	6.3	88	168	67	84	429	299
5	150 + 100	7.7	6.4	61	120	54	67	444	337
6	100 + 0	7.7	6.6	105	194	86	93	341	291
7	100 + 50	7.8	6.3	73	150	61	87	356	280
8	100 + 150	7.6	6.2	87	168	74	83	393	303
9	0 + 100	7.8	6.4	24	59	20	32	363	314
10	100 + 0	7.8	6.4	33	71	28	68	359	287
	Signif. Level(%) :	84	84	99	99	99	99	99	94
	BLSD(.05),(.10)* :			18	27	14	15	64	48*
	CV(%) :	27.	2.9	24.	19.	23.	15.7	11.	9.3

1/ Samples were taken in September before the 1983 treatments were applied.

2/ Rates applied in fall of 1982 for 1983 crop.

Use of the 1:50 soil to Bray P1 solution ratio on the calcareous Aastad soil at Morris indicated slightly more than twice as much extractable P in the soil as with the 1:10 ratio at higher levels

and about 3 times as much when no P was applied. Soil P values obtained with Olson's $NaHCO_3$ test on the calcareous soil at Morris were slightly but consistently lower than values from the Bray P1 test (1:10 ratio).

Soil test K was influenced by K applications at all locations in 1983 (Tables 3 and 4). The response to annual K applications was not as pronounced as with P. Highest soil test K levels were associated with the annual application of 100-lb K_2O/A; however, these values were not always greater than the annual application of 50-lb K_2O/A (treatment 7). Soil pH was not related to P and K treatments.

Soil samples were taken from both the corn and soybean areas at Lamberton in 1983 (Table 4). P values averaged lower and K values higher following soybeans. Differences in P and K values were not great between sites and values compared very similarly on a relative basis. Soil pH was significantly lower on the 1983 corn site. Differences in soil pH between the corn and soybean sites had no effect on the relative extraction of P by the 1:50 soil to Bray P1 solution ratio or the Olson's $NaHCO_3$ test when compared to the 1:10 ratio (Table 4). The 1:50 ratio averaged 70% higher and the Olson's $NaHCO_3$ test averaged 30% lower than the 1:10 ratio across all treatments.

Table 4. Soil test values as influenced by ten year's application of P and K treatments for the corn and soybeans at Lamberton.[1/]

Treatment		Corn					Soybean				
No.	Description[2/]	pH	P_{10}	P_{50}	P_{01}	K	pH	P_{10}	P_{50}	P_{01}	K
	lb P_2O_5+K_2O/A		----------lb/A----------					----------lb/A----------			
1	0 + 0	5.4	45	107	31	269	6.1	45	81	29	250
2	0 + 100	5.6	32	60	22	338	6.0	42	74	27	323
3	50 + 100	5.9	62	114	47	340	6.4	64	124	45	363
4	100 + 100	5.4	95	166	67	318	6.1	115	174	74	379
5	150 + 100	5.7	79	125	52	311	6.3	56	104	38	320
6	100 + 0	5.4	107	150	69	263	6.0	87	154	59	279
7	100 + 50	5.5	102	164	74	298	6.1	78	134	53	324
8	100 + 150	5.6	111	177	85	291	6.1	85	159	62	303
9	0 + 100	5.8	38	69	27	312	6.3	44	76	30	342
10	100 + 0	5.5	80	121	58	289	6.0	71	122	47	311
	Signif. Level(%):	57	99	99	99	99	43	99	99	99	99
	BLSD(.05) :		23	48	16	38		17	31	11	44
	CV(%) :	6.2	22.4	26.3	21.7	8.3	5.3	18.1	18.8	18.0	9.6

1/ Samples were taken in September before the 1983 treatments were applied.

2/ Rates applied in fall of 1982 for 1983 crop.

Approximately 9½, 6½ and 6 weeks after planting at Lamberton, Morris and Waseca, respectively, ten plants randomly selected from each plot were measured, harvested, dried and weighed to determine early plant growth. Early plant weight and height were increased significantly (p=99) by treatments at Morris and Waseca (Table 5). Although plant weight was increased by treatments at Lamberton, there was no corresponding increase in plant height. Both early plant weight and height were lowest with the check treatment (no. 1) at all locations; however, plant height was not statistically different at Lamberton. At Morris and Waseca, both early plant height and weight were increased by the 50 and 100-lb P_2O_5 rates over the 0-P_2O_5 rate (no. 2). At the Waseca site, there was a significant increase in plant height from the 50 and 100-lb K_2O treatments over the 0-K_2O treatment (no. 6) by 7.7 and 9.7%, respectively. Early plant weight was also significantly higher at the 100-lb K_2O rate when compared to the 0-K_2O rate at Waseca.

Analysis of the leaf opposite and below the ear at silking was made at the Waseca site only in 1983 (Table 6). Concentrations of P, K, Ca, Mg, Mn, Zn and Cu were significantly affected (p=99) by the treatments at Waseca. Leaf P was significantly increased by the application of P although no difference was detected between the 50 or 100-lb P_2O_5 treatments. Leaf K concentration was increased by K application at all rates. Annual applications of 100-lb K_2O with P resulted in significantly higher leaf K than lower or less frequent K_2O applications (nos. 7 and 8) or K applications without P (nos. 2 and 9) (Table 6). Leaf Ca and Mg were reduced by K treatments. Leaf Mn was reduced by K application and leaf Zn was reduced below the control (no. 1) by all P and K additions. Leaf Cu was

significantly increased by the application of K but reduced by the application of P. Lowest leaf Cu was observed with the application of 100-lb P_2O_5/A without K (treatments 6 and 10).

Table 5. Early plant growth as influenced by high P and K rates at the three experimental sites in 1983.

Treatment No.	Treatment Description	Weight La	Weight Mo	Weight Wa	Height La	Height Mo	Height Wa
	lb P_2O_5+K_2O/A	g/dry plant			-------inches-------		
1	0 + 0	35.0	4.0	2.5	36.8	24.4	14.5
2	0 + 100	43.8	5.1	2.5	40.3	26.6	19.7
3	50 + 100	40.5	6.1	3.2	38.6	29.2	20.8
4	100 + 100	45.0	7.0	3.4	40.9	30.3	21.3
5	150 + 100	39.8	6.4	3.5	39.2	30.4	20.6
6	100 + 0	40.0	6.0	2.6	38.7	28.7	19.4
7	100 + 50	48.2	6.5	3.1	41.4	29.9	20.9
8	100 + 150	43.5	6.4	3.3	40.4	30.0	21.1
9	0 + 100	50.5	5.4	2.8	40.9	28.2	19.5
10	100 + 0	43.0	6.1	2.9	38.5	29.0	19.9
Signif. Level(%):		96	99	99	43	99	99
BLSD(.05) :		10.4	1.2	0.58		1.9	0.9
CV(%) :		13.6	12.4	10.6	7.9	4.6	2.7

Table 6. Effect of high P and K rates on the nutrient concentrations in the corn leaf plants at Waseca in 1983.

Treatment No.	Treatment Description	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb P_2O_5+K_2O/A	----------%----------				----------ppm----------				
1	0 + 0	.25	.94	.47	.49	161	50	28	3.8	8.3
2	0 + 100	.23	1.38	.42	.34	143	40	25	4.8	8.8
3	50 + 100	.25	1.66	.38	.32	156	38	23	4.9	7.9
4	100 + 100	.29	1.57	.41	.32	158	39	21	4.1	8.3
5	150 + 100	.30	1.54	.44	.33	167	42	23	4.4	8.4
6	100 + 0	.31	.92	.54	.50	176	52	22	3.2	8.7
7	100 + 50	.30	1.24	.46	.38	162	46	22	3.5	8.3
8	100 + 150	.30	1.25	.46	.39	163	50	25	3.5	8.4
9	0 + 100	.26	1.35	.44	.37	141	42	23	4.3	8.5
10	100 + 0	.30	.99	.50	.45	169	48	22	3.0	8.3
Significance:		99	99	99	99	82	99	99	99	18
BLSD(.05) :		.02	.14	.04	.04		6	3	.6	
CV(%) :		4.6	6.7	6.0	6.3	9.3	8.0	6.4	9.8	6.8

Plant populations were significantly affected by treatments at the Morris site. Final population was lowest on the check plots but populations on P and K fertilized plots were affected inconsistently and differences were probably not due to treatments alone.

Ear and grain moisture at Lamberton and Morris (respectively) was significantly higher for treatments 1 and 2 which received no P (Table 7). No difference in grain moisture was observed among treatments at Waseca.

The influence of 10 years of P and K applications on silage and grain yield is given in Table 8. Silage yields were significantly increased (p=92) over the control by P treatments at Morris and Waseca. No advantage was observed for the application of P at rates over 50-lb P_2O_5/A. Response to the triannual application of 150-lb P_2O_5/A was favorable. No response to K on silage yields was noted at either site. Grain yields at Morris were depressed on those plots with soil P tests in the low range (treatments 1 and 2). No differences in grain yield due to P and K applications were detected at either the Lamberton or Waseca sites.

Table 7. Population and grain moisture at harvest as influenced by high P and K rates in 1983.

Treatment No.	Treatment Description	Final Population La	Final Population Mo	Final Population Wa	Ear Moisture La	Grain Moisture Mo	Grain Moisture Wa
	lb P_2O_5+K_2O/A	plants/A x 10^{-3}			----------%----------		
1	0 + 0	24.5	24.7	25.7	34.0	35.7	20.1
2	0 + 100	24.9	25.8	26.1	35.6	37.3	21.1
3	50 + 100	24.2	26.6	26.4	31.2	31.4	20.4
4	100 + 100	25.9	25.9	26.4	32.8	32.0	20.5
5	150 + 100	24.8	25.3	25.5	31.4	31.4	20.9
6	100 + 0	24.8	26.4	25.3	32.2	30.7	20.6
7	100 + 50	26.0	25.8	26.2	31.5	31.0	20.4
8	100 + 150	26.3	26.1	26.6	30.9	31.6	20.9
9	0 + 100	25.0	24.9	26.6	32.2	31.4	20.4
10	100 + 0	25.6	26.1	26.4	29.6	31.5	20.1
	Signif. Level (%):	82	94	32	96	99	52
	BLSD (.05),(.10)*:		1.2*		3.9	2.5	
	CV (%) :	4.5	3.	3.5	6.9	5.3	2.9

Table 8. Corn, silage and grain yields as influenced by high P and K rates in Minnesota in 1983.

Treatment No.	Treatment Description	Silage Yield La	Silage Yield Mo	Silage Yield Wa	Grain Yield La	Grain Yield Mo	Grain Yield Wa
	lb P_2O_5+K_2O/A	--------T DM/A--------			----------bu/A----------		
1	0 + 0	ND[1/]	5.94	5.53	51.2	106.5	128.1
2	0 + 100		6.13	5.23	48.9	105.1	126.9
3	50 + 100		7.18	6.68	50.0	129.0	130.1
4	100 + 100		7.19	6.11	48.5	128.2	129.8
5	150 + 100		7.31	6.67	47.9	128.3	130.5
6	100 + 0		7.13	6.35	54.2	126.6	134.7
7	100 + 50		6.90	5.91	55.7	133.6	125.8
8	100 + 150		6.90	6.73	57.3	125.7	137.0
9	0 + 100		7.18	5.30	57.3	124.7	127.6
10	100 + 0		7.18	5.64	63.2	127.6	128.3
	Signif. Level (%):		92	92	59	94	06
	BLSD (.10) :		0.96	1.23		19.0	
	CV (%) :		8.8	11.5	18.	9.9	7.7

1/ ND = Not Determined. Silage yields not taken because of severe lodging.

Soybean yields were not influenced by the P and K treatments at Lamberton (Table 9).

Table 9. Soybean yields at Lamberton as influenced by high P and K rates in 1983.

Treatment No.	Treatment Description	Yield
	lb P_2O_5+K_2O/A	bu/A
1	0 + 0	34.4
2	0 + 100	34.9
3	50 + 100	34.4
4	100 + 100	38.2
5	150 + 100	35.0
6	100 + 0	32.4
7	100 + 50	37.8
8	100 + 150	35.4
9	0 + 100	35.8
10	100 + 0	33.8
	Significance Level(%):	32
	CV(%) :	11.7

ACKNOWLEDGMENT

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NITROGEN AND PHOSPHORUS FERTILIZATION OF POTATOES ON NONIRRIGATED SOILS OF NORTHWESTERN MINNESOTA

J. Grava, W. E. Fenster, M. O'Leary, T. King, G. Buzicky, D. Preston

The main objective of this study was to generate experimental data for an examination of macronutrient recommendations for potatoes on nonirrigated mineral soils. Currently Minnesota recommendations are considerably higher than those made by the North Dakota State University, particularly for phosphorus. A second objective of these investigations was to generate plant analysis data for potatoes. Results of five field trials conducted in 1982 were summarized in Misc. Publ. 2, 1983.

EXPERIMENTAL PROCEDURE

Three separate experiments were established in the spring of 1983 on the Paul Hoff Farm, East Polk County, to determine effects of N, P and K on the yield and quality of potatoes. The trials were discontinued because of delayed growth and extreme stand variability caused by heavy rainfall during June.

Don Mack Farm, West Polk County

Effects of N and P were determined in two separate experiments on a calcareous silty clay soil. The field had been in wheat in 1982 and it was fall plowed. Broadcast and band fertilizers were applied on May 19 and incorporated into the soil with a row-marker. Norchip potatoes were planted on May 19, and emerged on June 3. The farmer's regular practices were effective in controlling weeds and insects.

Broadcast N treatments consisted of four rates (0, 50, 100, 150 lb. N/A). Urea (46-0-0) was the source of nitrogen. All plots received broadcast 50 lb. P_2O_5/A. In the phosphorus trial, three rates of phosphorus (0, 25, 50 lb. P_2O_5/A) were used with the fertilizer either broadcast or band (just below seed-piece placement) applied. All plots received broadcast urea at 80 lb. N/A. Fertilizer treatments in these trials were arranged in a randomized complete block design replicated four times. Individual plots were 19 ft. wide and 40 ft. long.

Soil samples were collected in the spring of 1983 prior to fertilizer application and were analyzed by the University of Minnesota Soil Testing Laboratory. Soil test results (Table 1) indicated high levels of Olsen extractable P (27, 26 lb/A); exchangeable K was very high (477, 490 lb/A). Medium levels of NO_3-N in the top two feet of soil were found on this field (47, 35 lb/A).

The petiole and leaflets of the 4th leaf from the growing tip of 15 plants were collected at random from each plot at two different times during the growing season. At the early season sampling on July 19, 61 days after planting (45 days after emergence), the plants were in the initial flowering stage with some flowers just appearing. At the second sampling on August 8, or 81 days after planting (65 days after emergence), the potatoes had reached the late flowering stage with most plants past the peak of flowering. Kjeldahl N, nitrate-N (both the NO_3 and NO_2 forms are measured), and elemental analyses were made by the Research Analytical Laboratory.

Potatoes were harvested with a potato plot harvester. Total weight of nongraded tubers was determined and expressed as cwt/A.

RESULTS

Broadcast nitrogen treatments increased the total N and NO_3-N concentration of leaf tissue at initial and late flowering stages (Table 2). Although only 35 lb/A of NO_3-N were measured in the top two feet of the soil, nitrogen fertilization did not significantly affect either the yield or specific gravity of tubers. In the phosphorus experiment, the yield was increased by 20 cwt/A with 25 lb. P_2O_5/A applied either broadcast or in band (Table 3). Neither the specific gravity of tubers nor the concentration of P in leaf were affected by phosphorus fertilization. Leaf-P was 0.45 and 0.35% at initial flowering and late flowering, respectively. Extractable P by the Olsen method was 27 lb/A, considered to be a high level. Currently, 75 lb. P_2O_5/A would be recommended for potatoes on nonirrigated mineral soils at such a soil test level.

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The concentration of other macro- and micronutrients in leaf tissue from the phosphorus trial is reported in Table 4. Although there was significantly higher Ca and Mg in leaf tissue at initial flowering associated with some phosphorus treatments, adequate levels of these two plant nutrients existed in all treatments. There is no pattern or logical explanation for this significance. The exceptionally high Mn and Zn levels in leaf tissue at late flowering, however, were due to the application of a fungicide containing these chemical elements.

SUMMARY

Data from this two-year study indicate that potato yields ranging from 125 to 231 cwt/A can be produced on nonirrigated mineral soils of northwestern Minnesota with lower N and P rates than are currently recommended by the University of Minnesota. At high Olsen P levels (21-30 lb/A), for a 200-250 cwt/A yield, the phosphate rate could be decreased from 75 to 25 lb. P_2O_5/A without adversely affecting the yield or quality of potatoes.

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We wish to thank Dr. Gary Varvel and Mr. Russ Severson, Northwest Experiment Station for their help in conducting these experiments. Sincere appreciation is given to Dr. Florian Lauer, Department of Horticultural Science for the use of plot harvesting equipment.

Table 1. Soil test results, Mack Farm.[1/]

Experiment	Sampling Depth (inches)	pH	O.M. %	Bray 1 1:10 P lb/A	Bray 1 1:50 P lb/A	Olsen P lb/A	Exch. K lb/A	Zn ppm	NO_3-N lb/A
Phosphorus trial	0-6	8.2	4.6	6	56	27	477	0.6	
	0-24								47
Nitrogen trial	0-6	8.0	4.6	3	ND	26	490	ND	ND
	0-24								35

[1/] Soil test results are averages of four samples collected from check plots in May 1983 prior to planting.

ND = not determined

Table 2. The effect of broadcast nitrogen on yield, specific gravity and N content of leaf tissue of potatoes, Mack Farm, W. Polk Co., 1983.

Treatment N lb/A	Yield cwt/A	Specific Gravity	Sampling: Initial Flowering Total Kjeldahl N %	Initial Flowering NO_3-N ppm	Late Flowering Total Kjeldahl N %	Late Flowering NO_3-N ppm
0	130	1.074	4.06	916	3.44	430
50	151	1.075	4.72	2735	3.63	994
100	148	1.072	5.09	3863	3.85	1576
150	146	1.072	5.42	5276	4.24	2462
Significance	ns	ns	**	**	**	**
BLSD (0.05)	--	--	0.31	879	0.37	834
C.V., %	10.5	0.2	4.1	17.9	5.9	37.7

All plots received broadcast 50 lb/A of P_2O_5.

Table 3. The effect of broadcast and row phosphorus on yield, specific gravity and P content of leaf tissue of potatoes, Mack Farm, W. Polk Co., 1983.

Treatment: P_2O_5 lb/A	Treatment: Method of Application	Yield cwt/A	Specific Gravity	Sampling: Initial Flowering P %	Sampling: Late Flowering P %
0		125	1.072	0.45	0.33
25	broadcast	145	1.072	0.44	0.32
25	band	148	1.074	0.45	0.33
50	broadcast	143	1.071	0.46	0.35
50	band	148	1.074	0.44	0.33
Significance		+	ns	ns	ns
BLSD (0.05)		19			
C.V., %		7.8	0.2	3.8	5.7

All plots received broadcast 80 lb. N/A.

+ = significant at 10% level of probability

Table 4. The concentration of macro- and micronutrients of potato leaf tissue collected from phosphorus trial at two different stages of growth, Mack Farm, W. Polk Co., 1983.

Treatment		Sampling															
		Initial Flowering								Late Flowering							
P_2O_5 lb/A	Method of Application	K %	Ca %	Mg %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	B ppm	K %	Ca %	Mg %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	B ppm
0		3.58	1.05	0.91	222	41	25	15	34	3.23	1.05	0.95	140	194	132	13	30
25	broadcast	3.64	1.22	1.04	258	45	24	15	39	3.17	1.10	1.00	143	159	107	12	30
25	band	3.64	1.16	0.98	238	43	24	14	39	3.23	1.03	0.94	130	156	104	12	30
50	broadcast	3.53	1.04	0.93	221	40	25	14	37	3.32	1.06	0.98	143	170	120	13	30
50	band	3.61	1.16	1.05	231	43	23	14	39	3.38	1.07	0.99	142	171	113	12	30
Significance		ns	**	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
BLSD (0.05)			0.09	0.09													
C.V., %		4.6	5.3	5.5	10.2	6.6	4.8	5.3	9.1	7.8	5.5	5.9	20.8	14.5	13.8	7.3	5.0

RESEARCH IN SOIL FERTILITY AND CHEMISTRY OF SOIL AND WATER - 1983

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Research during 1983 focused on nitrogen loss mechanisms in paddy soil and water, factors associated with crop failure, and possible causes for growth differences observed along the ditches. The research was conducted on University land in Grand Rapids and in growers' fields near Aitkin and Gully. A growth chamber and 4 x 4 ft. boxes at St. Paul were also utilized for some of the work.

A. WEATHER CONDITIONS

Average air temperatures recorded at four U. S. weather stations were below normal during April and May, followed by nearly normal June, and above normal during July and August (Table 1).

Several growers in the Aitkin area had commented that the wild rice yield in some paddies fell below expectations. General browning and early dying of plants was observed, apparently not caused by disease. The possible cause was the high air temperature between flowering and maturity which resulted in moisture stress. Weather data recorded at the Pine River Dam U. S. Weather Station (northwest of Aitkin) showed 12 days during July and 8 days during August with the maximum air temperature of 90° F or above. In contrast, during 1982, such high temperatures were recorded only on 4 days in July and on 2 days in August.

Soil, water and air temperatures were measured at Grand Rapids within the experimental paddy No. 1 East, and on the St. Paul Campus within an area where experiments in 4 x 4 ft. boxes were conducted (Fig. 1 and 2).

B. YIELD VARIABILITY ON A MINERAL SOIL

A stand of Netum wild rice was established in paddy No. 1 East at the North Central Experiment Station, Grand Rapids. The soil is classified as an Indus clay loam (very fine, montmorillonitic, frigid Typic Ochraqualf). Soil tests (Table 2) indicated a very high level of Bray-1 extractable phosphorus (85 lb/A) and a medium level of exchangeable potassium (202 lb/A).

Wild rice seed was broadcast by hand on May 5 at a rate of 45 lb/A. Individual plots occupied a 14 x 16 ft. area and were separated from adjoining plots by 5 ft. wide alleys. Since the objective was to establish a stand for future studies, no fertilizer treatments were made. Water level was maintained at 8 to 12 inches. A 16 sq. ft. area from each plot was hand-harvested on August 22nd.

Netum grain yield (7% moisture) of individual plots ranged from 512 to 1027 pounds per acre. The overall mean yield was 778 lb/A with a standard deviation of 158, and a coefficient of variability of 20%. These data illustrate the variability of grain yield frequently observed in first year wild rice stands.

C. DIURNAL CHANGES IN THE pH OF PADDY FLOODWATER

Nitrification-denitrification was traditionally thought to be the major mechanism of nitrogen loss from flooded soils. Recently researchers with white rice have suggested that ammonia volatilization may be more important, especially in soils such as peat in which ammonium ions are not held strongly by the soil cation-exchange complex. High floodwater pH and high NH_4-N concentration in the floodwater result in high nitrogen losses. Urea hydrolysis and algal CO_2 consumption are known to raise the pH of paddy water above 9 under the afternoon sun.

Floodwater samples were collected from six wild rice paddies during June and July. The water samples were collected in 250 ml polyethylene bottles by submerging the bottle 2.5 cm below the surface. The pH was determined immediately after sample collection using a combination electrode and portable pH meter. Duplicate water samples were collected and stored in 250 polyethylene bottles, with a preservative added. Chemical analyses were made by the Research Analytical Laboratory. Chemical composition of the water is given in Table 3.

Floodwater pH showed considerable variation during a 24-hour period. The strongest alkalinity (high pH) and greatest variation of the floodwater pH were observed in paddies having shallow water depth

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(15 cm) (see Fig. 3 and 4). The floodwater pH at Gully, Polk County, during afternoon hours on a sunny day was above 9.0, reached a maximum of 9.5 (water temperature 29°C) and then steadily declined to a minimum of 7.9, measured at 7:00 a.m. (water temp. 17°C). This paddy had considerable growth of waterplantain, other weeds and some algae. In the paddies with relatively deep water (35 cm), the floodwater pH showed similar but less pronounced variation than that observed in shallow water, and the maximum pH values did not exceed 8.5. The wild rice was in the tillering stage.

At Grand Rapids on a mineral soil, at 15 cm water depth, the maximum floodwater pH of 9.6 was recorded at 2:30 p.m. (water temp. 28°C), declined to 7.0 at 7:00 a.m. (water temp. 23°C) and by noon reached 9.0 (water temp. 29°C). Various rooted water plants and some algae were observed at this sampling site. In 35 cm deep water, the floodwater pH showed less pronounced diurnal change.

In a Kosbau Bros. paddy, Aitkin County, floodwater samples were collected from an area with relatively deep water level (45 cm). No weeds or algae were present. The floodwater pH on this acidic peat remained constant near 6.5 during a 24-hour period. The water temperature fluctuated from a maximum of 27° to 23° C.

Theoretically, 12.5% of ammonium (NH_4) present in the water at pH 8.4 is in the ammonia (NH_3) form, which can volatilize. At higher pH values a larger fraction of the ammonium nitrogen is in the NH_3 form while at low pH less is in the volatile form. Ammonia volatilization should not occur in paddies similar to that investigated in Aitkin County where the floodwater was slightly acid. Nitrogen losses through NH_3 volatilization may be significant, however, at shallow water depth particularly in paddies of the Clearwater River area because of extremely high floodwater pH. Maintenance of proper depth of water in the paddy until the plant canopy closes appears to be important to minimize possible nitrogen losses through NH_3 volatilization.

D. STUDIES IN 4 x 4 FT. BOXES

A nitrogen source and placement experiment was conducted in 4 x 4 ft. wooden boxes on the St. Paul Campus. A 30 cm thick layer of hemic peat was placed into the boxes. Dolomitic aglime was added to the peat to increase its pH from 4.1 to 6.0 and the corresponding base saturation from 15 to 50 percent. Seven fertilizer treatments were replicated four times. Nitrogen fertilizers were applied at a 90 kg/ha (80 lb/A) rate; all boxes received 67 kg/ha of P_2O_5 and 135 kg/ha of K_2O. Nitrogen fertilizer was either deep placed at a 10 cm depth or applied on the soil surface. Phosphorus, potassium and deep placed nitrogen were applied pre-plant; surface nitrogen was applied after seeding. Seed of K2 wild rice variety was placed in rows on May 27. Two extra boxes (51 and 52) without plants were set up, No. 51 with deep placed urea and No. 52 as Control. Boxes were filled with 15 cm of water. On June 1 gas development in several boxes caused foaming and scum accumulation on the surface of water. By June 6 all boxes had gone through the first cycle of foaming and had developed a floating peat condition. The gas was mainly CO_2 with traces of CH_4. A small amount of "Triton" wetting agent was sprayed on the surface to break up the scum (and later the algae) so that it could be skimmed off. Wild rice developed slowly and very few plants survived. So, the experiment was used mainly for monitoring inorganic nitrogen, pH and temperature of the water and soil.

Samples of the floodwater were collected in 250 ml polyethylene bottles 2.5 cm below the surface. Diurnal sampling was conducted to measure the changes in pH and inorganic nitrogen from day to night so as to determine the potential for ammonia volatilization.

Soilwater was collected in ceramic cups placed in selected boxes at depths of 5 cm and 30 cm below the soil surface, i.e., shallow and deep, respectively. The cups and the connecting 91 cm long (6.25 cm diameter) plastic tubes were purged of air with three volumes of argon and sealed to prevent oxygen from entering the anaerobic peat. Samples were extracted by means of a small hand-held vacuum pump. The pH was determined immediately and samples for N analyses were treated with 1 ml of 20% H_2SO_4/100 ml and refrigerated at 4° C. Nitrogen was analyzed by distillation. On August 4 ceramic cups were removed from boxes No. 24 and 44 because of extremely poor rice stand and placed in boxes No. 33, 42 and 43.

The temperature and dissolved oxygen (DO) profiles of floodwater were established in two boxes (No. 24 GU, surface; 44 GU, 10 cm) to determine if stratification in 23-30 cm of water was possible. Both DO and temperature were measured with a YSI DO meter.

The pH values of the diurnal study of floodwater in selected boxes on 6/23 are reported in Table 4. Most of the boxes, except No. 35, showed significant changes in pH from daytime highs of 9-10 and nighttime lows of 5.5-6.5. There was a potential for NH_3 volatilization at these high pH values.

The pH may not have changed much in box No. 35 (GU, surface) because of a lack of a high algal (phytoplankton) population. The dominant algae in the boxes appeared to be Cyanophyta (blue-greens).

The concentrations of ammonium and nitrate in the floodwater on 6/23 from the diurnal study are given in Table 5. Lowest amounts of NH_4-N and NO_3-N were found in boxes receiving no nitrogen fertilizer (Control). It is difficult to determine which placement of urea contributed the greatest amount of N to the floodwater. Gas production within the peat caused a very significant disruption of the soil stability and convectively carried N into the floodwater. There appeared to be very little change in inorganic N from day to night. It is expected, however, that as the pH decreased from 9-10 to 5-7 most of the ammonia was changed to ammonium.

Only trace amounts of inorganic N in floodwater was found on 7/19. The algal growth was very heavy, suggesting that any ammonium or nitrate N would be quickly taken up by algae.

Before the collection of soilwater samples, the water in the ceramic cups was discarded and fresh soilwater was allowed to enter the cups. Liming had achieved the desired pH levels as indicated by soilwater pH (Table 6). The inorganic N levels of soilwater on 7/1/83 are shown in Table 7.

An attempt was made to determine if NH_4-N would be higher in box No. 52 (Control, no plants) compared to box No. 34 (Control, with plants). But the plant growth in all boxes was so poor that there appeared to be no reduction in the NH_4-N level due to an uptake by plants. The soilwater in Control boxes had about one-half of the NH_4-N as the fertilized boxes. The nitrate values of boxes No. 24 and 44, with cups placed 30 cm deep, indicate that argon may have escaped and oxygen was causing nitrification in the cups. It is unlikely that the nitrate came from the floodwater because it contained less than 2 ppm of NO_3-N on 6/23. Later on improvements were made to seal the argon in the cups and very little NO_3-N was detected in the soilwater on subsequent samplings. Ceramic cups were removed from boxes No. 24 and 35 and placed in boxes No. 33, 42 and 43.

The concentrations of NH_4-N in soilwater samples collected on 8/15 and 9/16 are reported in Tables 8 and 9. No NO_3-N was detected in the soilwater on these two dates. Soilwater pH ranged from 5.7 to 6.2 on 8/15.

Dissolved oxygen and temperature profiles were determined in boxes No. 24 and 44 on 6/30 at 9:00 a.m. (Fig. 5). There was a substantial profile development of DO indicating that the floodwater was not mixing from top to bottom. The graphs show that the water near the surface was highly enriched with oxygen and the DO level decreased with depth and approached zero near the surface of peat.

There was very little wind on 6/30. Open areas of paddies with very little plant growth would probably have thoroughly mixed floodwater. As plants develop and buffer the effects of wind energy, stratification could occur. The reason for the stratification is the temperature gradient from the top to the bottom of the floodwater. At 9:00 a.m. a 2°C temperature difference existed in the profile. As the day progressed the topmost layers of water probably became warmer, imparting an even stronger density stratification to inhibit mixing.

Discussion- Wild rice developed slowly and grew poorly in the boxes because of heavy algal growth which caused low light penetration into the floodwater. This could have inhibited vigorous growth by starving the plants of an energy source. Early planting that would permit the plants to develop before the algae would help this situation. The algae may also have given off toxins detrimental to wild rice. The blue-green algae (Mycrocystis) is notorious for toxin production that can badly blister the udders of cattle wading into farm ponds.

Mechanical disruption of the seedbed by CO_2 evolution prevented many plants from establishing a solid footing in the peat.

Generally, inorganic N concentration was higher in flood- and soilwater in boxes receiving nitrogen fertilizer compared to the Control. Nitrogen concentration in floodwater decreased with increased algal growth while nitrogen in the soilwater tended to increase due to mineralization. The analytical results may be somewhat suspect because of the disruption in the boxes by CO_2 evolution. But NH_4-N levels in Control boxes increased from about 5-10 ppm to 10-15 ppm with the fertilized boxes having 20-30 ppm. The attempt to observe a decrease in NH_4-N through plant uptake did not materialize because of poor plant growth.

E. EFFECTS OF THE ADDITIONS OF HIGH LEVELS OF STRAW AND SULFATE

The effect of straw, nitrogen and gypsum (calcium sulfate) on wild rice growth was investigated in one-gallon plastic containers in an environmental growth chamber. Each container was filled to a depth of 15 cm with either an acidic peat from the Kosbau Bros. paddies, Aitkin County, or a neutral peat from the Clearwater Rice, Inc., Clearwater County. The soil was amended with the above mentioned materials, flooded with 5-7.5 cm of demineralized water and planted with K2 variety of wild rice. The young plants ranged from 5 to 10 cm in length. Growth conditions were: 16 hrs. of light at 18-19°C, 8 hrs. of dark at 15-16°C, and a humidity of approximately 90-95%. Wild rice tops were harvested after 50 days, dry weight and chemical composition of plant tissue were determined.

Results of the growth chamber experiment are reported in Table 10. The plants in containers No. 2, 6 and 8 did not grow well and developed no panicles. The plants in containers No. 1, 4, 7 and 9 grew relatively well and developed panicles. Percentage of N in the plant ranged from 1.19 to 1.52% and varied very little while the dry weight of tops varied from zero to 3.73 g per container.

Measurements of the redox potential, Eh, of the soil were in the negative range indicating strongly reduced conditions.

The two containers with Kosbau peat (No. 1 and 2) had drastically different plant growth after 50 days. Containers No. 3 and 9 with the Clearwater peat and various amendments had quite different levels of plant production. The combination of gypsum and 3X rate (24,900 kg/ha) of wheat straw killed all wild rice seedlings even with repeated replanting. The addition of ammonium to 3X rate of straw (container No. 4) increased plant weight nearly five times over 3X straw only (container No. 6), but it did not help the survival of plants in container No. 5 (3X straw + gypsum + N).

The application of a low rate of straw (8,300 kg/ha) produced about 5.5 times more dry matter than the 3X rate of straw. Gypsum alone had a detrimental effect on wild rice and reduced the yield even more than 1X rate of straw. The highest dry weight of wild rice was produced with the application of nitrogen (container No. 9), but the vegetative growth was stimulated by N to such extent that the plants had difficulty remaining upright.

The environmental growth chamber study with various treatments of straw, ammonium and gypsum was designed to establish extreme conditions in an organic soil and to observe wild rice growth under such conditions. Nutrient elements such as N, P, K, Ca, Zn did not seem to be the factors in the growth problems observed. This experiment may provide a clue to the problems observed in the nitrogen source and placement study, i.e., various interrelationships of phytotoxins originating either in the soil or in the root or both. This is an area that needs further investigation.

F. INVESTIGATIONS RELATING TO THE "DITCH EFFECT"

Growers and others have observed strips along ditches where the wild rice appears to be greener and taller (and presumably yield more grain) than the plants in the rest of the field. Thus, the term "ditch effect".

Manomin

On July 26, color differences were observed from a distance in several paddies of the Manomin Wild Rice Company, Aitkin County. On August 22, soil samples were collected and wild rice was hand-harvested from several 4 x 4 ft. areas. The yield and stand density of wild rice, percent of ash, pH and chemical composition of peat determined either by soil tests or ICP analysis of acid digest are given in Table 11.

Wild rice near ditches produced from 50 to 238 pounds of grain per acre more than harvested in the field. In two paddies the number of stems per 16 square feet was greater near the ditch compared to the field. The ash content of the organic soils (0-6 inch depth) near the ditch was 2 to 4 percent higher than the peat further in the paddy. Such a slightly higher ash content of the peat may reflect higher proportion of mineral matter apparently deposited near the ditches during the digging and dredging operations. The content of aluminum (Al) and iron (Fe) found in the soil from the two different areas show trends similar to those observed in ash content, and again, may indicate a peat with more mineral matter along the ditch than the organic soil in the main part of a paddy. The soil of both areas in the field had similar content of other macro- and micronutrients.

Diebold Farm

Similar striking differences in height of wild rice had been observed prior to harvest in several paddies of Diebold Farms, Aitkin County. Soil samples were collected from two paddies near the ditch and in the field. The main difference in soil characteristics (Table 12) is the higher ash content in samples collected along the ditches compared to the soil in the field. In paddy No. 11, the soil along the ditch actually is a mineral soil, containing 89% ash and a high content of exchangeable potassium, deposited there during the ditch cleaning operation the previous year. No yield data were obtained on the Diebold Farm.

No definite conclusions as to the cause of the so-called "ditch effect" can be drawn because of preliminary nature of these investigations. The growth differences in wild rice observed along the ditches and in the main field may be due to three factors: 1) More mineral matter in the peat along the ditches. Differences in the ash content observed in Aitkin County would support this. 2) Plant density differences. There was some evidence of greater number of stems along the ditches. 3) There may be some differences in water depth (not measured in this study) that may affect the growth and nutrition of the plant.

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Table 1. Average air temperature as measured at four U.S. weather stations.[1/]

Station Year	Month April	May	June	July	August	5 Month Average	GDD T_b=40
	----------average air temperature, °F----------						
Fosston, Polk Co.							
Normal[2/]	41.0	54.6	63.6	69.4	67.5	59.2	2955
1974	41.0	50.5	63.4	71.6	62.8	57.9	2744
1975	34.8	55.7	61.9	70.5	64.6	57.5	2852
1976	46.6	54.9	66.8	68.8	70.9	61.6	3315
1977	49.1	66.4	64.6	70.3	60.6	62.2	3446
1978	41.7	59.2	63.4	67.8	67.7	60.0	3060
1979	36.0	48.7	63.6	69.6	63.6	56.3	2627
1980	48.9	61.3M[3/]	68.5	71.0	64.6	62.9	3466
1981	44.4	55.3	60.8	68.1	65.7	58.8	2898
1982	37.0	55.1	55.5	66.8	63.0	55.5	2477
1983	37.7	50.5[4/]	63.7[4/]	69.0	68.5	57.9	2819
Grand Rapids, N.C. School							
Normal	39.9	52.7	62.0	67.4	65.1	57.4	2681
1974	41.6	49.4	62.7	70.7	62.8	57.4	2670
1975	34.7	57.0	62.2	71.5	65.2	58.1	2951
1976	47.1	54.4	66.1	68.2	67.4	60.6	3166
1977	48.2	63.8	64.0	69.2	60.2	61.1	3284
1978	41.3	57.9	62.8	66.5	66.0	58.9	2892
1979	37.1	49.5	61.5	68.1	62.6	55.8	2511
1980	46.1	59.9	64.0	69.0	66.4	61.1	3237
1981	43.9	54.8	62.0	68.0	67.0	59.1	2941
1982	38.6	57.7	58.5	68.0	64.4	57.6	2753
1983	39.0	49.7	62.5	71.1	70.1	58.5	2873
Aitkin							
1974	42.9	49.8	63.1	71.1	63.3	58.0	2770
1975	39.0M	59.4M	64.4M	72.1	66.2M	60.2	3141
1976	47.5	54.8	66.8	69.3M	68.1	61.3	3267
1977	48.3M	64.4M	65.4M	70.3M	61.0	61.9	3446
1978	40.7M	57.5M	64.1M	67.0M	66.9	59.2	2938
1979	37.7	50.6	62.0	68.1M	63.4	56.4	2585
1980	53.9	58.3	64.0	68.5	66.0	62.1	3394
1981	45.1M	53.8	62.1M	67.5	66.0	58.9	2902
1982	38.3	57.4	57.6	68.6	64.8	57.3	2723
1983	39.6M	49.3M	60.3M	72.1M	71.9M	58.6	2881
St. Paul, U of M							
1982	43.4	61.3	62.4	73.9	67.3	61.6	3332
1983	42.1	55.2	68.7	76.4	76.0	63.7	3640

1/ Source: Climatological Data, Minnesota, Vol. 80-89 (1974-83), U.S. Dept. of Commerce.
2/ Normals for the period 1931-1960.
3/ M = less than 10 days record missing.
4/ Northwest Divisional Data.

Table 2. Soil test values of experimental paddy No. 1 East, Grand Rapids.[1/]

pH	Organic Matter %	Bray-1 P lb/A	Exchangeable K lb/A	Exchangeable Mg lb/A	S ppm	DTPA Extractable Zn ppm	DTPA Extractable Cu ppm	NO_3-N lb/A
5.6	3.4	85	202	446	8	5.6	0.8	30

1/ Samples collected from 0-6 inch depth on 5/5/83.

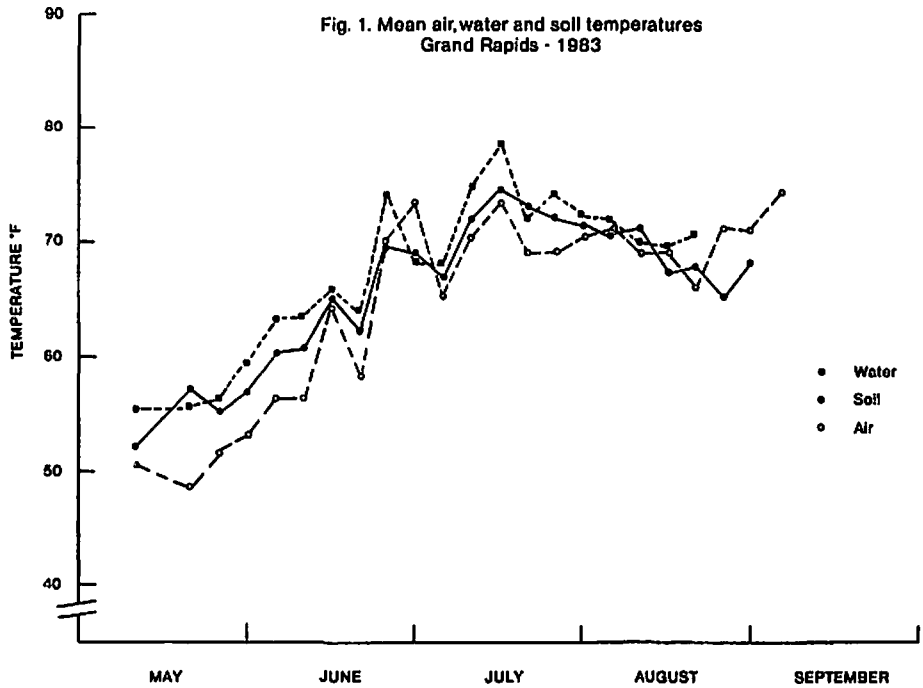
Fig. 1. Mean air, water and soil temperatures
Grand Rapids - 1983
TEMPERATURE °F
90
80
70
60
50
40
MAY
JUNE
JULY
AUGUST
SEPTEMBER
Water
Soil
Air

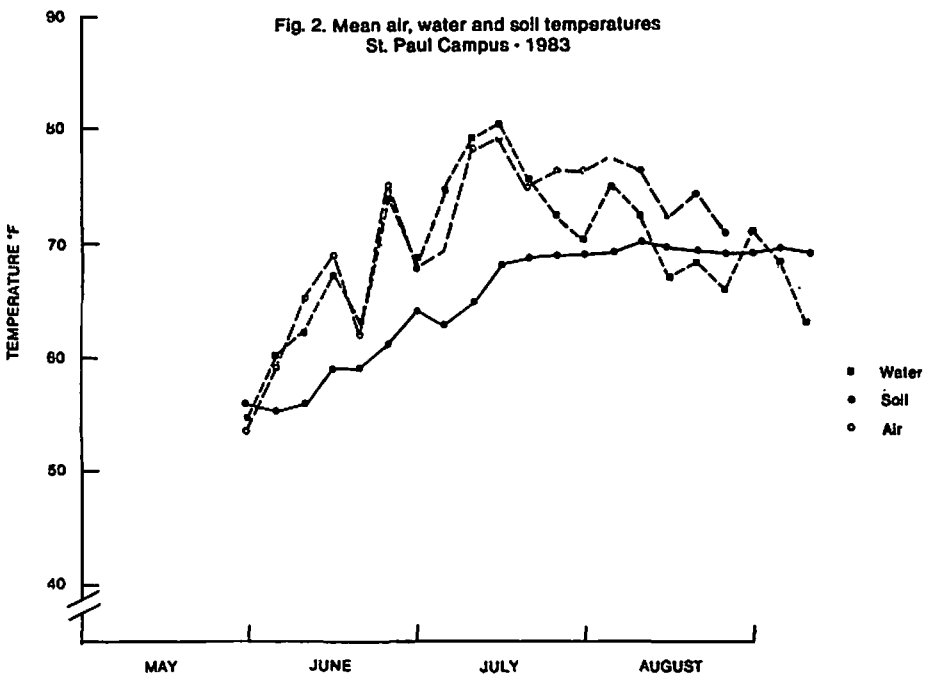
Fig. 2. Mean air, water and soil temperatures
St. Paul Campus - 1983
TEMPERATURE °F
90
80
70
60
50
40
MAY
JUNE
JULY
AUGUST
Water
Soil
Air

Table 3. Chemical composition of water collected from wild rice paddies - 1983.

Sample No.	Sampling Date	Location	pH	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Nitrate & Nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm	Na ppm
1	6/28	Gully-E, deep water	7.7	152	279	3.6	<0.05	0.30	0.20	28.5	71.8	23.9	9.3	7.7
6	6/28	Gully-W, shallow water	9.2	167	335	1.2	<0.05	0.40	0.34	45.6	84.5	29.7	2.1	8.8
12	6/28	Gully-W, deep water	8.5	ND[1/]	473	2.2	<0.05	0.52	0.49	ND	122.2	40.2	8.7	9.2
18	7/7	Aitkin, diversion ditch	ND	63	85	1.2	<0.05	0.09	0.02	1.6	22.1	6.7	0.6	2.7
19	7/7	Aitkin, pump	ND	61	85	1.2	<0.05	0.08	0.03	1.4	22.1	6.7	0.6	2.7
20	7/7	Aitkin, paddy	6.6	58	78	1.9	<0.05	1.20	1.09	1.4	18.7	7.2	1.8	4.0
24	7/20	Grand Rapids, paddy 1E, 30-35 cm depth	7.9	68	79	0.9	<0.05	0.08	0.04	1.0	21.2	5.8	1.3	2.8
25	7/20	Grand Rapids, paddy 9A, 15 cm	9.6	67	75	1.5	<0.05	0.11	0.05	0.7	18.7	6.1	2.5	3.4
26	7/20	Grand Rapids, Prairie River	ND	68	79	1.0	<0.05	0.08	0.02	0.9	21.4	5.7	0.9	2.5

1/ ND = not determined.

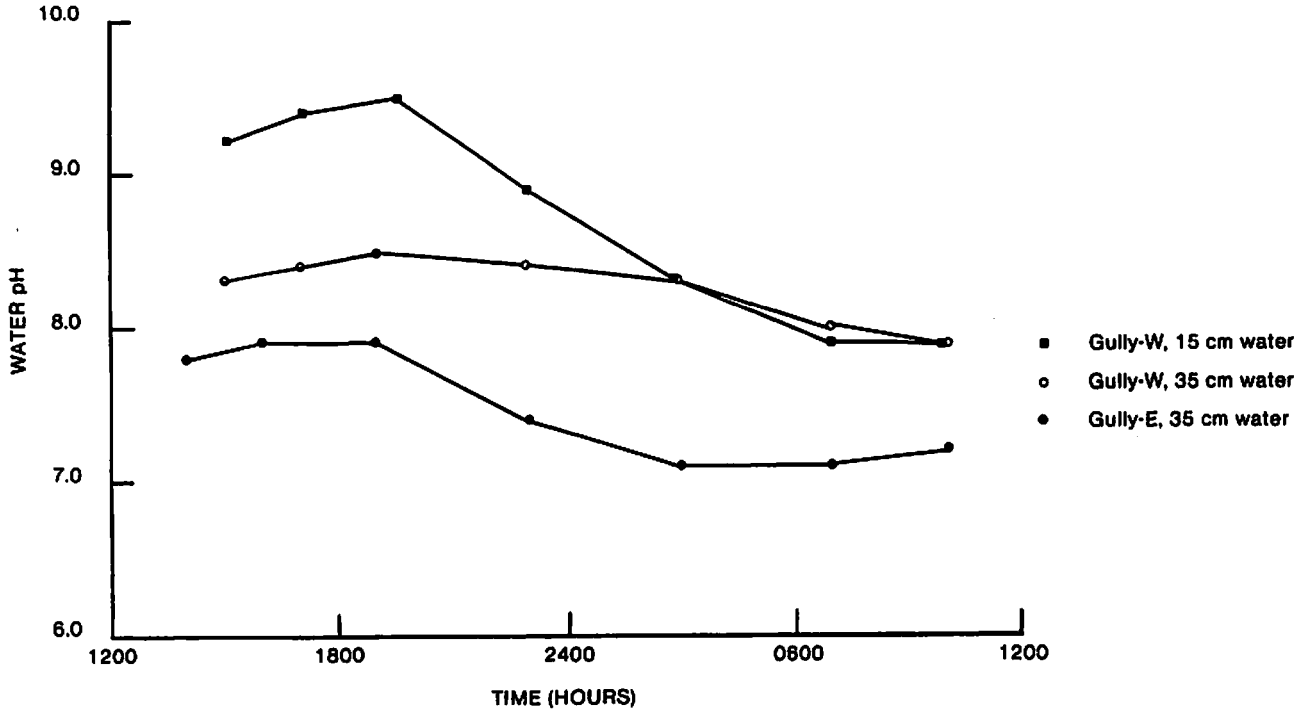

Fig. 3. Changes in the pH of paddy floodwater on peat.

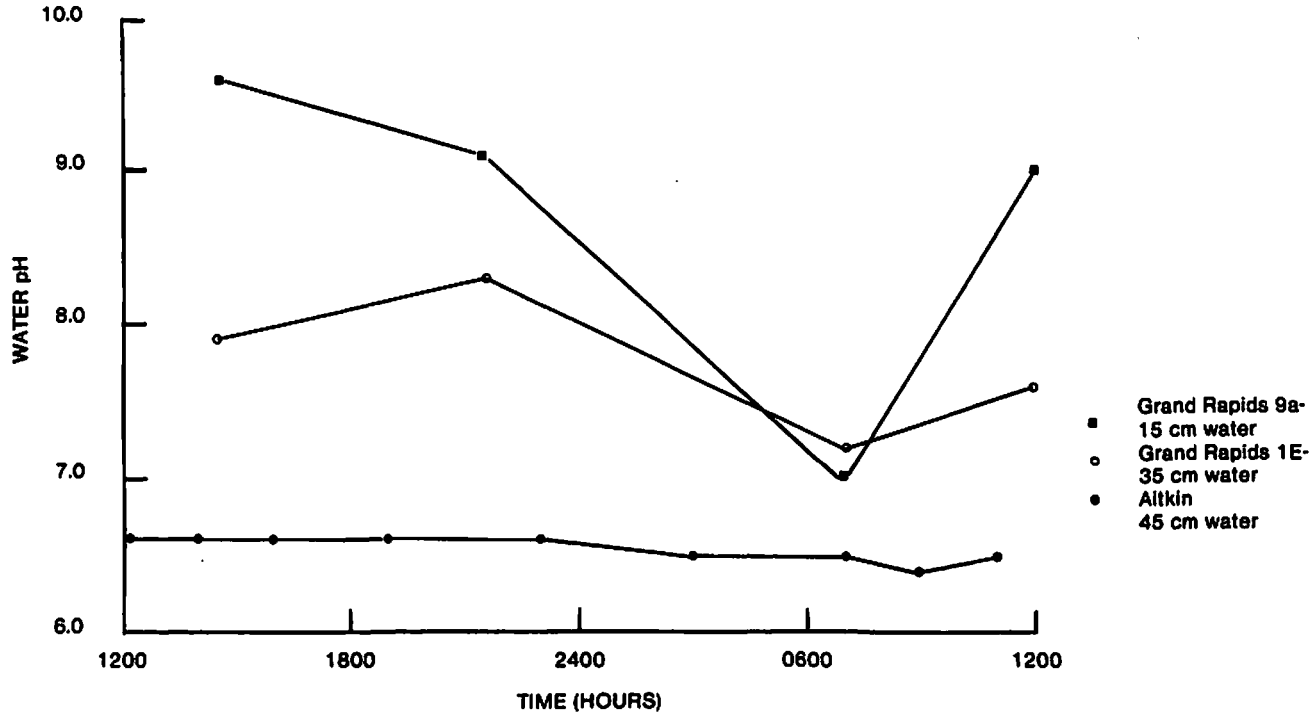

Fig. 4. Changes in the pH of paddy floodwater on mineral and organic soils.

Table 4. Diurnal changes in the pH and temperature of floodwater in 4 x 4 ft. boxes on 6/23-24/83.

Box No.	Fertilizer Treatment	Time (hours) 1200	1400	1600	1900	2300	0300	0700	1200
		Floodwater Temperature, °C							
		29.4	32.3	31.8	28.5	24.5	22.4	20.9	20.2
		Floodwater pH							
34	Control	9.6	9.8	10.1	9.7	6.4	5.4	5.6	5.8
42	Control	9.1	9.6	9.8	9.5	7.5	6.6	6.6	6.5
52	Control	10.0	9.8	9.9	9.3	6.4	6.9	6.4	6.3
24	GU, surf. applied	9.0	8.9	9.3	8.6	6.5	6.4	6.2	6.3
35	GU, surf. applied	6.4	6.5	6.6	6.8	6.4	6.1	6.2	6.1
36	GU, 10 cm depth	9.0	9.0	9.0	8.6	6.5	6.3	6.3	6.3
44	GU, 10 cm depth	8.0	8.1	8.1	7.3	6.2	6.0	6.1	5.8
51	GU, 10 cm depth	9.2	7.9	8.8	6.9	6.2	7.6	6.5	6.1

GU = Granular urea, commercial grade.

Table 5. Inorganic N of floodwater in 4 x 4 ft. boxes from diurnal study on 6/23-24/83.

Box No.	Fertilizer Treatment	Time (hours) 1400	2300	0300	Time (hours) 1400	2300	0300
		NH_4-N, ppm			NO_3-N, ppm		
34	Control	0.07	**	**	0.0	0.0	0.07
42	Control	0.0	0.28	0.21	0.0	0.0	0.0
52	Control	0.07	0.35	0.0	0.0	0.71	0.0
24	GU, surf. applied	3.12	2.69	2.62	1.28	0.92	0.99
35	GU, surf. applied	2.13	2.20	1.91	2.48	2.48	2.55
36	GU, 10 cm depth	1.13	1.20	1.13	1.42	1.13	1.13
44	GU, 10 cm depth	2.13	2.27	2.41	1.20	0.92	0.92
51	GU, 10 cm depth	1.13	1.84	1.84	0.43	0.35	0.07

** Values were about 3 ppm NH_4-N, but are omitted because the water became turbid from suspended matter.

Table 6. Soilwater pH at different depths in 4 x 4 ft. boxes on 7/1/83.

Box No.	Fertilizer Treatment	5 cm Deep, Ceramic Cup No. 1	2	3	30 cm Deep, Ceramic Cup No. 1	2	3
		Soilwater pH					
34	Control	5.8	6.0	5.9	ND	ND	ND
52	Control	5.9	6.3	6.2	6.0	5.8	ND
24	GU, surf. applied	7.2	6.3	6.1	6.4	5.9	ND
44	GU, 10 cm depth	5.6	5.9	5.9	5.9	5.4	ND
51	GU, 10 cm depth	6.2	6.6	5.7	6.2	5.8	ND

ND = not determined.

Table 7. Soilwater inorganic N at different depths in 4 x 4 ft. boxes on 7/1/83.

Box No.	Fertilizer Treatment	5 cm Deep Ceramic Cup No. 1	2	3	30 cm Deep Ceramic Cup No. 1	2	3
		Soilwater NH_4-N, ppm					
34	Control	8.71	8.3	7.6	-	-	-
52	Control	10.0	7.8	6.1	9.1	7.9	-
24	GU, surf. applied	21.1	16.9	24.3	16.1	14.5	-
44	GU, 10 cm depth	17.0	16.0	21.6	11.3	7.9	-
51	GU, 10 cm depth	22.4	15.2	16.2	12.6	13.4	-
		Soilwater NO_3-N, ppm					
34	Control	0.0	0.0	0.0	-	-	-
52	Control	0.0	0.0	0.0	0.0	0.0	-
24	GU, surf. applied	0.0	0.0	0.3	16.5	21.7	-
44	GU, 10 cm depth	0.0	0.0	-	7.3	0.0	-
51	GU, 10 cm depth	0.2	0.0	-	0.9	0.0	-

- = no ceramic cup available

Table 8. Soilwater inorganic N at different depths in 4 x 4 ft. boxes on 8/15/83.

Box No.	Fertilizer Treatment	5 cm Deep Ceramic Cup No. 1	2	3	30 cm Deep Ceramic Cup No. 1	2	3
		Soilwater NH_4-N, ppm					
34	Control	15.2	12.9	15.9	-	-	-
42	Control	16.2	15.7	-	17.2	-	-
52	Control	7.5	11.4	-	15.9	13.6	-
43	GU, surf. applied	25.6	25.7	-	27.3	-	-
51	GU, 10 cm depth	21.3	17.3	23.5	24.7	-	-
33	SCU, 10 cm depth	38.5	32.2	-	30.7	29.3	-

GU = Granular urea, commercial grade; SCU = Sulfur coated urea; - = no ceramic cup available.

Table 9. Soilwater NH_4-N at different depths in 4 x 4 ft. boxes on 9/16/83.

Box No.	Fertilizer Treatment	5 cm Deep Ceramic Cup No. 1	2	3	30 cm Deep Ceramic Cup No. 1	2	3
34	Control	13.1	5.6	15.4	-	-	-
42	Control	16.4	13.8	-	16.8	-	-
52	Control	10.9	22.8	16.0	6.0	-	-
43	GU, surf. applied	21.0	13.8	-	23.7	-	-
51	GU, 10 cm depth	17.0	15.4	23.4	17.0	15.4	23.4
33	SCU, 10 cm depth	36.8	29.4	-	29.2	30.5	-

GU = Granular urea, commercial grade; SCU = Sulfur coated urea; - = no ceramic cup available.

Table 10. Effect of straw, ammonium and gypsum application on growth of wild rice.

Container No.	Peat	Amendment	pH 6 cm in peat	Eh mv	Dry Wt. of Plant g	Concentration in Plant Tops N %	P %	K %	Ca %	Mg %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	B ppm	Al ppm	Na ppm
1	Kosbau	None	5.2	-105	2.5*	1.26	0.53	2.6	0.39	0.15	81	194	41	16	7	25	764
2	"	3S	5.9	-126	0.1	1.37	-	-	-	-	-	-	-	-	-	-	-
3	Clearwater	3S, G	6.9	-172	-	-	-	-	-	-	-	-	-	-	-	-	-
4	"	3S, N	6.7	-176	1.8*	1.19	0.35	3.1	0.37	0.10	29	238	25	8	3	4	452
5	"	3S, G,N	6.9	-137	-	-	-	-	-	-	-	-	-	-	-	-	-
6	"	3S	7.0	-192	0.4	1.43	0.42	3.2	0.53	0.10	39	245	26	7	4	12	739
7	"	1S	6.8	-214	2.1*	1.25	0.38	3.3	0.43	0.09	42	405	32	8	4	12	629
8	"	G	6.9	-178	0.9	1.52	0.42	2.0	0.11	0.23	65	374	47	16	15	5	972
9	"	N	7.0	-204	3.7*	1.44	0.31	1.1	0.35	0.17	26	118	22	10	6	6	3068

3S = 24,900 kg/ha wheat straw; 1S = 8,300 kg/ha; G = 10,000 kg/ha gypsum; N = ammonium chloride, 150 kg N/ha;
* = plants developed panicles

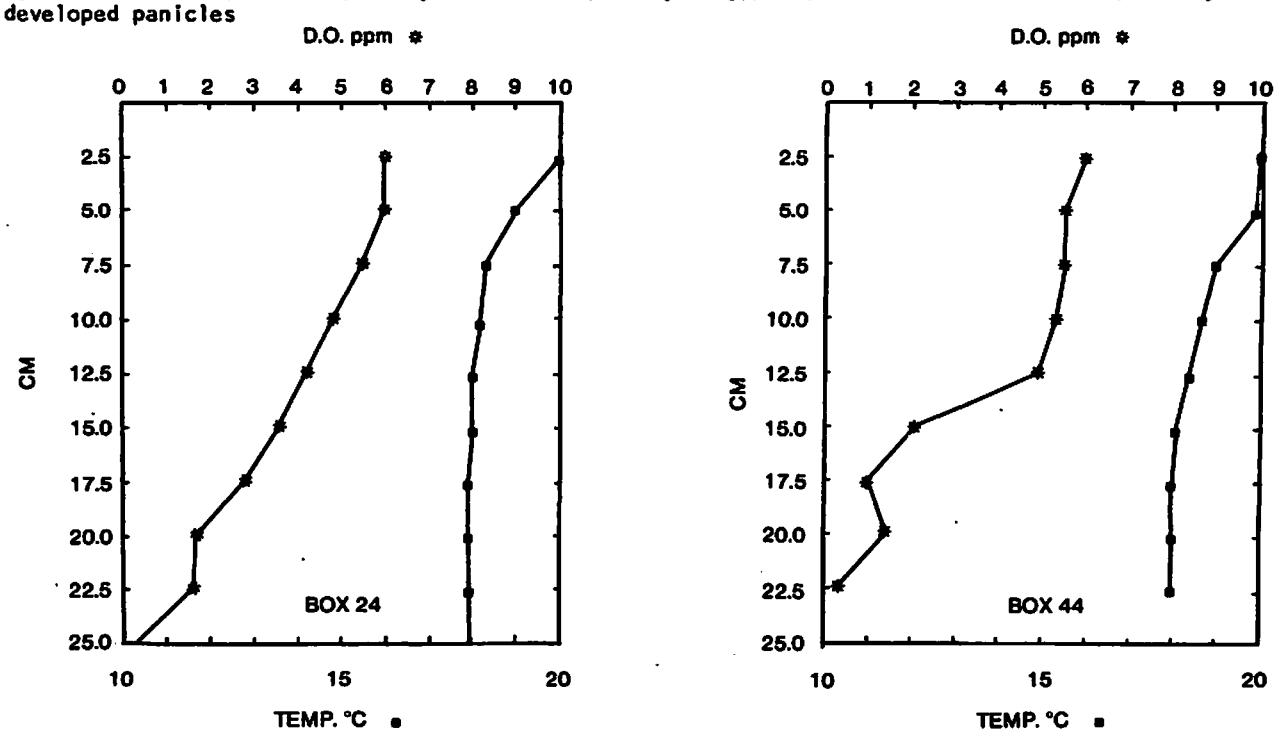

Fig. 5. Dissolved oxygen (DO) and temperature profiles of the floodwater in boxes No. 24 (GU, Surf) and 44 (GU, 10 cm.) on 6/30/83, 9:00 a.m.

Table 11. Yield and density of wild rice, and soil characteristics in different areas of paddies, Manomin Wild Rice Company, Aitkin County - 1983.

Paddy No.	Location	Sampling Depth inches	Grain Yield lb/A	Stems per 16 sq.ft.	Ash %	pH	Extract-able P lb/A	Exchange-able K lb/A	Zn ppm	S ppm	Cu ppm	N %	Ca %	Mg %	Al %	Fe %	Mn ppm	B ppm
116	near	0-6	301	57	34	6.2	56	49	13	53	5	2.1	2.7	0.3	0.80	0.92	239	15
	ditch	6-12			27	6.1	37	35	8		3	2.3	2.7	0.2	0.76	0.89	198	12
		12-18			26	6.1	14	44	3		2	ND	→					
116	distant	0-6	230	63	31	5.9	51	53	14	49	5	ND	→					
	from	6-12			26	5.6	18	68	11		4	ND	→					
	ditch	12-18			21	5.4	9	68	3		1	ND	→					
117	near	0-6	458	85	35	6.1	57	55	14	92	5	2.4	2.6	0.3	0.89	1.01	233	15
	ditch	6-12			26	5.8	12	48	4		3	3.0	2.5	0.3	0.70	1.18	175	14
		12-18			54	6.0	10	86	2		3	2.0	1.9	0.4	1.60	1.75	161	14
117	distant	0-6	408	56	31	6.0	35	56	16	48	5	2.2	2.5	0.3	0.84	0.86	181	11
	from	6-12			23	5.6	8	35	6		3	2.6	2.7	0.3	0.60	1.03	144	9
	ditch	12-18			24	5.6	9	47	ND		ND	3.1	2.4	0.3	0.62	1.01	144	10
118	near	0-6	498	76	35	6.0	52	51	14	61	4	2.2	2.4	0.3	0.78	1.01	227	10
	ditch	6-12			24	5.8	27	22	8		3	2.7	2.2	0.3	0.53	0.96	166	11
		12-18			22	5.6	9	50	5		3	3.0	1.9	0.3	0.57	1.08	115	9
118	distant	0-6	260	61	33	6.0	39	84	13	40	4	2.4	2.5	0.3	0.73	0.95	198	11
	from	6-12			20	5.7	8	35	5		2	2.9	2.1	0.3	0.51	0.93	137	9
	ditch	12-18			24	5.7	9	58	4		2	2.9	2.0	0.3	0.70	0.97	127	10

ND = not determined

Table 12. Soil characteristics in different areas of paddies, Diebold Farm, Aitkin County - 1983.

Paddy No.	Location	Sampling Depth inches	Ash %	pH	Extract-able P lb/A	Exchange-able K lb/A	Zn ppm	S ppm	Cu ppm	B ppm
10	near ditch	0-6	25	5.2	34	95	18	21	1.4	0.3
		6-12	22	5.1	17	73	15	31	1.4	0.3
10	distant	0-6	21	5.3	31	117	19	47	1.1	0.3
	from ditch	6-12	21	5.3	34	135	18	23	1.3	0.3
11	near ditch	0-6	89	5.4	36	303	1	12	1.0	0.1
		6-12	87	5.5	60	260	2	10	1.6	0.2
11	distant	0-6	23	5.5	50	191	23	22	2.2	0.4
	from ditch	6-12	20	5.3	26	137	22	24	2.1	0.2