A Report on Field Research in Soils

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A Report on Field Research in Soil Science

The 1986 edition of the "Bluebook" is a compilation of data collected and analyzed throughout Minnesota. Information was contributed by personnel of the Department of Soil Science including Extension Soil Specialists, Soil Scientists at the branch stations of Crookston, Lamberton, Morris, and Waseca; Becker and Staples experimental sites; and Soil and Crop area agents. Associated personnel from the Soil Conservation Service, and the Soil and Water Research group of the ARS-USDA, the Tennessee Valley Authority, the Departments of Agriculture and Natural Resources also contributed information.

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Some of the results are from 1985 experiments and should be regarded on this basis. Since most data are from only 1985 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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AGRICULTURAL YEAR PRECIPITATION, 1984 - 1985

E.L. Kuehnast and D.G. Baker

The usual way to consider precipitation totals is for the period from January through December, that is, the calendar year. However, for most agricultural purposes a better picture is obtained if the 12-month period from September of one year to August of the next year is considered. For full season crops such as corn and beans, the water year in effect ends in August. The precipitation that falls in September, for example, is ordinarily not very essential for the current crop and it goes toward storage in the soil for next year's crop. As a result in our annual reviews of the Minnesota climate we have emphasized the agricultural year precipitation.

For the September 1984 - August 1985 precipitation year Fig. 1 is presented. The annual totals almost everywhere are impressive with the amounts ranging from a low of about 21 inches in the extreme northwest (Polk county) to highs of more than 40 inches in north central and east central Minnesota.

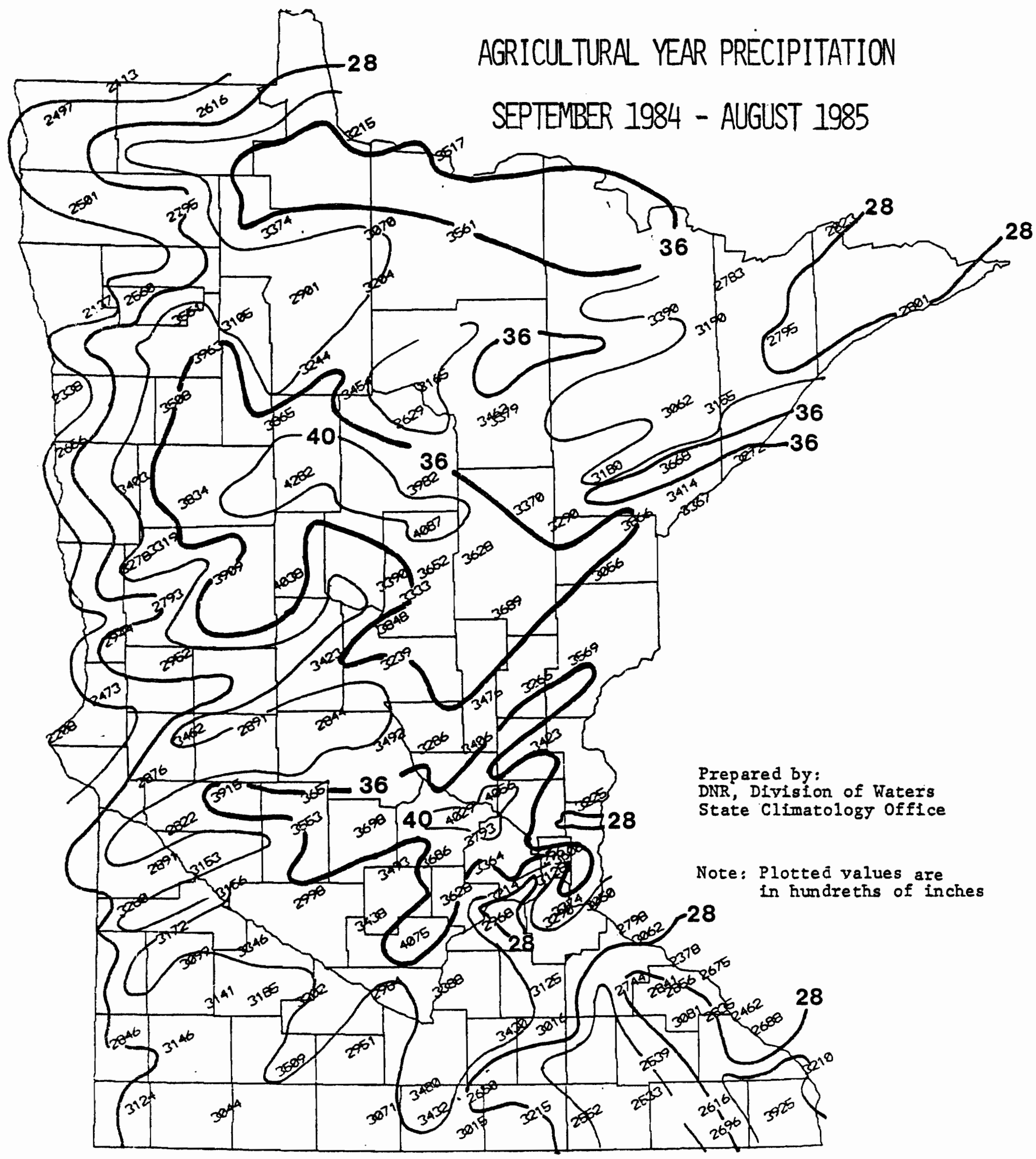

Fig. 1. Total agricultural year (September, 1984 - August, 1985) precipitation in inches.

The departure from normal map, Fig. 2, shows that almost all of the state received more than the 1951-1980 normal precipitation. The only exception occurred in the southeast. In the southeastern counties only Houston county was not below normal. Fillmore, Olmsted, Dodge, and Mower counties had areas that were as much as 6 inches below normal. Grand Meadow was the lowest in the state with 6.31 inches below normal.

The wettest area with more than 12 inches of precipitation above normal was a strip about 15 miles wide running across southern Kandiyohi, northern Meeker and Wright counties, and extending into Anoka county. A second even larger area with an excess of 12 inches above normal included eastern Polk, Mahnomen, Becker, southern Clearwater, and most of Hubbard and northern Cass counties. The Park Rapids station had 16.88 inches above normal, the wettest station in the state during this last agricultural year.

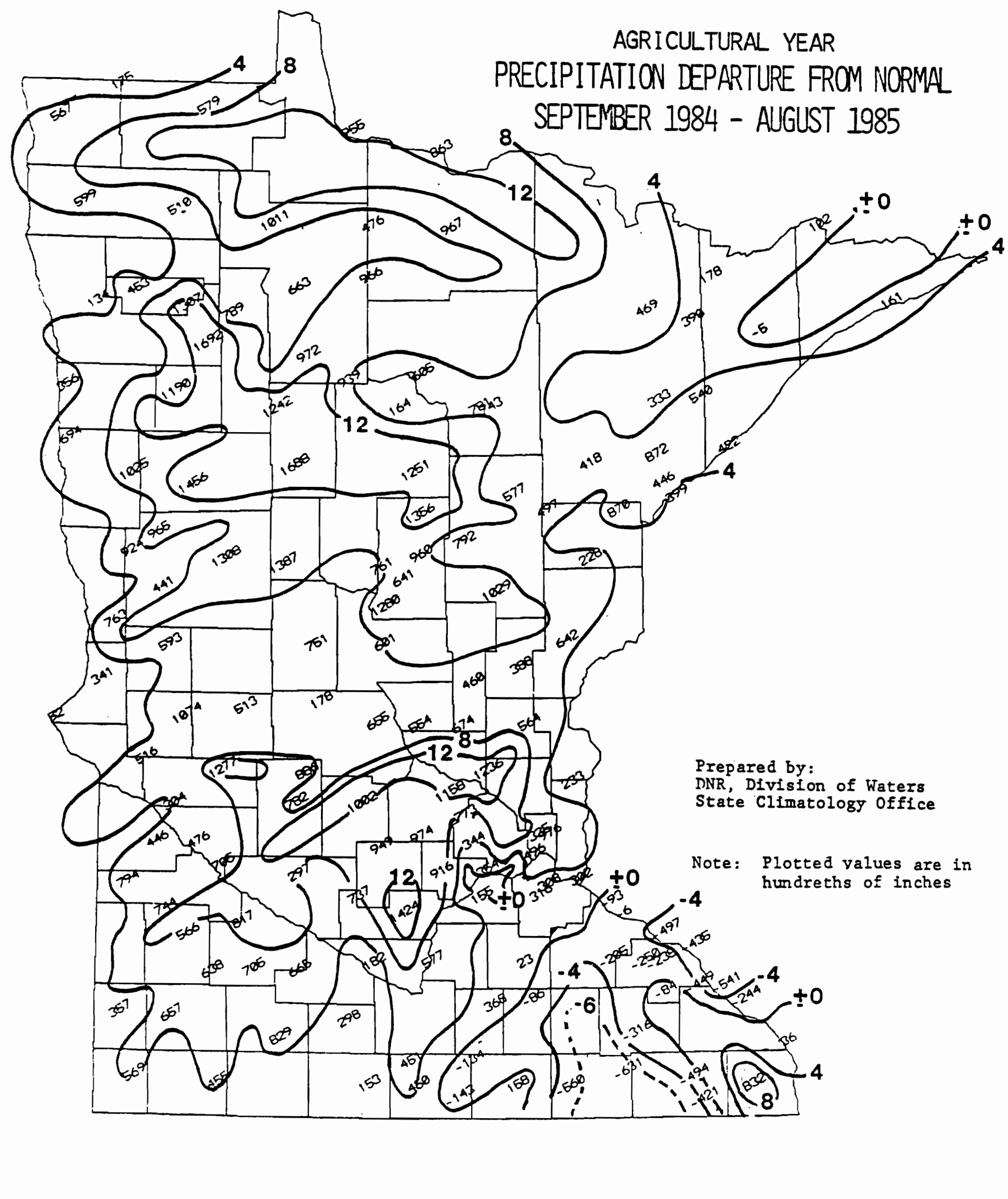

Fig. 2. Precipitation departure from normal in inches for the September, 1984 - August, 1985 agricultural year.

SOIL MOISTURE SITUATION, SPRING 1986

E.L. Kuehnast and D.G. Baker

This report is based on precipitation data which have been modeled mathematically into soil moisture amounts for precipitation measuring stations across the state. 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 10 inches.

Fig. 3 shows the soil moisture amounts calculated for the National Weather Service Cooperative Observer stations. Lines of equal soil moisture values were drawn based on some 440 locations. The individual stations are too numerous to show on a map of this scale.

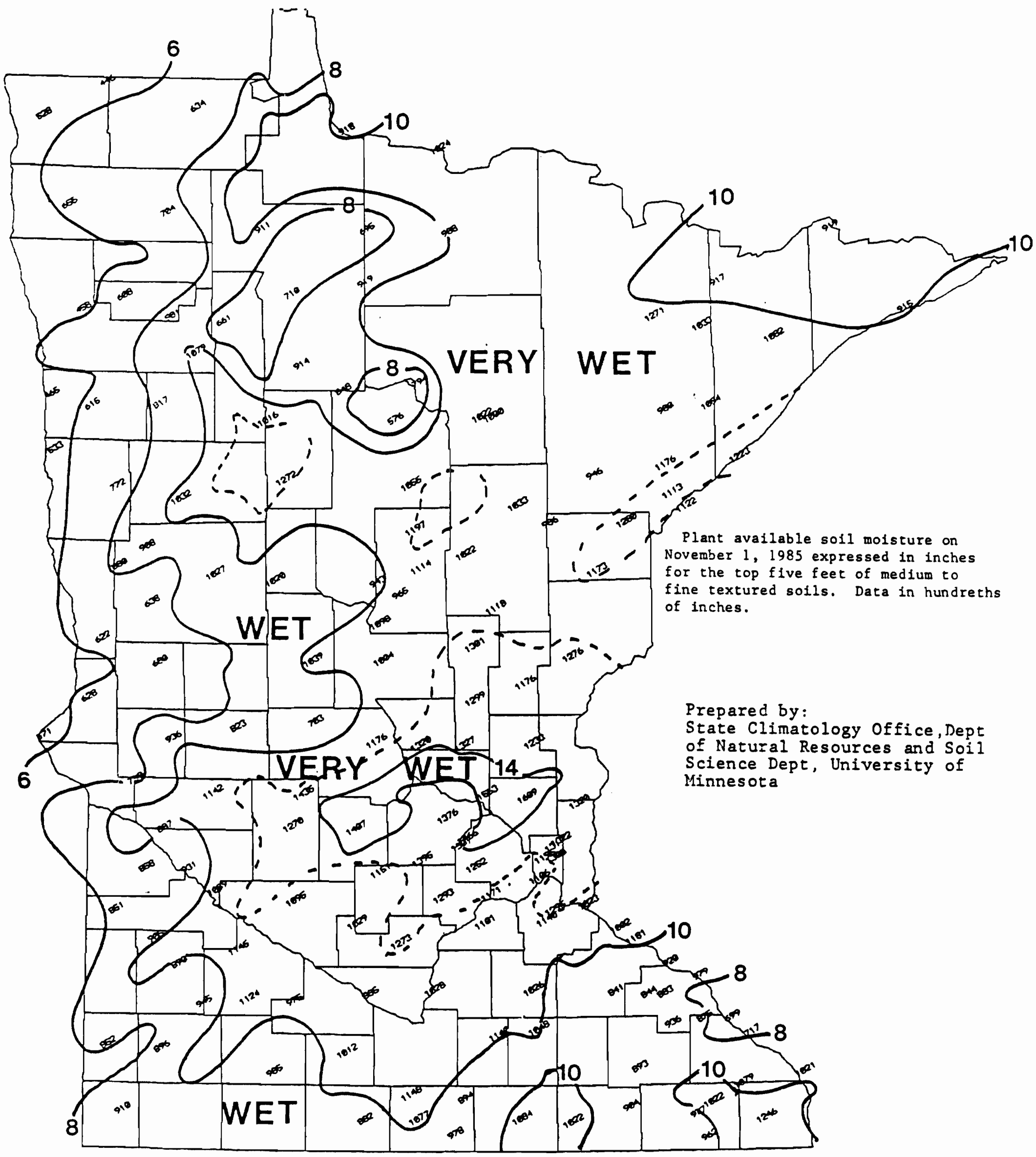

Fig. 3. Total plant available soil moisture on Nov. 1, 1985, expressed in inches, within the top 5 feet of medium to fine textures soils.

This is the fifth consecutive year in Minnesota that wet fall and winter soil moisture conditions have occurred. The 8 to 10-inch amounts of soil moisture extend over the entire state except for the Red River valley area - the western one to one and a half county-wide area from Big Stone county north to the Canadian border. Even these counties have more than their average soil moisture. Soils with 10-inches of soil moisture are considered to be at their maximum water holding capacity. Any excess will be lost through overland flow, which usually causes soil losses, or through internal drainage. Some of the surplus water reaches streams, lakes or groundwater reserves. Early last fall, areas of heavy surface runoff included most of Meeker, Sherburne and Anoka counties, and parts of Stearns, Wright, Benton, Mille Lacs, Isanti, Hennepin, and Chisago counties.

To determine soil conditions for tillage operations, crop planting, and agricultural applications this spring, several factors need to be considered. First, last fall and this winter soil moisture conditions have been wet to very wet across the state. Second, a shallow soil frost (see Fig. 12, p.) has resulted from the early heavy snow cover in late November and early December. These conditions have been with us all winter. The shallow frost means the soil water has been able to percolate to deeper depths. For example, in the Twin Cities a water-table that was 18 inches from the surface in October was lowered to 55 inches by the 1st of February. Other evidence of continued percolation of the water over winter is shown from the winter stream flows recorded by U.S. Geological Survey observers who have noted continued very high river flow, which has been record breaking in some instances. Another factor with respect to the shallow soil frost, that could be a positive factor, is that soils are expected to thaw out a week earlier than normal. In southern Minnesota this would be about the last week of March rather than the first week of April. As a result, the surface soil would have a week longer to dry.

Our interpretation of the current situation is that soil preparation and planting will depend on how much rainfall is received during the early spring. Normal or above rains will cause delays in spring field work. We suggest that one not "dilly-dally" because of the high soil moisture amount but make as much use as possible of the spring working period, which all too frequently is very brief. The "window of opportunity" in terms of field work ordinarily decreases rapidly as the maximum precipitation period of early June approaches.

LAMBERTON AND WASECA SOIL MOISTURE

D.G. Baker, W.W. Nelson, G.W. Randall, and D.L. Ruschy

Precipitation during the last four years at Lamberton, 1982-1985, has resulted in much above average soil moisture contents. This is evident in Fig. 4, 5, 6, and 7 which depict the seasonal change for each of the years 1982, 1983, 1984, and 1985, respectively.

The amount of water present during these four seasons indicates that moisture stress has not occurred except perhaps for the briefest of periods. As a result, insofar as moisture is concerned, corn yields would be high, particularly with the moisture contents remaining relatively high during the critical silking and tasseling period of mid- to late July.

These four years, 1982-1985, of nearly constant high soil moisture during the growing season at Lamberton are proving to be unique. In the Lamberton soil moisture record, which now exists from 1964-1985, there is not to be found a similar set of four consecutive years with such favorable years.

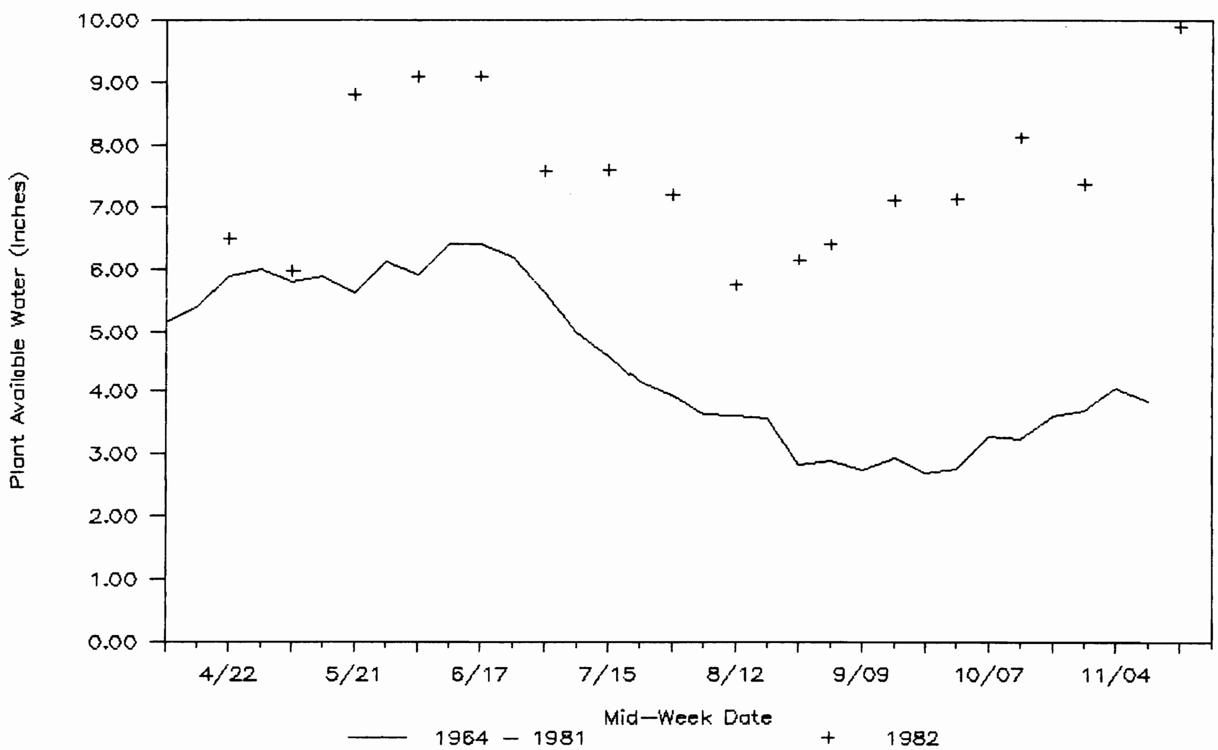

Fig. 4. Total plant available soil moisture under corn in 5 feet of soil during the 1982 season compared to the 1964-1981 average, Lamberton, Minnesota.

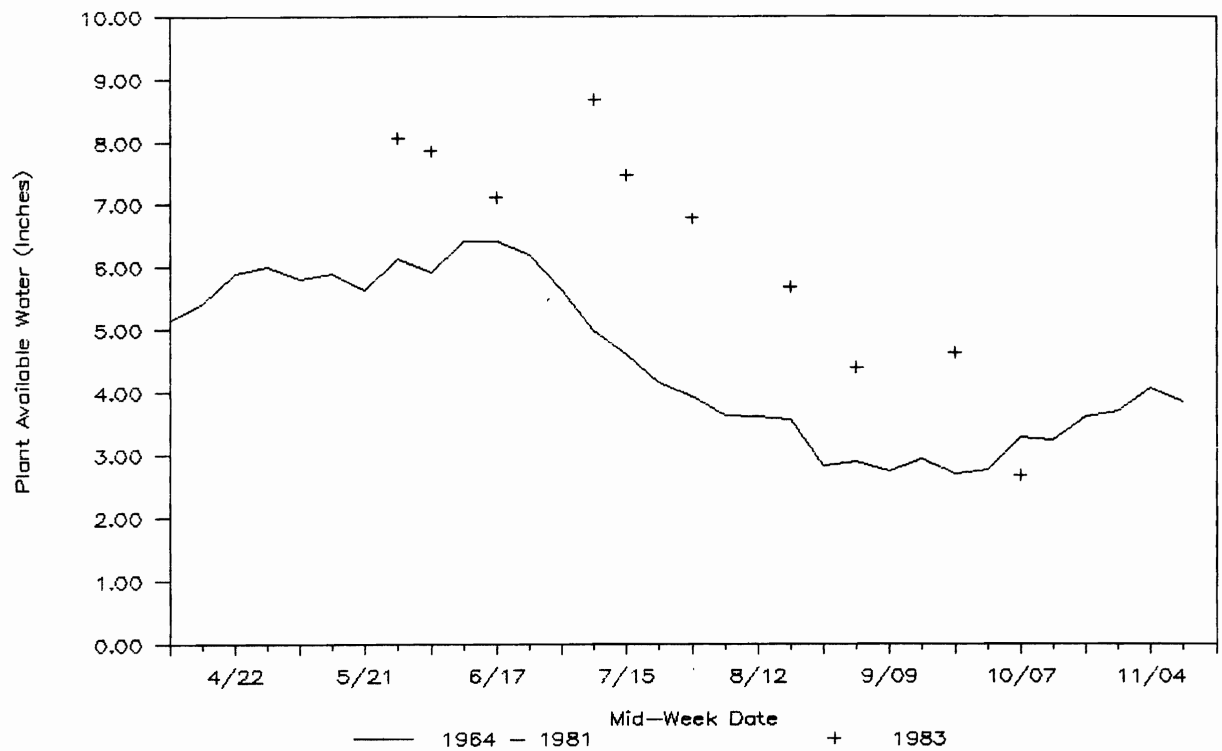

Fig. 5. Total plant available soil moisture under corn in 5 feet of soil during the 1983 season compared to the 1964-1981 average, Lamberton, Minnesota.

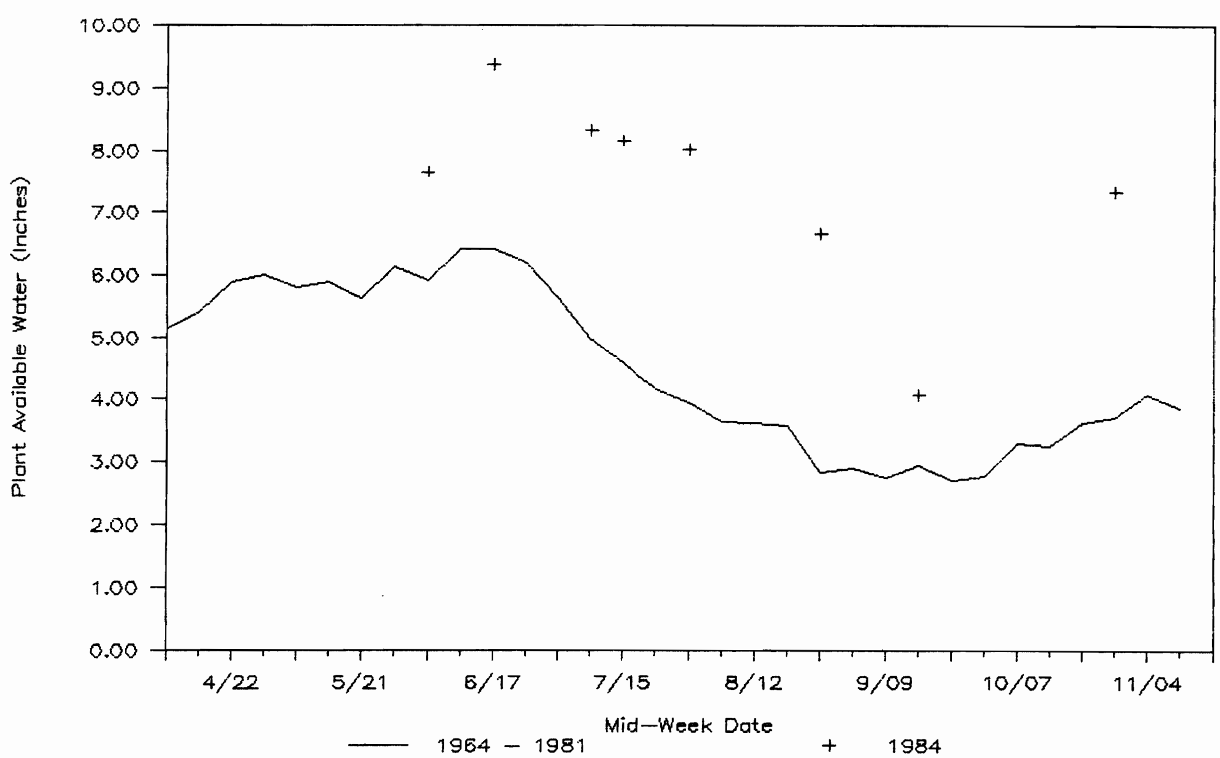

Fig. 6. Total plant available soil moisture under corn in 5 feet of soil during the 1984 season compared to the 1964-1981 average, Lamberton, Minnesota.

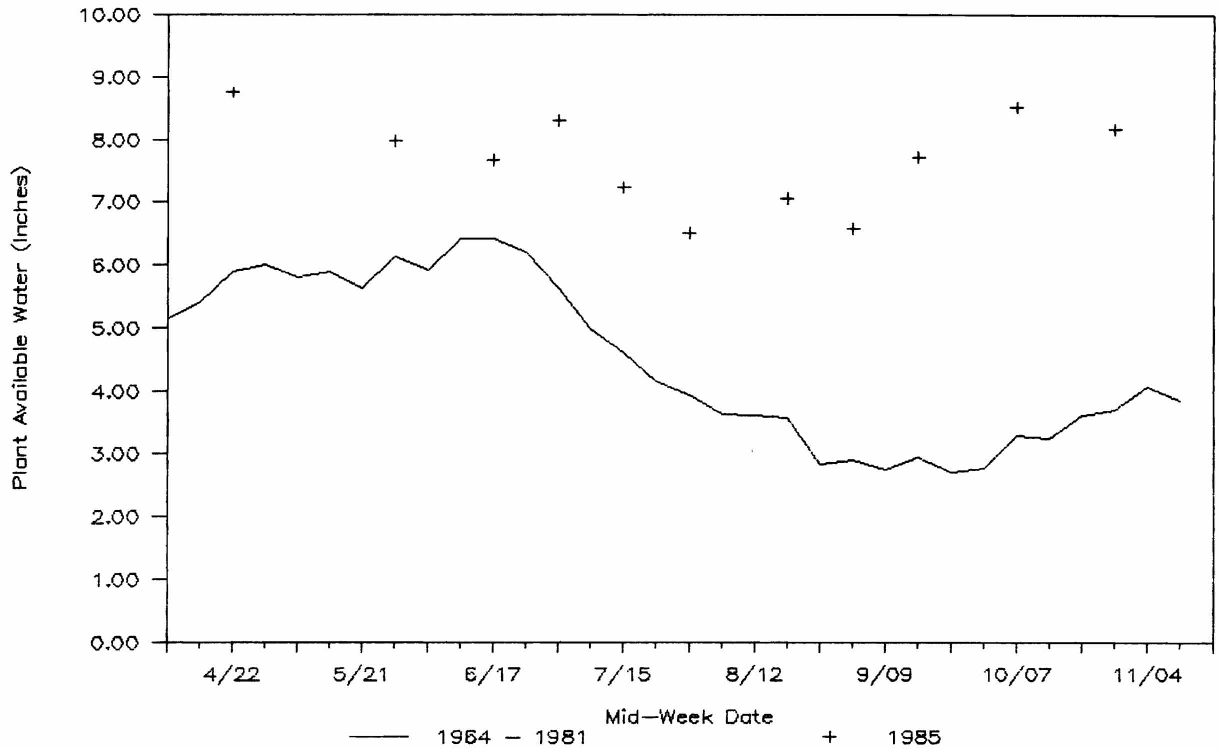

Fig. 7. Total plant available soil moisture under corn in 5 feet of soil during the 1985 season compared to the 1964-1981 average, Lamberton, Minnesota.

That the last four years have in general been above normal in precipitation amounts has been observed across several states including Minnesota and North Dakota. For example, the lake levels of a number of our lakes are well above average. This includes Lakes Cornelian and Vermilion in Minnesota and Devil's Lake in North Dakota. Even Great Salt Lake in Utah is currently above average and has been for several years. So, too has been the flow of the Mississippi and Minnesota Rivers as measured at St. Paul and at most river gage stations across the state. These occurrences are not just singular items but are a part of a general upward trend in precipitation to be found across much of the region. There are "holes" in this trend to be sure, and there are areas where the precipitation has been deficient. But in general we do seem to be experiencing a wet period that is not just a local feature. Fig. 8 shows how much greater the average total soil moisture at Lamberton during 1982-1985 has been than the 18 year average of 1964-1981. There is a seasonal difference that ranges from about 1.5 inches to more than 3 inches in favor of the last 4 years.

The Waseca soil moisture, Fig. 9, during the 1985 season has not exhibited the large difference in water content that is found at Lamberton. In fact in mid-season it was less than the 1977-1984 average from early July to early August - but not by very much. Certainly the corn crop must not have been subjected to any undue stress with the total soil moisture contents remaining above 5 inches.

In Fig. 10 is shown the 1977-1985 average soil moisture contents at both Lamberton and Waseca under corn. As with all of these figures relating to soil moisture the inches of water shown are the amounts that are readily available in a column of soil 5 feet deep. The difference in water content between the two stations is a good indicator of what is probably the major climatic difference between them. And the difference is clearly in favor of Waseca, which has the higher soil water content. However, this advantage, at least during the record period of 1977-1985, is not all that large during the very critical silking and tasseling period of mid- to late July.

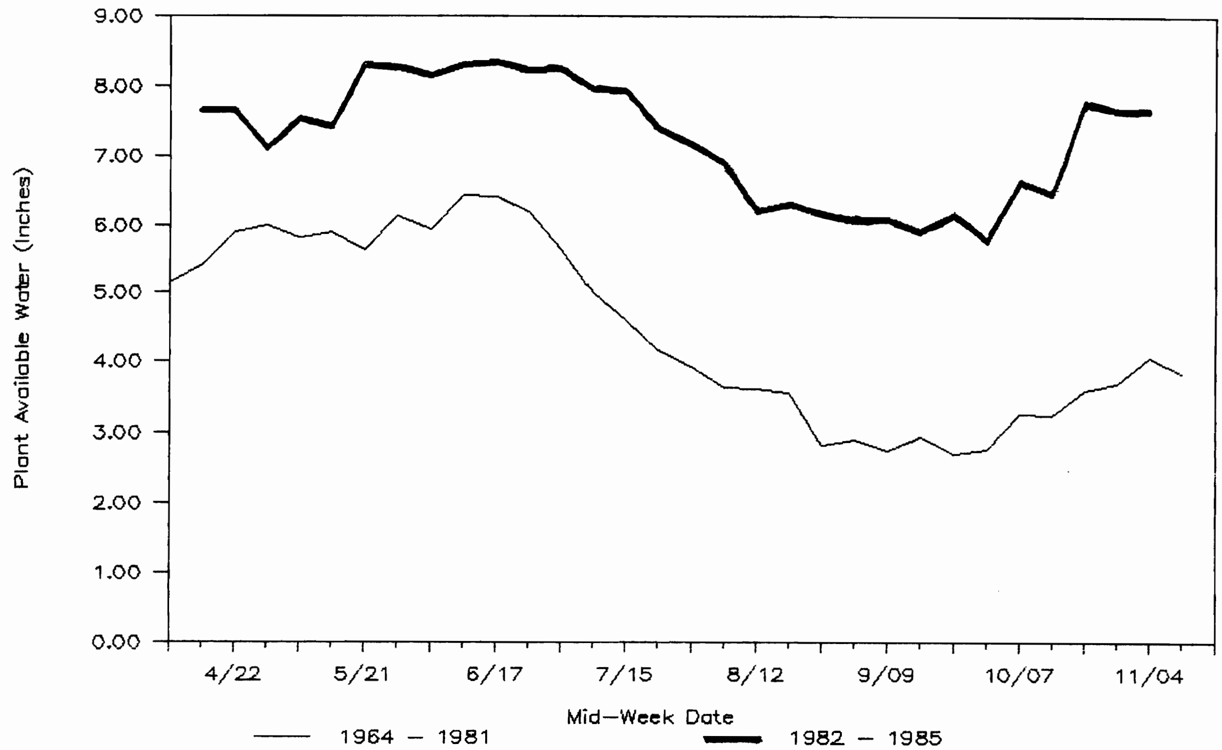

Fig. 8. Comparison between the average total plant available soil moisture under corn in 5 feet of soil during the 1982-1985 seasons and the 1964-1981 seasons, Lamberton, Minnesota.

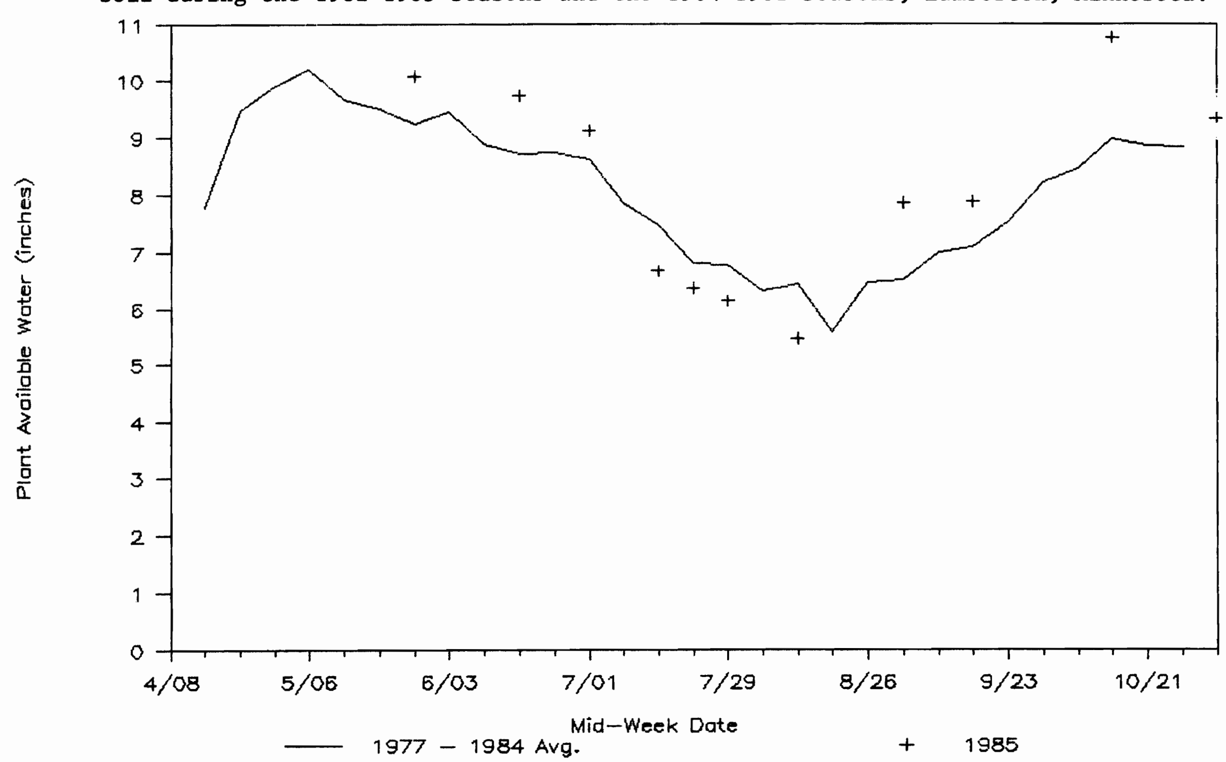

Fig. 9. Total plant available soil moisture under corn in 5 feet of soil during the 1985 season compared to the 1977-1984 average, Waseca, Minnesota.

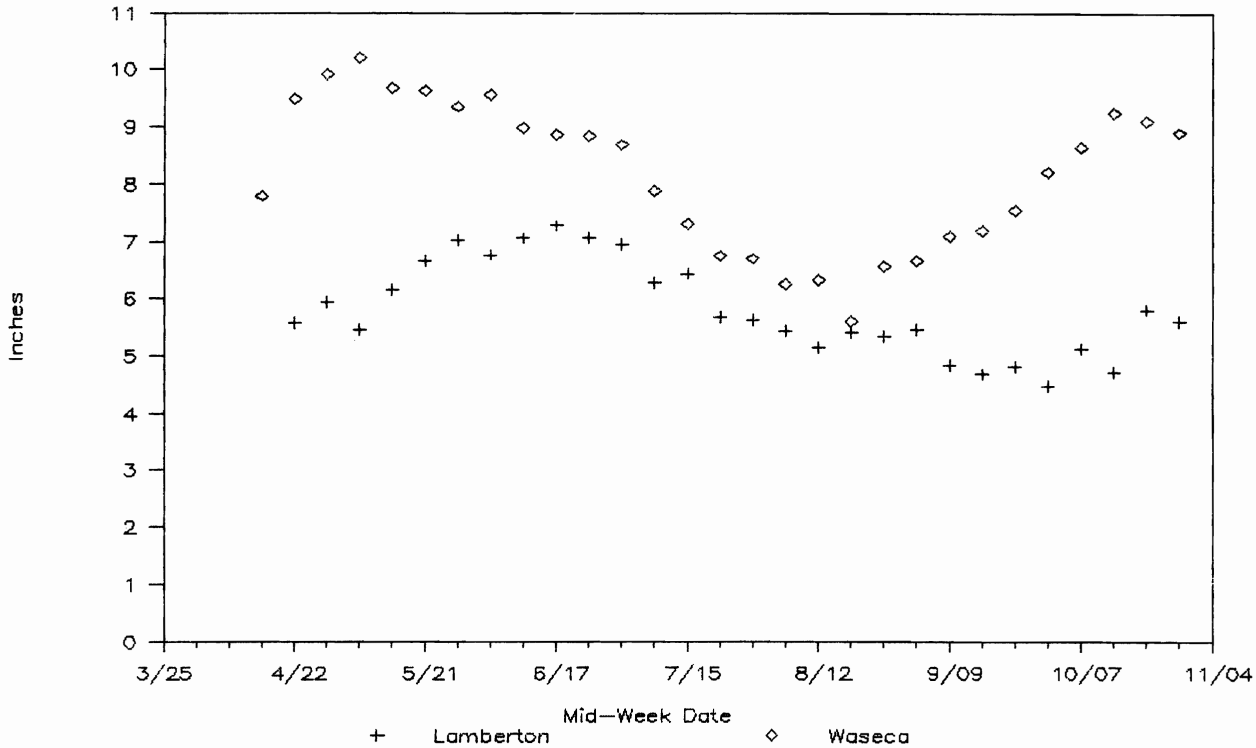

Fig. 10. Comparison between the average plant available soil moisture under corn at Lamberton and at Waseca, 1977-1985.

LONG TERM TWIN CITY TEMPERATURE AND PRECIPITATION TRENDS

D.G. Baker, D.R. Ruschy, and E.L. Kuehnast

Fig. 11 is shown as a matter of general interest. This is a comparison of the long term trends in temperature and precipitation based upon the Minneapolis-St. Paul record. So that credit is properly given we should understand that from 1820-1890 this record is based essentially upon that from Fort Snelling. The earliest part of the military record was observed by the post surgeon and the latter part was the responsibility of the Signal Corps, U.S. Army. With the formation of the U.S. Weather Bureau in 1890 the records have since been in the Bureau's hands or its successor the National Weather Service.

There are several things of real interest in Fig. 11. One is the general increasing trend in the annual temperature from approximately the 1870's to the 1960's. Note that the current temperatures are comparable to those experienced in the 1930's.

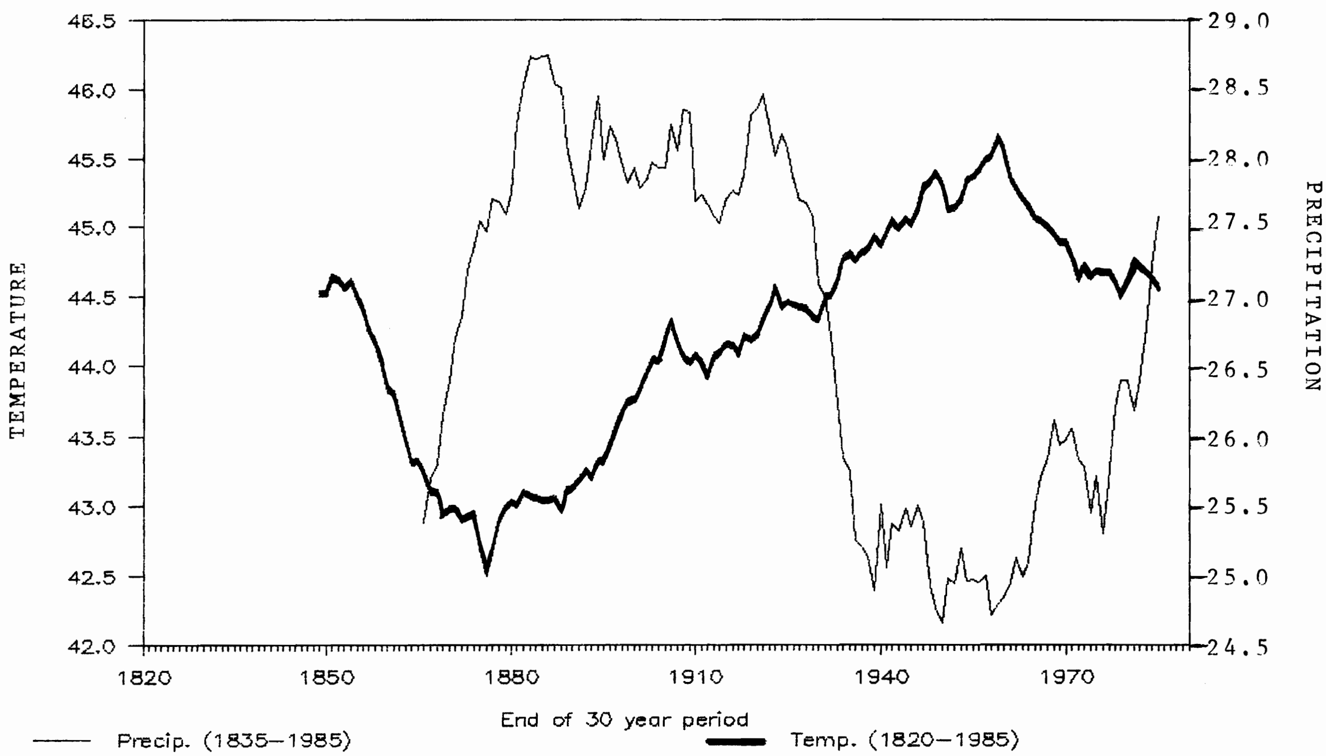

Fig. 11. Comparison of the long-term 30-year average annual temperatures and annual total precipitation at Minneapolis-St. Paul. The 30-year average value is plotted at the end of each 30-year period. The temperature record is from 1820-1985 and the precipitation record is from 1837-1985.

The precipitation record in Fig. 11 shows two very precipitous changes in the total annual amount. One is the very rapid increase at the beginning of the record. The second great change is the fall in the annual amount that occurred beginning in the 1920's. Only lately has the precipitation begun to recover from that low period.

The apparent reversal of the temperature and precipitation records (that is, when one is high the other one is low) seems to be indicated. It certainly is a tempting conclusion to reach when first looking at Fig. 11. It is true that with higher precipitation one might expect lower temperatures to result, because more of the available energy is consumed in evapotranspiration and less energy remains to heat the air. However, it should be noted that the high precipitation period remained high and relatively constant while the temperature was generally increasing. That is, the temperature showed no precipitous changes similar to that of the precipitation. So this apparent inverse relationship between temperature and precipitation may be just that: more apparent than real.

DEPTH AND DURATION OF FROZEN SOIL

D.B. Wall and D.G. Baker

At our St. Paul campus weather station we have been measuring soil temperatures not only during the growing season but throughout the entire year. As a result we have a long series of winter soil temperatures that now exist from 1964. These measurements permit us to trace the freezing isotherm within the soil. Fig. 12 shows what has been found so far in this 1985-1986 winter through Feb. 28. The heavy and persistent snow cover, averaging about 40 cm (16 inches), has prevented the soil from freezing deeper than about 30 cm (12 inches).

It is interesting to see just how valuable snow is as an insulator. A comparison of Fig. 12 with Fig. 13 permits this to be done. Except for the occasional periods when we were unable to remove the snow for a day or so, usually on a weekend, we kept a plot free of snow cover. Without the insulation provided by snow the freezing depth reached about 160 cm (64 inches) as shown in Fig. 13 instead of 40 cm (16 inches) under the actual snow cover of this winter.

The shallow frost this winter can also be compared to the long-term average of 1964-1984, Fig. 14, showing that the mean freezing depth is more nearly 90 cm (36 inches). It should be noted in Fig. 14 that the maximum depth of freezing is reached nearly at the end of winter - in late February or early March. Another thing to observe is that the soil thaws both from the top and the bottom. And in most years the last part of the soil to thaw is at a depth of about 24 inches (60 cm) in the first week of April. This last feature explains why in the early spring meltwater or rain can be held on the open fields for several days and then to seemingly disappear overnight. The water has drained through the soil once the subsoil has thawed.

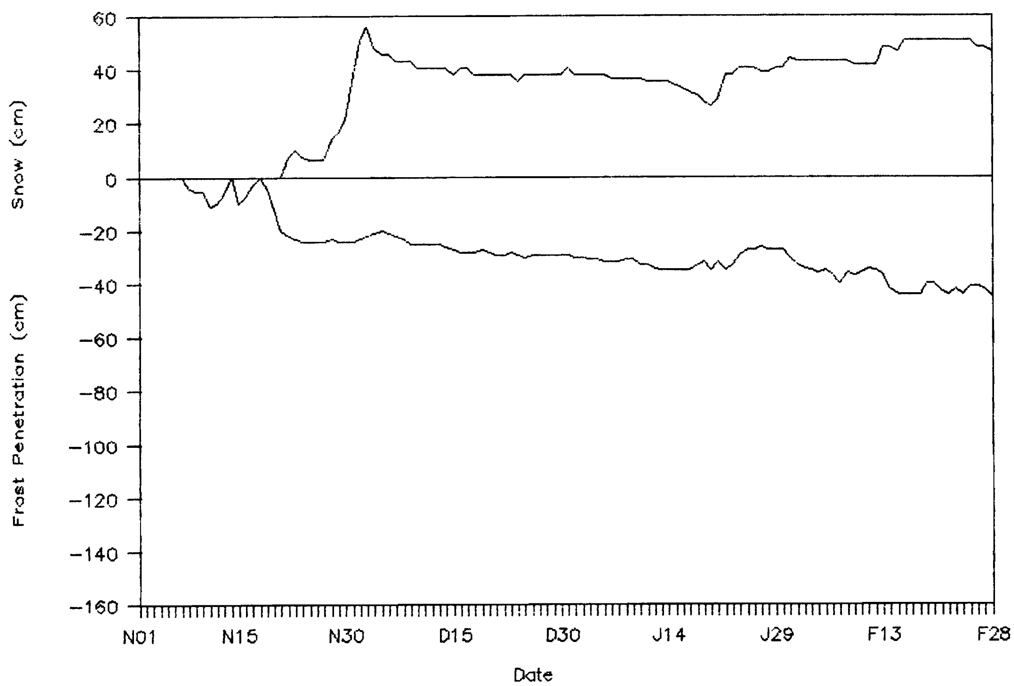

Fig. 12. Soil freezing depth and depth of snow cover in centimeters (10 cm = 4 inches) during the 1985-1986 winter at the University of Minnesota, St. Paul campus. The period is from Nov. 1 to Feb. 28.

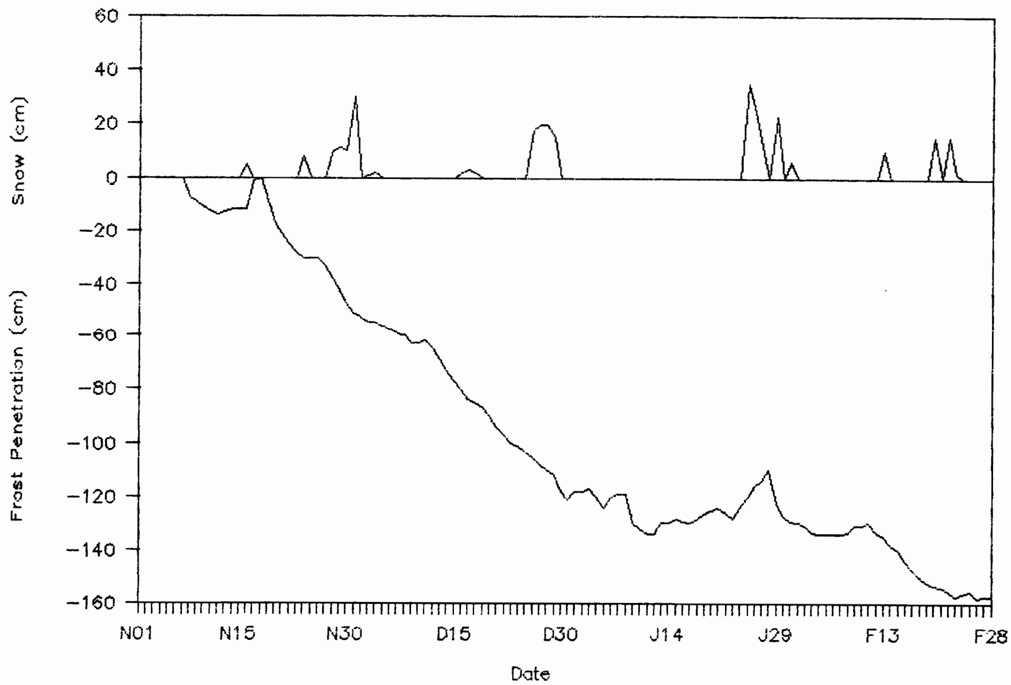

Fig. 13. Soil freezing depth in centimeters (10 cm = 4 inches) under a plot kept free of snow (except as indicated) during the 1985-1986 winter at the University of Minnesota St. Paul campus. The period is from Nov. 1-Feb. 28.

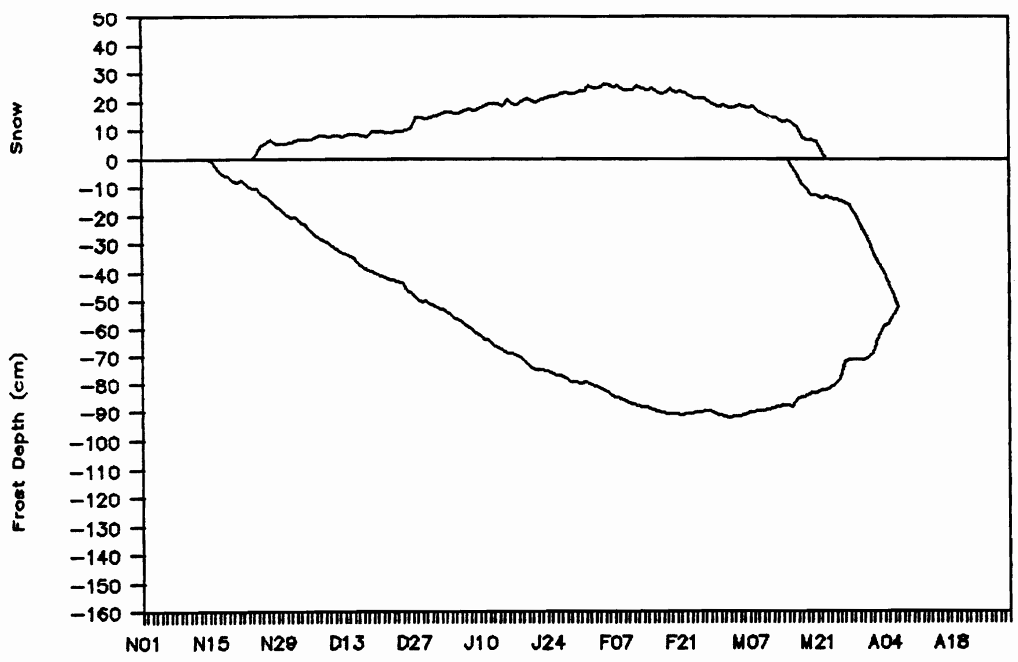

Fig. 14. Average soil freezing depth and average depth of snow cover in centimeters (10 cm = 4 inches) at the University of Minnesota St. Paul campus for 21 winters, 1964-1965 through 1983-1984.

MANAGEMENT OF UAN ON THE COARSE TEXTURED IRRIGATED SOILS OF MINNESOTA FOR EFFICIENT CORN PRODUCTION BECKER, MN 1985

G.L. Malzer and T. Graff

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

Experimental Procedures

Two separate experiments were established at the Sand Plain Research Farm near Becker, Minnesota.

Experiment 1 consisted of 25 treatments with four replications arranged in a randomized complete block design. Treatment variables included factorial combinations of six N rates of UAN (100, 134, 168, 202, 235, and 269 kg/ha) and four methods of application (2/3 of N rate early 1/3 late, all late, 2/3 early with DCD 1/3 late, and 2/3 early with N-Serve, 1/3 late), plus a zero N control. Early N treatments were applied at the 3-4 leaf growth stage (May 5) while late applications were made at the 9-10 leaf growth stage (June 13). All treatments were injected into the soil on 76 cm centers approximately 7 cm deep and 18 cm away from the row. Nitrification inhibitors were mixed with the UAN prior to application and were applied at rates of 7.84 kg/ha for DCD and 0.56 kg/ha a.i. for N-Serve.

Experiment 2 consisted of 24 treatments with four replications in a randomized complete block design. Treatment variables included factorial combinations of three rates of N as UAN (100, 168, and 235 kg/ha), two methods of application (broadcast vs. injected), and two times of application (3-leaf and 8-leaf growth stages). Additional nitrification inhibitor (DCD and N-Serve - similar to above) treatments were applied to provide comparisons for all injected N treatments applied at the three-leaf growth stage. Four additional treatments were included to assess the influence of adding ammonium thiosulfate (10% of the N) to UAN. Treatments were injected at two N rates (100 and 168 kg/ha) at two times of application.

Experiment 1 and 2: Prior to planting, broadcast applications of potassium-magnesium sulfate (336 kg/ha 0-0-22), and (280 kg/ha 0-14-42) were made and incorporated by plowing. Corn (Pioneer 3906 - 95 relative maturity) was planted on April 26th in .76 m rows at a population of 75,800 seeds/ha. Starter fertilizer was applied at the rate of 185 kg/ha 8-10-30, side banded at planting. A tank mix of Atrazine (2.24 kg/ha) and Lasso (2.24 kg/ha) was applied on April 4th for weed control.

Leaf samples from opposite and below the ear at mid-silking were obtained on July 15th, dried and analyzed for Kjeldahl N. Total dry matter production and grain yields were determined on September 16-17th by hand harvesting 9.29 m^2 of plot area. Ears were separated from the stalks, field weights obtained, and samples removed for moisture and N determination. Grain yields were adjusted to 15.5% moisture.

The irrigation program was started on April 30th and continued through August 27th with a total of 22.22 cm being applied through irrigation. An additional 60.5 cm of water was obtained during the growing season as rainfall.

General Results

The 1985 growing season was characterized as being warm and dry during the early portions of the season and cool and wet during the latter portion of the season. Yields obtained at this location in 1985 were excellent. In general, the lack of precipitation early in the growing season (when most of the N loss normally takes place) resulted in minimal N loss, and relatively little response to N management and/or nitrification inhibitors. The results for experiment 1 are presented in Tables 1 and 2 and experiment 2 results are presented in Tables 3 and 4.

Experiment 1: Yield increases in the order of 8.7 mt/ha (140 bu/A) could be associated directly with fertilizer N application. Optimum rates of application appeared to be in the order of 168 kg/ha (150#/A). The use of nitrification inhibitors with split N applications had little effect on grain yield suggesting that N losses from leaching during the 1985 season were relatively low. Split N applications were superior to one single late (9-leaf stage) N application. The reason for the reduced effectiveness of this treatment is not well understood. It may have been due to reduced availability created by the positioning of the N later in the season under relatively dry conditions. Mechanical damage to the root system with a late injection of N close to the row is also a possibility, but is questionable since a portion of the N for all treatments of the split N applications were also injected at the same time. Only if the root systems were different and would react differentially to such an application would such a result be anticipated.

Experiment 2: Optimum N rates were similar to that found in experiment 1 (150 #N/A). Nitrification inhibitors had no influence on grain yield or N utilization since leaching losses of N were relatively low. Early vs. late applications of UAN also had similar results suggesting minimal leaching N losses. Broadcast methods of N placement were, however, substantially inferior (23 bu/A to injected applications. This may have been due to several factors including volatilization, immobilization, or N positioning. Many of these factors are confounded so that it is impossible to clearly isolate the mechanism responsible for reduced availability. The hot, dry conditions after application would support volatilization losses, but the fact that the soil surface is acidic and has no residue on the surface would suggest that volatilization losses should be minimal. Immobilization is a possibility, but since no surface residue was present the magnitude of loss may be questionable. Positioning of N in certain situations can reduce N availability. The fact that the magnitude of loss was similar regardless of the time of application would suggest that positioning of N was not the major reason for reduced availability. A combination of volatilization and immobilization of the surface applied UAN would seem the most logical reason for reduced availability.

Table 1. Influence of N rates, nitrification inhibitors and method of application on grain yield, and dry matter production on irrigated corn Becker, MN - 1985.

Treatments					Grain Yields		Dry Matter Production		
N-Rates	Split 1	Inh.	Split 2	Meth.			Grain	Stover	Total
kg/ha	kg/ha		kg/ha		Bu/A	mt/ha	--------mt/ha---------		
Control	----	----	----	---	58.5	3.6	3.10	4.35	7.45
100	67	----	34	1	151.5	9.5	8.03	7.99	16.02
100	----	----	100	2	156.9	9.8	8.32	6.79	15.11
134	90	----	44	1	174.9	11.0	9.27	8.46	17.74
134	----	----	134	2	170.3	10.7	9.03	7.66	16.69
168	112	----	56	1	185.1	11.6	9.80	8.32	18.14
168	----	----	168	2	171.8	10.8	9.10	7.73	16.84
202	134	----	68	1	187.1	11.7	9.92	8.92	18.84
202	----	----	202	2	172.6	10.8	9.14	7.24	16.38
235	157	----	78	1	188.4	11.8	9.99	8.64	18.62
235	----	----	235	2	173.6	10.9	9.20	7.31	16.51
269	179	----	90	1	195.9	12.3	10.38	9.82	20.20
269	----	----	269	2	180.0	11.3	9.54	7.71	17.25
100	67	DCD	34	3	152.1	9.5	8.06	7.68	15.74
100	67	NS	34	4	146.7	9.2	7.78	7.35	15.13
134	90	DCD	44	3	172.3	10.8	9.13	8.27	17.40
134	90	NS	44	4	174.4	10.9	19.24	8.46	17.70
168	112	DCD	56	3	192.3	12.1	10.20	8.56	18.75
168	112	NS	56	4	187.4	11.7	19.93	8.07	18.00
202	134	DCD	68	3	188.7	11.8	10.00	8.80	18.81
202	134	NS	68	4	189.7	11.9	10.05	8.34	18.39
235	157	DCD	78	3	196.3	12.3	10.40	9.09	19.50
235	157	NS	78	4	186.5	11.7	19.88	8.78	18.67
269	179	DCD	90	3	195.8	12.3	10.38	8.82	19.21
269	179	NS	90	4	188.6	11.8	9.99	8.78	19.04
P-Value					99	99	99	99	99
BLSD (.05)					10.2	0.6	0.54	0.73	1.08
Main Effects									
Rates kg/ha									
100					151.8	9.5	8.05	7.45	15.50
134					173.0	10.8	9.17	8.21	17.38
168					184.2	11.6	9.76	8.17	17.93
202					184.5	11.6	9.78	8.32	18.10
235					186.2	11.7	9.87	8.46	18.32
269					190.1	11.9	10.07	8.85	18.93
P-Value					99	99	99	99	99
BLSD (.05)					5.1	0.3	0.27	0.36	0.53
Method	Early	Late							
1	2/3	1/3			180.5	11.3	9.57	8.69	18.26
2	---	3/3			170.9	10.7	9.05	7.41	16.46
3	2/3+DCD	1/3			182.9	11.5	9.68	8.54	18.24
4	2/3+NS	1/3			178.9	11.2	9.47	8.34	17.82
P-Value					99	99	99	99	99
BLSD (.05)					4.4	0.3		0.28	0.43
Rate X Method					94	94	94	99	99

Table 2. Influence of N rates, nitrification inhibitors and method of application on leaf, grain, and stover N content and total N removal by irrigated corn Becker, MN - 1985.

Treatments					N-Concentration			N-Removal		
N-Rates	Split 1	Inh.	Split 2	Meth.	Leaf	Grain	Stover	Grain	Stover	Total
kg/ha	kg/ha		kg/ha		---------%-----------			--------kg/ha---------		
Control	----	----	----	----	1.09	1.01	0.38	31.9	16.9	48.8
100	67	----	34	1	2.75	1.22	0.51	98.5	41.4	139.9
100	----	----	100	2	2.43	1.27	0.51	106.4	35.2	141.5
134	90	----	44	1	2.62	1.35	0.63	125.6	53.3	178.8
134	----	----	134	2	2.48	1.28	0.55	116.5	42.9	159.4
168	112	----	56	1	3.00	1.45	0.61	142.6	51.1	193.8
168	----	----	168	2	2.66	1.35	0.60	123.6	46.8	170.4
202	134	----	68	1	3.06	1.34	0.77	133.0	68.7	201.7
202	----	----	202	2	2.10	1.44	0.63	131.9	45.9	177.8
235	157	----	78	1	3.02	1.45	0.63	145.2	55.8	200.1
235	----	----	235	2	2.86	1.53	0.66	141.0	48.6	189.6
269	179	----	90	1	2.89	1.50	0.74	155.3	72.6	228.0
269	----	----	269	2	2.54	1.44	0.65	137.7	50.5	188.2
100	67	DCD	34	3	2.48	1.27	0.58	102.7	44.4	147.1
100	67	NS	34	4	2.56	1.07	0.43	83.6	32.1	115.7
134	90	DCD	44	3	2.75	1.20	0.57	109.9	47.0	156.9
134	90	NS	44	4	2.71	1.27	0.55	117.8	46.9	164.7
168	112	DCD	56	3	2.85	1.37	0.55	140.1	47.7	187.8
168	112	NS	56	4	2.94	1.33	0.62	132.4	50.7	183.2
202	134	DCD	68	3	3.00	1.36	0.63	137.3	55.8	193.1
202	134	NS	68	4	3.02	1.51	0.58	152.6	48.9	201.4
235	157	DCD	78	3	2.96	1.43	0.69	148.5	63.1	211.6
235	157	NS	78	4	2.65	1.48	0.66	146.5	58.4	204.9
269	179	DCD	90	3	2.80	1.53	0.76	158.6	67.2	225.8
269	179	NS	90	4	2.92	1.43	0.71	142.9	64.7	207.5
P-Value					99	99	99	99	99	99
BLSD (.05)					0.25	0.08	0.15	14.7	8.2	18.5
Main Effects										
Rates										
100					2.55	1.21	0.51	97.8	38.3	136.0
134					2.64	1.28	0.57	117.2	47.4	164.9
168					2.86	1.38	0.60	134.6	49.1	183.8
202					2.79	1.41	0.65	138.7	54.8	193.5
235					2.87	1.47	0.66	145.3	56.3	201.5
269					2.79	1.47	0.71	148.6	63.8	212.4
P-Value					99	99	99	99	99	99
BLSD (.05)					0.13	0.07	0.04	7.4	4.1	9.3
Method	Early	Late								
1	2/3	1/3			2.89	1.38	0.65	133.4	57.0	190.4
2	---	3/3			2.51	1.39	0.60	126.2	44.9	171.2
3	2/3+DCD	1/3			2.81	1.36	0.63	132.8	54.2	187.1
4	2/3+NS	1/3			2.80	1.35	0.59	129.3	50.3	179.6
P-Value					99	47	98	87	99	99
BLSD(.05)					0.01		0.04		3.4	8.1
Rate X Method					99	92	98	97	99	99

Table 3. Influence of N rates, nitrification inhibitors, method, and time of application on grain yield and dry matter production on irrigated corn Becker MN. - 1985.

N-Rate	Treatments Method	Inh.	Time	Grain Yields		Dry Matter Production Grain	Stover	Total
kg/ha				Bu/A	mt/ha	---------mt/ha----------		
Control	---------	----	----	73.3	4.6	3.88	4.55	8.42
100	Broadcast	----	1	135.2	8.5	7.15	7.46	14.63
100	Broadcast	----	2	143.8	9.1	7.62	7.28	14.92
100	Injected	----	1	163.7	10.3	8.67	7.95	16.64
100	Injected	----	2	172.1	10.8	9.12	7.24	16.37
100	Injected	DCD	1	169.3	10.6	8.96	7.26	16.24
100	Injected	NS	1	169.3	10.6	8.96	8.15	17.11
168	Broadcast	----	1	173.8	10.9	9.21	8.47	17.67
168	Broadcast	----	2	165.3	10.4	8.76	7.59	16.35
168	Injected	----	1	194.4	12.3	10.30	8.67	18.97
168	Injected	----	2	190.4	11.9	10.08	8.04	18.12
168	Injected	DCD	1	193.1	12.1	10.21	8.02	18.26
168	Injected	NS	1	195.9	12.3	10.37	9.12	19.51
235	Broadcast	----	1	178.9	11.2	9.48	8.49	17.96
235	Broadcast	----	2	180.7	11.4	9.56	7.71	17.29
235	Injected	----	1	204.3	12.8	10.82	9.83	20.65
235	Injected	----	2	193.7	12.2	10.26	8.33	18.59
235	Injected	DCD	1	194.8	12.2	10.30	9.05	19.35
235	Injected	NS	1	202.1	12.7	10.71	9.45	20.16
100	Injected	NH4T	1	163.3	10.3	8.65	8.00	16.67
100	Injected	NH4T	2	172.7	10.9	9.14	7.19	16.33
168	Injected	NH4T	1	190.3	12.0	10.08	8.43	18.52
168	Injected	NH4T	2	184.8	11.6	9.79	7.91	17.72
100	Inj. NH4T	----	1	168.3	10.5	8.92	7.24	16.15
P-Value				99	99	99	99	99
BLSD (.05)				14.4	0.9	0.76	0.85	1.46
Factorial Arrangement (N-Rate X Inhibitor DCD and N-Serve)								
N-Rate								
100				168.6	10.6	8.93	7.67	16.60
168				193.4	12.2	10.25	8.47	18.73
235				198.7	12.5	10.53	9.17	19.70
P-Value				99	99	99	99	99
BLSD (.05)				7.2	0.4	0.38	0.51	0.79
Inhibitor								
None				186.4	11.7	9.88	8.35	18.23
DCD				185.7	11.6	9.84	8.12	17.96
N-Serve				189.7	11.9	10.02	8.92	18.94
P-Value				28	28	28	96	86
BLSD (.05)							0.61	
N-Rate X Inhibitor				3	3	3	7	1

Table 3 continued on page after next.

Table 4. Influence of N rates, nitrification inhibitors, method, and time of application on leaf, grain, and stover N content and total N removal by irrigated corn Becker MN - 1985.

N-Rate	Treatments Method	Inh.	Time	N-Concentration Leaf	Grain	Stover	N-Removal Grain	Stover	Total
kg/ha				---------%-------------			---------kg/ha------------		
Control	---------	----	----	1.09	1.14	0.40	44.13	18.55	62.72
100	Broadcast	----	1	1.95	1.13	0.43	81.09	32.16	113.34
100	Broadcast	----	2	2.36	1.22	0.44	93.56	32.28	125.85
100	Injected	----	1	2.55	1.23	0.51	106.52	40.71	147.24
100	Injected	----	2	2.62	1.19	0.57	108.91	41.54	150.45
100	Injected	DCD	1	2.72	1.21	0.54	109.46	40.26	149.72
100	Injected	NS	1	2.64	1.16	0.56	104.32	45.70	150.02
168	Broadcast	----	1	2.56	1.26	0.55	116.29	46.64	162.93
168	Broadcast	----	2	2.60	1.25	0.53	109.27	40.36	149.64
168	Injected	----	1	2.76	1.33	0.62	137.24	54.34	191.60
168	Injected	----	2	2.79	1.41	0.63	142.48	50.89	193.38
168	Injected	DCD	1	3.14	1.44	0.62	147.90	50.40	198.30
168	Injected	NS	1	3.00	1.46	0.59	151.89	53.83	205.73
235	Broadcast	----	1	2.83	1.23	0.57	118.01	49.16	167.17
235	Broadcast	----	2	2.81	1.38	0.55	132.35	42.53	174.88
235	Injected	----	1	2.88	1.49	0.71	161.80	70.19	232.00
235	Injected	----	2	2.88	1.43	0.68	147.77	57.28	205.05
235	Injected	DCD	1	2.91	1.63	0.71	168.24	64.48	232.72
235	Injected	NS	1	3.05	1.44	0.73	155.16	69.17	224.35
100	Injected	NH4T	1	2.53	1.07	0.47	92.50	38.25	186.75
100	Injected	NH4T	2	2.52	1.22	0.55	111.38	40.16	151.56
168	Injected	NH4T	1	2.95	1.43	0.61	144.51	52.10	196.63
168	Injected	NH4T	2	2.65	1.41	0.62	138.99	49.34	188.34
100	Inj. NH4T	----	1	2.62	1.37	0.52	122.21	37.97	160.19
P-Value				99	99	99	99	99	99
BLSD (.05)				0.30	0.15	0.07	17.53	7.65	20.92
Factorial Arrangement (N-Rate X Inhibitor DCD and N-Serve)									
N-Rate									
100				2.63	1.20	0.54	107.30	42.06	149.36
168				2.92	1.41	0.61	144.87	52.37	197.24
235				2.93	1.50	0.70	158.24	65.28	223.53
P-Value				99	99	99	99	99	99
BLSD (.05)				0.14	0.07	0.03	8.77	4.27	11.08
Inhibitor									
None				2.75	1.35	0.62	134.12	52.49	186.61
DCD				2.92	1.42	0.62	141.86	51.71	193.58
N-Serve				2.90	1.35	0.62	137.12	56.24	193.37
P-Value				95	87	5	72	81	61
BLSD (.05)				0.17					
N-Rate X Inhibitor				59	79	43	42	4	18

Table 4 continued on next page.

Table 3. continued

Treatments N-Rate	Method	Inh.	Time	Grain Yields (Bu/A)	Grain Yields (mt/ha)	Dry Matter Production Grain	Stover	Total
kg/ha				Bu/A	mt/ha	---------kg/ha----------		
Factorial Arrangement (N-Rate X Method X Time)								
N-Rate								
100				153.7	9.7	8.14	7.50	15.64
168				180.9	11.4	9.59	8.20	17.79
235				189.4	11.9	10.04	8.60	18.64
P-Value				99	99	99	99	99
BLSD (.05)				7.8	0.5	0.41	0.34	0.68
Method								
Broadcast				162.9	10.2	8.62	7.84	16.46
Injected				186.4	11.7	9.88	8.33	18.23
P-Value				99	99	99	99	99
Time								
Early				175.1	11.0	9.28	8.49	17.77
Late				174.3	11.0	9.24	7.71	16.95
P-Value				17	17	17	99	17
Rate X Method				44	44	44	91	19
Rate X Time				82	82	82	83	85
Method X Time				31	31	31	74	57
Rate X Method X Time				41	41	41	63	54

Table 4. continued

	N-Concentration Leaf	Grain	Stover	N-Removal Grain	Stover	Total
	-----------%-----------			-----------kg/ha---------		
Factorial Arrangement (N-Rate X Method X Time)						
N-Rate						
100	2.37	1.19	0.48	97.54	36.67	134.22
168	2.68	1.31	0.58	126.32	48.06	174.38
235	2.85	1.38	0.63	139.98	54.79	194.78
P-Value	99	99	99	99	99	99
BLSD (.05)	0.17	0.08	0.03	8.90	3.28	9.40
Method						
Broadcast	2.52	1.24	0.51	108.45	40.52	148.97
Injected	2.75	1.35	0.62	134.12	52.49	186.61
P-Value	99	99	99	99	99	99
Time						
Early	2.59	1.28	0.56	120.18	48.87	169.04
Late	2.68	1.31	0.56	122.39	44.15	166.54
P-Value	77	68	5	42	99	45
Rate X Method	88	68	58	39	98	79
Rate X Time	67	3	76	35	98	88
Method X Time	55	78	60	72	25	74
Rate X Method X Time	47	81	22	88	58	93

1985 WEATHER

The weather for 1985 will be remembered as the second coldest year in over 100 years of weather records at Crookston. Ten of the 12 months were below normal in regard to temperature, accounting for the average annual temperature to be 3.2 degrees below normal. June, November and December were well-below normal with average monthly readings deviating 7.1, 13.9 and 11.9 degrees, respectively. March and May were the only 2 months with above-normal temperatures with March being 8.1 degrees above the long-time average. During 1985, the mercury exceeded 90 degrees on only one day. The cold temperatures of November and December both ranked second coldest in the Station history.

The last spring frost occurred April 25 (29 degrees) which initiated a 151-day frost-free period ending September 23 with a minimum-temperature reading of 31 degrees.

The 1985 precipitation was nearly normal recording only one-half inch below average. May and August were 2.13 and 1.41 inches above normal in regard to precipitation.

During the calendar year, 36.2 inches of snow was recorded containing 1.89 inches of moisture for a water equivalent of .052-inch per inch of snow. The winter snow-pack of 6 inches began melting in mid-February and was reduced to a trace by early March with the exception of two snowfalls in mid- and late-March. The ground frost reached a maximum depth of 44 inches by mid-March and had completely melted by the first part of May.

Precipitation during the growing season of April through August was 14.23 inches which is 1.12 inches above average for this period of time. The greatest amount of precipitation for a single day was received August 20 recording 2.00 inches of rain. The average mean temperature for the same period of time was 1.7 degrees below normal accounting for lower yield and quality of warm-season crops.

Table 1. Weather summary for 1985 with averages for precipitation and mean temperature (1890-1979)

	Precipitation					Mean Temperature	
Month	Snow	Precip	Rain	Total	90-Year Average	1985	1890-1979
	Inches					Degrees F	
January	6.7	.38	.00	.38	.56	3.1	3.7
February	3.2	.30	.10	.40	.59	7.1	8.1
March	8.6	.23	.13	.36	.84	31.0	22.9
April	0.0	.00	.66	.66	1.57	40.4	41.4
May	0.0	.00	4.72	4.72	2.59	59.4	54.6
June	0.0	.00	2.33	2.33	3.56	57.3	64.4
July	0.0	.00	2.81	2.81	3.09	66.4	69.6
August	0.0	.00	4.31	4.31	2.90	63.0	67.4
September	0.0	.00	1.55	1.55	2.16	52.0	57.5
October	0.0	.00	1.59	1.59	1.43	42.5	45.3
November	14.0	.81	.00	.81	.78	12.8	26.7
December	3.7	.17	.00	.17	.60	-0.4	11.5
Total	36.2	1.89	18.20	20.09	20.67	36.2	39.4

TILLAGE ROTATION STUDY

J. A. Lamb, C. E. Windels, and R. K. Severson

OBJECTIVE: Determine tillage and crop rotation effects on nitrogen utilization, soil physical and chemical properties, the incidence and distribution of soilborne fungi and diseases they cause, crop yields, and quality.

PROCEDURES: A long-term field study was established in the fall of 1984 with no-till, disk, and conventional plow tillage systems. The tillage plots were split with a spring application, April 24, 1985, of four nitrogen rates - 0, 50, 100, and 150 lb N/ac as Urea. The soil NO_3^--N 0-2 ft depth was 47 lb/ac in the fall of 1984. The treatments were replicated four times and arranged in a split-plot design. Before the tillage treatments were applied in the fall and before spring tillage operation, residue samples were taken. The spring samples used two methods of determining residue, an amount per acre basis and the line-intercept method.

Sugarbeet (Monoricca), spring wheat (Marshall), and spring barley (Robust) were planted April 30, May 1, and May 1, respectively. Population counts were taken in the sugarbeet before thinning and before tillering in the small grains. The sugarbeet were thinned to 125 plants/100 feet of row. Whole plant samples were taken at soft dough August 1 and August 8, 1985 for barley and wheat, respectively. Root rot ratings were taken July 3, 1985 in the small grains. The sugarbeet, wheat, and barley were harvested September 19, August 20, and August 6, 1985, respectively.

The tillage and N treatments for 1986 were applied October 21 and 28, 1985, respectively. Residue samples were taken after the treatments were applied.

RESULTS AND DISCUSSION:

Residues: The study was established on a Hegne silty clay loam with an average residue cover of 2084 lb/ac of barley stubble. Table 1 lists the spring and fall 1985 residue levels. A small study in the spring confirmed a high correlation between residue cover measured by the line-intercept method versus actual weight of the residue. The spring 1985 residue amounts were affected by tillage with no-till having the largest amount followed by disk and plow. The fall 1985 residues were significantly affected by tillage and N rate for all crops in the rotation. Residues following a crop of sugarbeet were considerably lower than when following small grains because of the type of harvest operation involved with sugarbeet.

Bulk Density: Bulk densitites were taken mid-October 1985 and are reported in Table 2. Except for the 3- to 6-inch depth in the wheat, the tillage system treatment affected the bulk density. No distinct trend was noted.

Sugarbeet: The data collected for the sugarbeet part of the rotation is presented in Table 3.

The population was influenced by tillage system. The no-till had the highest population followed by disk and then plow. Nitrogen did not affect the population. This tillage effect can be attributed to the better moisture conditions in no-till soil during the dry 3 weeks following planting.

The root yields were affected by the tillage systems ($P \geq 0.10$). No-till was the largest followed by disk and then the plow treatment. Nitrogen rate also significantly increased yield up to 100 lb/ac in disk and plow and to 150 lb/ac in no-till. This interaction was significant ($P \geq 0.20$).

The percent sugar was not affected by tillage system. Nitrogen rate did increase the sugar content up to 50 lb N/ac but decreased it significantly from 50 to 150 lb N/ac per acre. This is consistent with results reported in earlier studies.

The impurity index was affected by tillage system and N rate. The no-till had a lower impurity index with the plow system the highest. As the N rate increased, the index also increased. The effects of tillage and N rate on Na and Amino NO_3^- are the contributing factors in the changes of the index. Potassium was not affected by the treatments.

Recoverable sugar (lb/ac) integrates all of the above parameters. Both tillage system and N rate affected recoverable sugar. No-till had the greatest recoverable sugar with plow the least. Disk was intermediate. In the disk and plow tillage systems the maximum yield was achieved at 100 lb N/ac. No-till, on the other hand, had a yield increase at 150 lb N/ac and had not obtained maximum sugar yield. This interaction was significant ($P \geq 0.20$). The better moisture conditions at seeding under the no-till system may have caused a more vigorous seedling growth and allowed the no-till sugarbeet to obtain higher yield utilizing more N. These results may be considerably different under different environmental conditions.

Spring Wheat: The concentrations of elements in wheat forage are reported in Table 4. Phosphorus, K, and Zn were affected by tillage system. The disk system had lower concentrations of P and Zn than no-till and plow systems. Potassium was the opposite with the disk-system concentrations higher than no-till and plow. Increasing N application decreased plant P concentration but increased K, Ca, and Mg concentrations.

Grain yield, protein, and forage yield were affected by both tillage and N rate (Table 5). Although a wild oat weed problem occurred, excellent grain yields were obtained. No-till grain yield, protein, and forage yields were lower than plow and disk. The protein, grain, and forage yields for disk and plow tillage systems were similar. Nitrogen rate increased grain yield and protein in a quadratic fashion.

The maximum grain yield and protein occurred at the 150 lb N/ac rate. The no-till N grain yield and protein responses were different than disk and plow. The no-till grain yield at 0 lb N/ac was considerably lower than the other tillage systems. Grain protein was similar under all tillage systems at 0 lb N/ac. With increasing rates, no-till was less than plow and disk tillage systems. This was caused by immobilization of NO_3^--N by the increased microbial activity from larger amounts of residues in the no-till system. To obtain similar grain yields to plow and disk tillage systems, no-till systems required more N fertilizer.

Forage yields under plow tillage systems were maximized at 100 lb N/ac where no-till and disk required 150 lb N/ac. Test weight was not affected by tillage system. Increased N application significantly decreased test weight.

Plant population was not affected by N rate or tillage system in this study. Phosphorus and Ca uptake in the forage were affected by tillage system ($P \geq 0.20$) and N rate ($P \geq 0.01$). Phosphorus uptake was least in disk tillage systems followed by no-till and then plow tillage systems. Phosphorus uptake was maximized at 100 lb N/ac. Potassium uptake was significantly decreased in the no-till system compared to disk and plow systems. Nitrogen rate increased the K uptake linearly.

Root rot was not affected by N rate but was significantly decreased in no-till when compared to disk and plow systems.

Barley: Phosphorus, Mg, Mn and Zn barley forage concentrations were affected by tillage system (Table 6). Phosphorus and Zinc concentrations were greatest in no-till followed by disk and the plow tillages. Magnesium and Mn concentrations were greatest in plow followed by disk and then no-till tillage systems. Nitrogen rate affected all nutrients listed in Table 6. Phosphorus and Zn were decreased and K, Ca, Mg, and Mn increased by increasing N rate.

The wild oat weed problem that occurred in the wheat plots also occurred in the barley plots. Grain yields were significantly decreased by the wild oats when compared to normal barley yield reported in the area in 1985. The infestation was evenly distributed. Grain yield, protein, test weight, forage yield, and K uptake were affected by tillage (Table 7). In all cases, no-till tillage system was less than plow and disk tillage systems. Grain yield, protein, test weight, plumps, thins, forage yield, P uptake, K uptake, and root rot ratings were affected by N rate. The addition of N increased grain yield, protein, thins, forage yield, P uptake, and K uptake. Plumps and test weight were maximized at 50 and 100 lb N/ac, respectively. Root rot was reduced with 50 lb N/ac or greater application.

The grain yield data indicates a trend toward a tillage by N-rate interaction. At the lower N rates, no-till grain yields were less than plow and disk tillage systems. A significant tillage by N-rate interaction for protein also occurred. The no-till protein did not increase with N application as it did in the plow and disk tillage systems. These interactions were similar to those found for the wheat part of the rotation.

Table 1. Treatment means for residue on a tillage rotation study, NWES 1985.

		Wheat			Barley			Sugarbeet		
	N Rate	Spring		Fall	Spring		Fall	Spring		Fall
Tillage	lb/ac	lb/ac	%	%	lb/ac	%	%	lb/ac	%	%
No-till	0			90			53			11
	50			93			71			15
	100			94			67			10
	150			95			68			15
Disk	0			38			39			5
	50			45			46			6
	100			46			52			5
	150			46			51			5
Plow	0			10			12			2
	50			12			9			3
	100			16			18			2
	150			14			18			3
	0			46			35			6
	50			50			42			7
	100			52			45			5
	150			52			46			8
No-till		922	49	93	1069	50	65	816	46	12
Disk		264	14	44	312	17	47	293	18	5
Plow		155	6	13	142	5	14	139	7	2
Statistical Analyses										
Tillage		**	**	**	**	**	**	**	**	**
N Rate				*			**			*
N Linear				**			**			NS
N Quadratic				NS			*			NS
Tillage * N Rate				NS			++			NS
C.V.		16.4	22.0	10.7	20.5	19.6	14.9	11.6	18.9	36.2

**, *, ++, and NS are 0.01, 0.05, 0.10, and > 0.20 significance levels, respectively.

Table 2. Soil bulk density for tillage rotation experiment, fall 1985 NWES.

1985 Crop		Tillage	Bulk Density 0-3"	3-6"	6-9"	9-12"
			- - - - - - - -	g/cm^3	- - - - - - -	
Wheat		No-till	1.27	1.46	1.29	1.62
		Disk	1.06	1.44	1.28	1.57
		Plow	1.13	1.35	1.24	1.49
	Tillage		++	++	NS	*
	C.V.		8.8	4.5	6.2	3.2
Barley		No-till	1.31	1.41	1.40	1.60
		Disk	1.22	1.41	1.36	1.54
		Plow	1.12	1.25	1.25	1.53
	Tillage		+	++	**	NS
	C.V.		8.9	6.5	3.1	5.4
Sugarbeet		No-till	1.19	1.37	1.33	1.48
		Disk	1.13	1.33	1.30	1.51
		Plow	1.10	1.23	1.14	1.53
	Tillage		*	+	**	+
	C.V.		3.1	6.8	3.4	2.1

**, ++, +, and NS are 0.01, 0.10, 0.20 at >0.20 significance levels, respectively.

Table 3. Yield, quality and statistics for sugarbeet in the tillage-rotation study, NWES 1985.

	Population plants/ac	Yield t/ac	Sugar %	Recoverable Sugar lb/ac	Recoverable Sugar %	Recoverable Sugar lb/ton	Impurities Na	Impurities K	Impurities Amino N	Impurities Index
							- - - ppm	- - -		
No-till	86593	18.6	18.2	6229	92	336	249	2221	311	516
Disk	79660	18.1	18.3	6100	92	337	259	2194	324	519
Plow	73238	17.7	18.1	5880	92	333	285	2186	364	548
N Rate										
0	79967	14.0	18.2	4737	93	339	214	2195	238	467
50	78309	18.5	18.6	6403	93	346	208	2247	286	486
100	80945	19.6	18.1	6535	92	333	283	2181	363	545
150	80103	20.5	17.8	6603	91	323	353	2178	443	614
No-till										
0	95411	13.7	18.2	4624	93	337	220	2258	230	474
50	79633	19.0	18.7	6595	93	347	195	2273	265	476
100	82937	19.5	18.2	6565	92	336	230	2170	335	517
150	88394	22.0	17.8	7133	91	324	353	2185	413	598
Disk										
0	73619	13.7	18.4	4688	93	343	188	2190	238	456
50	83049	18.3	18.5	6288	93	343	205	2220	270	477
100	80598	20.3	18.2	6775	92	334	288	2218	355	547
150	81378	20.3	18.0	6650	91	327	358	2148	433	597
Plow										
0	70872	14.5	18.2	4900	93	337	235	2138	248	470
50	72245	18.2	18.8	6328	92	347	225	2248	323	504
100	79299	19.0	18.1	6265	91	330	330	2155	400	572
150	70537	19.0	17.6	6027	90	317	350	2203	485	646
Statistical Analyses										
Tillage	**	++	NS	++	+	NS	NS	NS	++	+
N Rate	NS	**	**	**	**	**	**	NS	**	**
Linear	NS	**	**	**	**	**	**	NS	**	**
Quadratic	NS	**	**	**	*	**	**	NS	NS	*
Tillage * N Rate	NS	+	NS	+	NS	NS	NS	NS	NS	NS
C.V.	15.0	7.7	1.9	7.8	0.6	2.3	16.2	5.3	13.7	7.0

**, *, ++, and + are 0.01, 0.05, 0.10 and 0.20 significance levels, respectively.

NS is not significant at > 0.20 level.

Table 4. Elemental analyses for wheat in tillage rotation study, NWES 1985.

Tillage	N Rate lb/ac	P	K	Ca	Mg	Mn	Zn
		- - - - - - - -	%	- - - - - - - -		- - ppm - -	
No-till	0	.29	.93	.09	.16	29.8	27.7
	50	.26	.91	.09	.14	27.0	23.7
	100	.24	.97	.09	.15	26.6	23.6
	150	.19	1.41	.13	.17	22.3	23.2
Disk	0	.21	.97	.09	.14	27.4	17.4
	50	.22	1.08	.09	.17	29.3	20.7
	100	.19	1.41	.13	.21	28.6	23.2
	150	.18	1.56	.14	.22	29.8	24.2
Plow	0	.27	.95	.08	.16	27.5	22.6
	50	.24	1.02	.08	.16	27.2	21.9
	100	.23	1.16	.10	.19	27.9	23.6
	150	.20	1.52	.13	.19	25.7	23.4
	0	.26	.95	.09	.15	28.2	22.6
	50	.24	1.01	.09	.16	27.8	22.1
	100	.22	1.18	.11	.18	27.7	23.5
	150	.19	1.50	.13	.20	26.0	23.2
No-till		.24	1.06	.10	.16	26.4	24.3
Disk		.20	1.26	.11	.18	28.8	21.4
Plow		.24	1.16	.10	.17	27.1	22.9
Statistical Analyses							
Tillage		*	+	NS	NS	NS	+
N Rate		**	**	**	**	NS	NS
N Linear		**	**	**	**	++	NS
N Quadratic		NS	*	*	NS	NS	NS
Tillage * N Rate		NS	NS	NS	*	++	+
C.V.		15.6	14.2	21.7	12.2	10.4	17.5

**, *, ++, +, and NS are 0.01, 0.05, 0.10, 0.20, and > 0.20 significance levels, respectively.

Table 5. Grain yield, protein, test weight, population, forage yield, P uptake, K uptake, and root rot rating for wheat in tillage rotation study, NWES 1985.

		Grain				Forage			
Tillage	N Rate lb/ac	Yield bu/ac	Protein %	Test Weight lb/bu	Population plants/ac	D.M. Yield	P	K	Root Rot
						- - - lb/ac - - -			
No-till	0	28.4	10.5	57.7	546242	2322	6.8	21.6	12
	50	47.5	10.0	57.7	541886	4339	11.2	39.9	15
	100	58.5	11.6	57.6	497455	6099	14.6	59.9	11
	150	70.9	12.1	57.1	561924	6110	11.8	84.0	10
Disk	0	40.7	10.4	57.6	555825	3833	8.0	37.0	25
	50	56.0	10.5	57.6	574992	5385	11.7	58.4	21
	100	66.8	12.1	57.8	581090	5708	10.8	82.3	21
	150	69.7	13.5	56.7	566280	6282	11.3	98.2	23
Plow	0	40.6	10.2	57.8	568022	3658	10.0	34.9	29
	50	54.0	10.6	57.7	577605	5604	13.6	57.4	22
	100	61.8	11.7	57.4	674309	6351	14.8	73.7	24
	150	66.4	13.5	56.2	595030	6174	12.4	95.4	23
	0	36.6	10.4	57.7	556697	3271	8.3	31.2	22
	50	52.5	10.4	57.6	564828	5109	12.2	51.9	19
	100	62.3	11.8	57.6	584285	6052	13.4	72.0	19
	150	69.0	13.0	56.7	574411	6189	11.8	92.5	19
No-till		51.3	11.1	57.5	536877	4718	11.1	51.3	12
Disk		58.3	11.6	57.4	569547	5302	10.4	69.0	23
Plow		55.7	11.5	57.3	603741	5447	12.7	65.3	24
Statistical Analyses									
Tillage		+	+	NS	NS	+	+	+	*
N Rate		**	**	**	NS	**	**	**	NS
N Linear		**	**	**	NS	**	**	**	NS
N Quadratic		**	**	**	NS	**	**	NS	NS
Tillage * N Rate		*	++	NS	++	+	NS	NS	NS
C.V.		8.3	4.8	1.1	8.7	13.6	19.0	22.6	34.4

**, *, ++, +, and NS are 0.01, 0.05, 0.10, 0.20, and > 0.20 significance levels, respectively.

Table 6. Elemental analyses for barley in tillage rotation study, NWES 1985.

Tillage	N Rate lb/ac	P	K	Ca	Mg	Mn	Zn
		- - - - - - - - % - - - - - - - -				- - ppm - -	
No-till	0	.31	.89	.15	.19	15.1	24.2
	50	.24	.95	.16	.17	14.8	18.2
	100	.23	.93	.15	.16	14.1	19.9
	150	.25	1.12	.16	.17	12.9	20.5
Disk	0	.28	.89	.14	.18	14.3	20.3
	50	.22	.96	.15	.18	14.3	16.0
	100	.26	.98	.14	.17	14.3	23.0
	150	.20	1.31	.22	.21	19.3	20.6
Plow	0	.26	.89	.13	.20	13.1	18.6
	50	.22	1.01	.13	.18	13.4	15.8
	100	.23	1.17	.20	.21	17.6	19.7
	150	.21	1.35	.35	.30	29.1	19.6
	0	.28	.89	.14	.19	14.2	21.0
	50	.23	.98	.15	.18	14.1	16.7
	100	.24	1.03	.16	.18	15.3	20.7
	150	.22	1.26	.24	.23	20.4	20.2
No-till		.26	.97	.15	.18	14.2	20.7
Disk		.24	1.04	.16	.19	15.5	20.0
Plow		.23	1.10	.20	.22	18.3	18.4
Statistical Analyses							
Tillage		++	NS	NS	+	++	+
N Rate		**	**	*	+	++	**
N Linear		**	**	*	+	*	NS
N Quadratic		+	+	NS	+	+	*
Tillage * N Rate		NS	NS	NS	NS	+	NS
C.V.		15.0	15.8	56.2	28.5	37.9	15.8

**, *, ++, +, and NS are 0.01, 0.05, 0.10, 0.20, and > 0.20 significance levels, respectively.

Table 7. Grain yield, protein, test weight, plump, thins, population, forage yield, P uptake, K uptake, and root rot rating for barley in tillage rotation study, NWES 1985.

		Grain						Forage			
Tillage	N Rate lb/ac	Yield bu/ac	Protein %	Test Weight lb/bu	Plumps %	Thins %	Population plants/ac	D.M. Yield	P	K	Root Rot
								- - - lb/ac - - -			
No-till	0	28.6	9.6	43.7	84	13	477418	4034	12.5	35.7	38
	50	44.4	9.8	45.0	84	13	514879	6478	15.7	63.4	28
	100	51.9	10.6	45.1	77	18	505296	7821	18.0	73.0	39
	150	61.8	11.7	45.4	75	23	509652	8899	21.8	100.8	33
Disk	0	39.3	9.5	45.3	84	14	496584	5257	14.7	46.6	37
	50	54.9	10.3	45.3	86	12	490485	7803	16.8	75.6	31
	100	59.9	12.1	46.5	83	15	489614	8052	21.2	79.0	25
	150	65.0	13.4	45.9	75	23	515750	9711	19.3	128.2	33
Plow	0	42.5	9.6	44.6	85	13	499198	5309	14.0	47.7	47
	50	51.5	10.8	45.7	88	11	453895	8567	18.7	88.4	33
	100	64.6	12.6	46.4	78	20	471319	8720	20.4	101.2	29
	150	63.8	13.6	45.2	83	14	480902	9401	19.9	125.7	28
	0	36.8	9.6	44.5	84	13	491066	4867	13.7	43.3	41
	50	50.3	10.3	45.3	86	12	486420	7616	17.0	75.8	31
	100	58.8	11.8	46.0	79	18	488743	8198	19.9	84.4	31
	150	63.5	12.9	45.5	78	20	502101	9337	20.3	118.3	32
No-till		46.7	10.4	44.8	80	17	501811	6808	17.0	68.2	35
Disk		54.8	11.4	45.7	82	16	498108	7706	18.0	82.4	32
Plow		55.6	11.6	45.5	83	15	476328	7999	18.2	90.8	35
Statistical Analyses											
Tillage		**	**	*	NS	NS	NS	*	NS	++	NS
N Rate		**	**	**	**	**	NS	**	**	**	*
N Linear		**	**	**	**	**	NS	**	**	**	*
N Quadratic		**	**	**	NS	NS	NS	**	+	NS	*
Tillage * N Rate		**	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.		2.9	9.8	1.6	6.3	31.9	7.3	11.1	17.0	22.1	25.2

**, *, ++, +, and NS are 0.01, 0.05, 0.10, 0.20, and > 0.20 significance levels, respectively.

DATE AND RATE OF SEEDING SPRING WHEAT

J.A. Lamb, R.K. Severson and S. Bigger

OBJECTIVE: The importance of early planting in spring wheat has been known for many years. In the past, a recommendation to producers who cannot or have not planted early has been to increase seeding to minimize the loss in grain yield caused by late planting. With this in mind, the following study was conducted in 1985 to determine the interaction effects between seeding date and seeding rates.

PROCEDURES: A study with three planting dates, April 19, May 10, and May 30, and four seeding rates, 1.0, 1.5, 2.0, and 2.5 bushels/ac in a factorial arrangement was conducted at the Northwest Experiment Station in 1985. Marshall wheat was planted and the twelve treatments which were replicated four times. Plant populations were taken before tillering occurred. The grain was harvested August 15, August 26, and September 12, 1985 for the respective planting dates. At the time of preparing this report the protein information was still at the laboratory for determination.

RESULTS: The rate by date interaction was not significant for any of the parameters measured, Table 1. The means for the main effects are presented in Table 2. The later seeding date negatively affected grain yield and test weight. This is the same as what has been reported before. The grain yield was reduced .7% per day. The test weight was affected the most between the May 10 and May 30 planting dates. The plant population increased with later planting dates. This is caused by better soil conditions for germination. North Dakota data suggest along with the study that 700,000 plants/ac is satisfactory for maximum grain yields.

Seeding rate did not affect grain yield. For some unknown reason, increasing seeding rate did increase test weight. Not surprising, the plant population was increased by increasing seeding rate.

In summary, using the recommended seeding rate, 1.5 bu/ac, at any planting date will give maximum grain yields. Also, the earlier spring wheat is planted, the better the grain yield.

Table 1. Statistical analyses for seeding rate and date study, NWES 1985.

	Grain Yield	Test Weight	Plant Population
Seeding Date	**	**	**
Seeding Rate	NS	++	**
Date * Rate	NS	NS	NS
C.V.	7.6	3.3	9.4

**, ++, and NS are 0.01, 0.10, and >0.20 significance levels, respectively.

Table 2. Main effects means for grain yield, test weight, and plant population, 1985.

Planting Date	Grain Yield	Test Weight	Plant Population
	bu/ac	lb/bu	plants/ac
4-19-85	67	59	746182
5-10-85	60	57	812394
5-30-85	48	54	884742
Seeding Rate bu/ac			
1.0	57	56	514880
1.5	58	56	680407
2.0	60	57	949027
2.5	59	57	1113443

INTENSIVE MANAGEMENT OF SPRING WHEAT

J.A. Lamb and R.K. Severson

OBJECTIVE: Determine what management practices in spring wheat production influence yield and protein levels. Intensive management of inputs into small grain production has become a popular practice in Europe. Much interest has been generated in the U.S. because of this success. This practice is being sold on a total program basis. Little information is available on what amount of yield increase is attributed to what practice. With this in mind, a study with the objective of determining what practices influence yield and protein levels in spring wheat.

PROCEDURE: The study involved four factors of production, yield goal, starter fertilizer, fungicide, and foliar N application. The soil test is reported in Table 1. Sixty and 110 bushel per acre yield goals were chosen to determine the preplant fertility program. The 60 bushel yield goal plots received 25 lb N/ac, 70 lb P_2O_5/ac, and no K_2O. The 110 bushel per acre received 150 lb N/ac, 100 lb P_2O_5/ac, and 50 lb K_2O/ac. The preplant fertilizer was applied April 26, 1985. Marshall wheat was planted May 2, 1985 with the starter treatment of 100 lb/ac of 18-46-0 applied at that time. The seeding rate was 90 lb/ac. At heading, July 1, 1985, the first application of fungicide and a foliar application of 15 lb N/ac as urea were applied. The second application of fungicide was July 12 for a total of 2 lb/ac of Dithane M-45 in the two applications. Grain yields were taken August 15, 1985.

Table 1. Soil test for intensive management study, 1985.

NO_3^--N 0-2'	96 lb/ac
$NaHCO_3$-P 0-6"	8 lb/ac
K 0-6"	320 lb/ac
ph	8.2
Organic Matter	3.1

RESULTS AND DISCUSSION: Main effect means for yield, bushel weight, plant population, and grain protein are shown in Table 2. The statistics are listed in Table 3.

Table 2. Grain yield, test weight, protein, and population means for main effects for intensive management experiment NWES, 1985.

Main Effect and Rate	Grain Yield	Test Weight	Protein	Population
	bu/ac	lb/ac	%	plants/ac
Yield Goal				
60 bu/ac	71.8	58.9	12.8	793881
110 bu/ac	77.6	56.8	13.7	770467
Starter				
0 lb/ac 18-46-0	73.7	58.0	13.3	795732
100 lb/ac 18-46-0	76.2	57.6	13.2	768616
Fungicide				
0 lb/ac	74.0	57.6	13.3	781683
2 lb/ac	75.5	58.0	13.2	782664
Foliar N				
0 lb/ac	73.9	57.6	13.2	780912
15 lb/ac	75.6	58.0	13.3	783518

Table 3. Statistical analyses for grain yield, test weight, protein, and population.

	Yield	Test Weight	Protein	Population
Goal	.02	.0001	.0001	.06
Starter	NS	NS	NS	.03
Fungicide (Fungi)	NS	NS	NS	NS
Foliar N (FN)	NS	.17	NS	NS
Goal * Starter	NS	NS	NS	.13
Goal * Fungi	.12	NS	NS	NS
Goal * FN	.16	NS	.19	NS
Starter * Fungi	NS	NS	NS	NS
Starter * FN	NS	NS	NS	NS
Fungi * FN	NS	NS	.18	NS
Goal * Starter * FN	NS	.09	NS	NS
Goal * Fungi * FN	.07	NS	NS	NS
Starter * Fungi * FN	.11	NS	NS	NS
Goal * Starter * Fungi * FN	NS	.06	NS	NS
C.V.	12.8	2.3	3.9	6.3

NS not significant at $\geq$ 0.20 significance level.

Yield goal (preplant fertilizer program) increased the yield and protein. The increased N fertilizer was the predominate reason for these increases. The bushel weight and population were decreased at the higher yield goal. No apparent reason can be offered for the decrease in bushel weight but the decreased population could have occurred because of salt effect from the extremely high fertilizer rates. Starter fertilizer also decreased the population because of salt effects. The application of foliar N increased the bushel weight probably caused by better N nutrition of grain fill.

Four two-way interactions were significant in this study (goal by fungicide and goal by foliar N for yield, goal by starter for population, and goal by foliar N for protein). Five three-way interactions occurred but were not explainable biologically so will not be discussed. Table 4 contains the yield means for the goal by fungicide interaction. These means suggest that at the higher yield goal a yield increase from the application of fungicide may occur. At the lower yield goal this increase did not occur.

The yield goal by foliar N interaction, Table 5, suggests that a yield response from a foliar application of 15 lb N/ac occurred at the 60 bushel yield goal but did not occur at the 110 bushel yield goal. This indicates that adequate N was not available to the plant at the 60 bushel yield goal for maximum yield.

The yield goal by foliar N interaction on protein, Table 6, indicates that a foliar application at the 110 bushel yield goal would slightly increase grain protein content where the content is slightly decreased when a foliar N application is made at the 60 bushel yield goal. Population counts suggest a yield by starter interaction, Table 7. The population was not decreased as much at the higher yield goal from starter fertilizer as it was at the 60 bushel yield goal.

SUMMARY: The extra fertilizer applied at the higher yield goal increased grain yield and protein substantially. Using a high yield goal and fungicide application may result in a higher yield level. A foliar N application does not increase yield if a high yield goal is used but may increase yield at a lower goal. The foliar application of 15 lb N/ac did not increase grain protein content as was hypothesized. The environmental conditions in 1985 favored high yields and high input use. If moisture would have been limiting at any time in the growing season, different effects would result.

Table 4. Grain yield means for the yield goal by fungicide interaction.

Yield Goal	Fungicide Rate lb/ac	
	0	2
bu/ac	- - - bu/ac - - -	
60	72.9	70.7
110	75.0	80.3

Table 5. Grain yield means for the yield goal by foliar N application interaction.

Yield Goal	Foliar N Rate lb/ac	
	0	15
bu/ac	- - - bu/ac - - -	
60	69.6	74.3
110	78.5	76.8

Table 6. Protein means for the yield goal by foliar N application interaction.

Yield Goal	Foliar N Rate lb/ac	
	0	15
bu/ac	- - - - % - - - -	
60	12.8	12.7
110	13.6	13.8

Table 7. Plant population means for the yield goal by starter interaction.

Yield Goal	Starter 18-46-0 lb/ac	
	0	100
bu/ac	- - plants/ac - -	
60	816967	774496
110	770794	766438

PHOSPHORUS PLACEMENT METHODS ON SPRING WHEAT

J.A. Lamb and R.K. Severson

OBJECTIVE: Determine the effect of knife, broadcast, and row placements of phosphorus on grain yield and phosphorus uptake efficiency.

METHODS AND MATERIALS: A study with the treatments listed in Table 1 was established at two locations (Ross and Peterson) September 12, 1985. Soil test information is listed in Table 2. The treatments were replicated four times in a randomized complete block design. The spring knife and broadcast treatments were applied May 21. The row treatments were applied May 22 when Marshall wheat was planted. The spacing for the knife treatments was 15 inches and to a depth of 4 inches. The fertilizer source was ammonium polyphosphate with an analysis of 10-34-0. A broadcast application of N as urea was applied at planting to correct for possible N deficiencies at the Peterson location. Forage yields and plant samples for elemental analyses were obtained August 14 for both locations. Grain yields were taken August 29.

RESULTS AND DISCUSSION: The means and statistical analyses for elemental concentration at the Ross and Peterson locations are listed in Tables 3 and 4, respectively. Because of the statistical design of the treatments, the check was compared with the rest of the treatments to determine if a treatment response occurred. Only the Zn concentration at the Peterson location was affected by the method and rate of P application. All methods had a lower Zn concentration than the check. The row application decreased the Zn concentration the most. Increasing P application decreases Zn concentrations linearly.

The grain yield, test weight, forge yield and forage uptake means and statistical analyses for the Ross location are listed in Tables 5 and 6, respectively. Grain yields were increased with the addition of phosphorus. This P response was linear. The fall knife treatment performed poorly compared to the other treatments. The broadcast treatments had the highest yields. Spring knife and row were intermediate. Normally, with a soil test of 17 lb/ac all placement methods would perform similarly, with the row and knife placement having a small advantage. This was not the case. Test weight was increased with the addition of P. The response within methods was not consistent.

The forage yield at soft dough was affected by both P rate and placement method. With increasing addition of P the forage increased linearly. The knife applications, both spring and fall, performed poorly. Application of P in the row was intermediate. The broadcast treatment had the highest forage yield. Again, this did not turn out as suggested by other studies in the literature. The phosphorus uptake in forage sample was affected by P fertilization. As expected, as the amount of P applied increased, the amount in the plant increased. The method of placement did affect the amount of P found in the plant at soft dough. The spring knife placement did not have any more plant P than the check. For some reason the fertilizer P was not getting in the plant. The broadcast applications had the greatest amount of P uptake which correlates well with the yield data. Zn uptake was not affected by the phosphorus treatments at this location.

The grain yield, test weight, forage yield, and forage (soft dough) uptakes are listed in Table 7. Table 8 has the statistical analyses. The addition of phosphorus did not affect grain yield, forage yield, or forage P uptake. The test weight was decreased by increasing rates of P. Overall, the Zn uptake was decreased by the addition of P fertilizer with any method. This location had a soil test of 11 lb/ac. A response to P was expected but did not occur.

Table 1. Treatments for phosphorus method experiment, 1985.

Treatment	Time	Method	P Rate
1	- - - - - - Check - - - - - - -		
2	Fall	Broadcast	10
3			20
4			30
5			40
6	Fall	Knife	10
7			20
8			30
9			40
10	Spring	Broadcast	10
11			20
12			30
13			40
14	Spring	Knife	10
15			20
16			30
17			40
18	Spring	Row	10
19			20
20			30
21			40

Table 2. Soil test data for Ross and Peterson sites, 1985.

		Ross	Peterson
NO_3^{-}-N	0-2 ft	160 lb/ac	59 lb/ac
P-$NaHCO_3$	0-6 in	17 lb/ac	11 lb/ac
	6-12 in	4 lb/ac	5 lb/ac
	1-2 ft	6 lb/ac	3 lb/ac
K-NH_4OAC	0-6 in	190 lb/ac	200 lb/ac
	6-12 in	110 lb/ac	150 lb/ac
	1-2 ft	130 lb/ac	100 lb/ac
pH	0-6 in	8.0	8.0
	6-12 in	8.8	8.1
	1-2 ft	8.7	8.3
OM	0-6 in	2.6%	3.0%
	6-12 in	1.2%	2.1%
	1-2 ft	2.8%	1.4%

Table 3. Elemental analyses of forage samples, soft dough for Ross and Peterson locations, 1985.

		Location							
		Ross				Peterson			
	Rate	P	K	Ca	Zn	P	K	Ca	Zn
Method	lb/ac	- - - % - - -			ppm	- - - % - - -			ppm
Check	0	.23	1.12	.15	14.3	.18	1.01	.11	22.5
Spring Broadcast	10	.23	1.10	.14	14.6	.18	1.14	.11	21.8
	20	.23	1.00	.13	14.2	.19	1.12	.12	17.7
	30	.20	1.00	.19	11.6	.19	0.96	.11	18.4
	40	.23	1.04	.16	13.7	.20	1.04	.12	16.4
Spring Row	10	.22	1.04	.15	15.0	.17	1.04	.15	18.2
	20	.22	1.08	.16	14.3	.16	1.22	.12	16.5
	30	.21	1.03	.17	12.6	.20	0.94	.12	17.2
	40	.23	0.95	.15	12.2	.19	1.09	.14	18.2
Spring Knife	10	.21	1.04	.17	15.1	.17	1.10	.12	21.6
	20	.20	1.13	.23	11.8	.18	1.09	.12	20.2
	30	.20	1.11	.20	12.9	.19	1.00	.11	24.4
	40	.21	1.07	.18	12.0	.18	1.07	.13	20.0
Fall Broadcast	10	.23	1.13	.15	13.4	.18	1.04	.11	20.2
	20	.23	1.11	.15	14.2	.18	1.11	.12	18.1
	30	.25	0.99	.15	13.3	.18	1.06	.13	16.0
	40	.23	1.10	.16	12.6	.20	1.11	.11	16.7
Fall Knife	10	.23	1.22	.14	15.0	.20	1.09	.11	20.4
	20	.24	1.08	.13	14.7	.17	1.09	.13	20.2
	30	.21	1.12	.17	13.4	.18	1.07	.13	17.2
	40	.21	1.07	.19	12.2	.20	1.08	.11	17.2
Check		.23	1.12	.15	14.3	.18	1.01	.11	22.5
Fall Broadcast		.24	1.08	.15	13.4	.18	1.08	.12	17.7
Fall Knife		.23	1.12	.16	13.8	.19	1.08	.12	18.8
Spring Broadcast		.22	1.04	.16	13.5	.19	1.07	.12	18.6
Spring Knife		.21	1.09	.20	13.0	.18	1.07	.12	21.5
Spring Row		.22	1.02	.16	13.5	.18	1.08	.13	17.5
	0	.23	1.12	.15	14.3	.18	1.01	.11	22.5
	10	.22	1.11	.15	14.6	.18	1.08	.12	20.4
	20	.23	1.08	.16	13.8	.18	1.13	.12	18.5
	30	.22	1.05	.18	12.8	.19	1.01	.12	18.7
	40	.22	1.05	.17	12.5	.19	1.08	.12	17.7

Table 4. Statistical analyses of element concentration in forage samples for Ross and Peterson location, 1985.

	Ross				Peterson			
	P	K	Ca	Zn	P	K	Ca	Zn
Check vs Rest	NS	NS	NS	NS	NS	NS	NS	*
Method	+	*	*	NS	NS	NS	NS	**
Spring vs Fall	*	*	++	NS	NS	NS	NS	+
Spring knife and row vs broadcast	*	NS	++	NS	NS	NS	NS	NS
Spring row vs knife	NS	++	**	NS	NS	NS	NS	**
Fall knife vs broadcast	++	NS	NS	NS	NS	NS	NS	NS
Rate	NS	+	NS	**	++	*	NS	*
P linear	NS	*	+	**	*	NS	NS	**
P quadratic	NS	NS	NS	NS	NS	NS	NS	NS
Method * Rate	NS	NS	NS	NS	NS	NS	NS	NS
C.V.	10.9	9.2	23.2	11.6	13.6	10.9	18.8	14.3

**, *, ++, and + are 0.01, 0.05, 0.10, and 0.20 significance levels, respectively.

Table 5. Grain yield, test weight and forage elemental uptakes for Ross location, 1985.

		Grain		Forage		
			Test		Uptake	
	P Rate	Yield	Weight	Yield	P	Zn
Method	lb/ac	Bu/ac	lb/bu	- - - - - - lb/ac - - - - - -		
Check	0	44.1	55.9	6344	14.3	.09
Fall Broadcast	10	50.4	58.8	7147	16.5	.10
	20	51.8	58.8	7727	17.9	.11
	30	52.0	58.3	7820	19.8	.10
	40	54.7	58.4	8200	18.5	.10
Fall Knife	10	42.4	56.8	6518	15.2	.10
	20	50.3	59.4	6744	16.4	.10
	30	50.7	57.5	7207	15.5	.10
	40	42.9	57.9	7699	16.3	.09
Spring Broadcast	10	49.6	57.8	7502	17.0	.11
	20	53.0	57.4	7330	16.7	.10
	30	51.3	57.0	7515	14.8	.08
	40	57.3	58.5	8090	18.2	.11
Spring Knife	10	46.9	57.5	6326	13.3	.10
	20	47.1	58.3	6849	14.0	.08
	30	48.3	58.9	7231	14.2	.09
	40	52.8	58.4	7547	15.6	.09
Spring Row	10	48.4	57.5	7142	15.4	.11
	20	51.3	59.5	6632	14.7	.09
	30	43.4	59.4	7333	15.8	.09
	40	50.4	58.8	7879	18.3	.10
Check		44.1	55.9	6344	14.3	.09
Fall Broadcast		52.2	58.5	7724	18.2	.10
Fall Knife		46.6	57.9	7042	15.9	.10
Spring Broadcast		52.8	57.7	7609	16.7	.10
Spring Knife		48.8	58.3	6988	14.3	.09
Spring Row		48.4	58.8	7247	16.1	.10
	0	44.1	55.9	6344	14.3	.09
	10	47.6	57.7	6927	15.5	.10
	20	50.7	58.7	7056	15.9	.10
	30	49.2	58.2	7421	16.0	.09
	40	51.6	58.4	7883	17.4	.10

Table 6. Statistical analyses for grain and forage yields and quality for Ross site, 1985.

	Grain		Forage		
		Test			
	Yield	Weight	Yield	P	Zn
Check vs Rest	++	**	*	+	NS
Method	*	*	++	**	++
Spring vs Fall	NS	NS	NS	*	NS
Spring knife and row vs broadcast	*	**	++	*	++
Spring row vs knife	NS	+	NS	*	+
Fall knife vs broadcast	**	++	*	**	NS
Rate	+	*	**	++	NS
P linear	++	++	**	*	NS
P quadratic	NS	++	NS	NS	NS
Method * Rate	NS	++	NS	NS	NS
C.V.	11.5	1.9	12.1	14.4	16.7

**, *, ++, and + are 0.01, 0.05, 0.10, and 0.20 significance levels, respectively.

Table 7. Grain yield, test weight, forage yield (soft dough), and forage elemental uptakes for Peterson location.

		Grain		Forage		
			Test		Uptake	
	P Rate	Yield	Weight	Yield	P	Zn
Method	lb P/ac	Bu/ac	lb/bu	- - - - - - - lb/ac - - - - - - -		
Check	0	44.2	58.6	7227	12.9	.16
Fall Broadcast	10	46.6	58.8	6612	12.3	.14
	20	46.6	58.5	7361	13.1	.13
	30	48.6	58.6	7156	12.7	.12
	40	48.2	57.0	7843	15.7	.13
Fall Knife	10	41.4	58.1	7424	14.7	.15
	20	41.0	58.4	7468	13.1	.16
	30	40.9	57.9	6853	12.2	.12
	40	43.7	57.8	7166	14.5	.12
Spring Broadcast	10	46.3	58.9	7361	12.8	.16
	20	46.8	58.5	7949	15.2	.14
	30	47.5	58.0	7369	13.8	.14
	40	49.2	56.8	8184	16.4	.14
Spring Knife	10	40.0	57.5	6816	11.6	.15
	20	42.6	57.9	6496	11.8	.13
	30	41.7	57.6	7131	13.6	.18
	40	44.7	57.0	6795	12.4	.14
Spring Row	10	44.2	57.1	7615	13.2	.14
	20	47.2	59.1	7691	12.4	.13
	30	52.3	56.3	7081	14.2	.12
	40	47.4	57.9	7431	13.7	.13
Check		44.2	58.6	7227	12.9	.16
Fall Broadcast		47.5	58.2	7243	13.4	.13
Fall Knife		41.7	58.0	7228	13.6	.14
Spring Broadcast		47.4	58.0	7716	14.6	.14
Spring Knife		42.2	57.5	6810	12.4	.15
Spring Row		47.7	57.6	7455	13.4	.13
	0	44.2	58.6	7227	12.9	.16
	10	43.7	58.1	7166	12.9	.15
	20	44.8	58.5	7393	13.1	.14
	30	46.2	57.7	7118	13.3	.13
	40	46.6	57.3	7484	14.6	.13

Table 8. Statistical analyses for grain and forage yields and quality for Peterson site, 1985.

	Grain		Forage		
		Test			
	Yield	Weight	Yield	P	Zn
Check vs Rest	NS	++	NS	NS	+
Method	**	+	+	NS	NS
Spring vs Fall	NS	*	NS	NS	NS
Spring knife and row vs broadcast	+	++	++	*	NS
Spring row vs knife	**	NS	++	NS	++
Fall knife vs broadcast	**	NS	NS	NS	NS
Rate	NS	**	NS	NS	NS
P linear	++	**	NS	++	+
P quadratic	NS	*	NS	NS	NS
Method * Rate	NS	*	NS	NS	NS
C.V.	11.6	1.5	14.7	21.4	22.2

**, *, ++, and + are 0.01, 0.05, 0.10, and 0.20 significance levels, respectively.

HIGH PHOSPHORUS AND POTASSIUM RATES ON CONTINUOUS SPRING WHEAT

J.A. Lamb 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.

EXPERIMENTAL PROCEDURE: Ten treatments consisting of P and K combinations and applications made to date are shown in Table 1. Treatments applied in the fall of 1984 were broadcast and plowed down. Nitrogen, as urea, was fall applied at 100 lb N/ac and incorporated with a field cultivator on October 9, 1984. Marshall wheat was planted on April 19, 1985 and harvested for grain yields on August 15, 1985. Whole plant samples were taken at soft dough August 6, 1985 for elemental analyses and used to determine forage yields, P, and K uptakes. Soil samples were taken after crop removal to measure the residual effects of the treatments. The 1985 soil samples are in the process of being analyzed at the time of this report so will not be reported.

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

Treatment	Application Date					
No.	Spring 1980	Fall 1980	Fall 1981	Fall 1982	Fall 1983	Fall 1984
	P_2O_5 (lb/ac) + K_2O (lb/ac)					
1	0 + 0	0 + 0	0 + 0	0 + 0	0 + 0	0 + 0
2	0 + 100	0 + 100	0 + 100	0 + 100	0 + 100	0 + 100
3	50 + 100	50 + 100	50 + 100	50 + 100	50 + 100	50 + 100
4	100 + 100	100 + 100	100 + 100	100 + 100	100 + 100	100 + 100
5	150 + 100	0 + 100	0 + 100	150 + 100	0 + 100	0 + 100
6	100 + 0	100 + 0	100 + 0	100 + 0	100 + 0	100 + 0
7	100 + 50	100 + 50	100 + 50	100 + 50	100 + 50	100 + 50
8	100 + 150	100 + 0	100 + 0	100 + 150	100 + 0	100 + 0
9	150 + 100	0 + 0	0 + 0	0 + 0	0 + 0	0 + 0
10	100 + 150	0 + 0	0 + 0	0 + 0	0 + 0	0 + 0

1985 RESULTS: The means for elemental analyses are in Table 2. In 1985 the treatments did not significantly affect any of the elements reported. Table 3 has the means for grain yield, protein, test weight, dry matter yield, P and K uptake. The treatments did not significantly affect these values.

Table 2. Effects of P and K rate combinations on the elemental analyses of whole plant samples of spring wheat taken at maturity (soft dough).

Treatment	Elemental Analyses							
No.	P	K	Ca	Mg	Mn	Zn	Cu	B
	%				ppm			
1	.24	.88	.09	.16	35	18	3.5	1.5
2	.22	.88	.10	.15	36	17	3.5	1.7
3	.25	.85	.09	.16	36	16	3.4	1.5
4	.20	.90	.10	.15	36	13	3.0	1.7
5	.25	.76	.08	.16	41	14	3.1	1.4
6	.24	.88	.10	.14	38	17	3.4	1.5
7	.23	.86	.09	.17	40	12	3.0	1.6
8	.25	.80	.08	.16	38	15	3.1	1.5
9	.22	.81	.09	.17	37	16	2.6	1.6
10	.19	.89	.10	.15	36	17	3.4	1.6
Trt	NS	NS	NS	NS	NS	NS	NS	NS
C.V.	17.1	13.9	22.8	12.5	13.4	24.6	16.3	23.7

Table 3. Effect of P and K rate combinations on grain yield, protein, test weight, forage yield, P, and K uptake.

Treatment No.	Grain Yield	Grain Protein	Grain Test Weight	Forage D.M. Yield	Forage Uptake P	Forage Uptake K
	bu/ac	%	lb/bu	lb/ac	lb/ac	lb/ac
1	55.8	12.9	58.9	7916	18.8	69.5
2	61.4	13.2	59.2	8381	18.0	74.2
3	52.5	12.6	58.2	7797	19.2	67.2
4	53.5	12.5	58.2	7763	15.8	68.8
5	54.3	12.4	58.3	8184	20.7	62.1
6	59.1	11.8	58.8	7601	18.0	66.6
7	53.8	13.3	58.6	7742	17.5	67.2
8	55.9	12.7	59.2	7679	19.4	61.5
9	59.7	12.7	58.3	7544	16.1	61.0
10	60.9	12.7	58.6	7343	14.2	64.7
Trt	NS	NS	NS	NS	NS	NS
C.V.	11.6	5.8	1.0	10.8	19.3	17.9

SIX-YEAR SUMMARY: The grain yields from 1980 to 1985 are reported in Table 4. Grain yield for 1980 was not taken because of poor emergence and stand caused by extreme heat and drought. No grain yield response occurred in 1983 and 1985. A grain yield from P fertilizer occurred in 1981, 1982, and 1984. A K fertilizer yield response occurred in 1981 and 1984.

Table 4. Historic grain yields for high P-K study.

Treatment No.	1980[1]	1981	1982	1983	1984	1985
	bu/ac					
1		51.7	55.0	46.1	50.4	55.8
2		58.5	54.4	47.7	55.9	61.4
3		59.6	58.0	46.4	63.1	52.5
4		58.1	59.4	48.6	62.4	53.5
5		56.6	60.1	48.4	65.0	54.3
6		53.3	58.0	46.6	59.4	59.1
7		56.3	57.5	48.3	63.4	53.8
8		58.0	61.6	51.4	62.0	55.9
9		58.7	58.2	45.5	57.3	59.7
10		57.0	59.8	50.3	58.9	60.7
Trt		++	*	NS	**	NS
C.V.		6.2	4.6	7.3	6.3	11.6

[1] No yield, drought.

**, *, ++, and NS are 0.01, 0.05, 0.10, and >0.20 significance levels, respectively.

The soil test P and K values, Table 5, indicate that annual applications of 50 lb P_2O_5 and 50 lb K_2O/ac "maintained" a soil test level of 11 and 130 ppm P (trt 3) and K (trt 7), respectively. The P level is actually 5 ppm greater than the unfertilized treatment (trt 1). Until 1984, the K level was similar to the unfertilized treatment (trt 1). In 1984, the soil test level increased by 20 ppm over treatment 1. Annual applications greater than 50 lb P_2O_5/ac and 50 lb K_2O/ac increased soil test levels.

Table 5. Soil $NaHCO_3$ P and exchangeable K values for 0-6 inch depth from 1980 to 1984.

Treatment No.	NaHCO3-P Fall of Year Initial	1980	1981	1982	1983	1984	Exchangeable K Fall of Year Initial	1980	1981	1982	1983	1984
	ppm											
1	5.5	6.0	5.5	5.0	5.0	3.5	125	132.0	102.5	131.5	131.5	140.5
2	5.5	6.0	6.5	5.5	5.0	4.0	125	135.5	125.5	158.5	160.5	178.0
3	5.5	11.0	10.0	10.0	12.5	13.0	125	135.0	117.0	148.0	151.0	179.5
4	5.5	15.0	12.5	17.5	22.0	24.0	125	141.0	124.5	153.0	153.5	182.5
5	5.5	18.5	11.5	10.5	16.5	13.5	125	142.0	123.0	159.5	159.5	186.5
6	5.5	9.5	15.0	15.0	19.5	20.5	125	130.0	109.0	128.0	125.5	135.0
7	5.5	15.5	13.5	17.5	18.0	21.0	125	132.5	110.0	134.0	136.5	157.5
8	5.5	15.5	14.0	18.0	21.5	27.5	125	150.5	130.0	140.5	154.5	178.5
9	5.5	16.0	11.5	9.5	8.0	7.0	125	139.0	115.0	137.5	136.5	108.0
10	5.5	17.0	9.0	7.5	7.0	5.5	125	144.5	108.0	136.5	127.5	139.5
Trt		**	**	**	**	**		**	**	**	**	**
C.V.		33.0	20.7	19.4	13.0	13.6		24.0	8.1	8.4	7.3	8.9

The P treatments which have applications once in 3 years (trt 5) and once in 6 years (trt 9 and trt 10) indicate that the soil test P increases dramatically with the addition of 100 and 150 lb P_2O_5/ac and decreased at a slower rate with the 1 in 6 year treatments becoming similar to the unfertilized treatment 4 and 5 years after application. This decrease is caused by both plant removal and soil unavailability. Treatment 5, 150 lb P_2O_5/ac application in 3 years, maintains the soil test P level at the same or greater than treatment 3, 50 lb P_2O_5/ac applied annually.

The variability in soil test K makes it hard to draw any conclusions on annual versus one application in 3 or 6 years.

CHLORIDE FERTILIZATION ON SPRING WHEAT

J.A. Lamb, C.E. Windels, and R.K. Severson

OBJECTIVE: The purpose of this study was to determine if spring wheat grown in the Red River Valley responded to chloride fertilization in yield and/or incidence of common root rot disease incidence caused by *Cochliobolus sativus*.

PROCEDURES: The treatments (Table 1) are divided into two sets: A) treatments 1 through 11 measure chloride response, and B) treatments 12 through 17 measure chloride - ammonia uptake interactions. Treatments 1 through 11 and 16 and 17 were broadcast fertilized with 60 lb N/ac as urea on May 1, 1985 according to the soil test given in Table 2.

Because of a calculation problem, only 43 lb N/ac were applied on treatments 12 through 15 on April 25, 1985. The experiment was arranged in a randomized complete block design and replicated four times. Marshall wheat was planted May 2, 1985 at a rate of 80 lb/ac. Plant populations were counted on May 20; forage samples were collected at the soft dough stage on August 7; and grain was harvested with a small plot combine on August 16 from a 4 1/2' by 18' area.

Because previous reports from North Dakota, South Dakota, and Oregon demonstrate that chloride reduces common root rot in small grains, root disease evaluations were made on July 10 (25 plants/plot) and August 15 (50 plants/plot). Subcrown internodes were rated on a scale from 0 to 3; 0 = clean, 1 = 1-25% discoloration, 2 = 26-50% discoloration, and 3 = 51-100% discoloration. Disease intensity was calculated using the McKinney's "infection index" where disease intensity (%) =

$$\frac{\sum(\text{category value x no. plants in category})}{\text{Total no. plants x maximum category value}} \times 100$$

RESULTS AND DISCUSSION:

Chloride Response Study - treatments 1-11: Grain yield, protein, population, forage yield, plant P, plant Ca, P uptake, Ca uptake, and root rot ratings were not affected by the addition of chloride fertilizers or the other compounds used to determine if other ions might be causing an effect. Perhaps the level of chloride in the soil at this location is sufficient to meet plant nutrient needs. Although typical root rot lesions were found on wheat roots in each plot, the season was too cool and wet to accurately measure the effects of soil fertility on root disease. This is because *C. sativus* needs moisture to infect roots, but root rot does not progress or affect plant development unless the crop is stressed by hot, dry weather. Under cool, wet conditions, plants infected by *C. sativus* recover with no apparent effects on grain yield or quality. Plant populations were significantly different between treatments, but these differences did not correlate with any of the treatments applied. The K concentration and K uptake at the soft dough stage were increased at the low rate of K fertilization but this did not occur at the high rate.

Chloride - Ammonia Uptake Study treatments 12-17: Grain yield, protein, and forage yield were significantly lower for the NH_4Cl treatment compared to the other N sources (NH_4NO_3, KNO_3, and $Ca(NO_3)_2$). Treatments with K (14, 16, and 17) resulted in increased K concentrations and K uptakes at soft dough stage. Plant populations, bushel weight, P and Ca concentrations, P and Ca uptakes, and root rot ratings were not affected by treatments 12 through 17.

The lower N application on treatments 12 through 15 resulted in significantly lower grain yield, protein and forage yield than for treatments 1 through 11.

The possibility of an adequate natural-occurring level of chloride in the test site combined with a growing season unfavorable for common root rot points to the need to measure soil chloride levels, conduct tests in low-chloride sites, and to continue tests for several seasons to more accurately evaluate the effects of chloride fertilizer on yield and common root rot.

Table 1. Treatments for chloride study, NWES 1985.

Treatment No.		
1	50 lb/ac K_2O as 0-0-60 KCl	
2	100 lb/ac K_2O as 0-0-60 KCl	
3	60 lb/ac $CaCl_2$	] Cl^- source to compare
4	120 lb/ac $CaCl_2$	treatments 1 and 2
5	100 lb/ac Gypsum $CaSO_4$	] Ca^{2+} source to compare
6	200 lb/ac Gypsum $CaSO_4$	treatments 3 and 4
7	92 lb/ac K_2SO_4	] K^+ source to compare with
8	184 lb/ac K_2SO_4	treatments 1 and 2
9	99 lb/ac Gypsum $CaSO_4$	] S source to compare
10	198 lb/ac Gypsum $CaSO_4$	treatments 7 and 8
11	Check	
12	190 lb/ac NH_4NO_3 (43 lb N/ac)	
13	242 lb/ac NH_4Cl (43 lb N/ac)	
14	458 lb/ac KNO_3 (43 lb N/ac)	
15	406 lb/ac $Ca(NO_3)_2$ (43 lb N/ac)	
16	200 lb/ac K_2O as 0-0-60 KCl	] Cl^- source for comparison
17	204 lb/ac K_2O as 0-0-60 KCl	of treatments 13 and 14

Table 2. Soil test for chloride study, NWES 1985.

NO_3^--N	(0-2')	57 lb/ac
P	(0-6")	7 lb/ac
K	(0-6")	340 lb/ac
pH		8.3
O.M.		2.8%

Table 3. Grain and forage parameters measured on chloride study, NWES 1985.

					Forage							Root Rot	
			Bushel	Population		Concentration			Uptake			Index	
	Yield	Protein	Wt.	plant/	Yield	P	K	Ca	P	K	Ca		
Treatment	bu/ac	%	lb/bu	ac	lb/ac	- -	ppm	- -	- -	lb/ac	- -	7/10	8/15
1	57.2	13.5	58.1	1032580	9828	1477	14445	1202	14.4	144.1	12.2	24	33
2	56.5	13.6	58.8	997734	8092	1672	11266	928	13.7	91.5	7.5	23	30
3	58.3	13.5	56.8	925410	8319	1766	10853	952	14.9	89.5	7.8	14	26
4	57.1	13.6	58.6	1041304	8803	1705	11827	1039	15.5	101.8	9.1	14	30
5	59.3	13.3	58.1	953294	9124	1688	11695	1118	15.4	107.4	10.3	19	27
6	59.7	13.3	57.9	1021262	9254	1650	12583	997	15.3	116.8	9.2	23	29
7	64.1	13.4	56.9	1055246	8986	1442	14048	1267	12.8	127.2	11.7	21	26
8	58.1	13.2	58.0	1044789	8603	1579	11712	983	13.7	100.8	8.4	20	35
9	59.2	13.0	58.2	1037818	8587	1480	12216	1076	12.7	104.7	9.2	19	26
10	61.0	13.0	58.0	1000349	9258	1720	11324	922	16.1	105.1	8.6	13	28
11(check)	62.4	13.3	56.0	940223	8846	1696	10282	1079	15.0	91.5	9.6	23	38
12	50.7	11.7	59.6	995120	8148	2005	8253	767	16.5	67.1	6.3	16	33
13	41.9	11.1	60.3	980307	7349	1913	9877	738	14.1	72.6	5.4	20	39
14	50.0	12.2	59.1	997734	8102	1587	10696	969	13.0	86.5	7.8	24	38
15	52.8	11.7	59.2	1036947	8167	1665	9603	887	13.7	78.2	7.3	14	26
16	56.1	12.6	59.3	1042175	8821	1850	11206	771	16.4	98.5	6.8	19	26
17	54.4	13.2	58.1	896654	8899	1794	11610	920	16.0	103.6	8.2	18	336
LSD (.05)	8.2	0.6	1.6	79596	1040	365	2485	274	3.9	26.6	2.9	11.7	12.3
LSD (.10)	6.8	0.5	1.3	66434	868	305	2074	228	3.3	22.2	2.4	9.7	10.3
TRT	**	**	**	**	**	+	**	*	NS	**	**	NS	NS
C.V., %	10.2	3.3	1.9	5.6	8.5	15.2	15.4	19.7	18.8	18.9	24.1	43.1	27.6

**, *, +, and NS are 0.01, 0.05, 0.20, and > 0.20 significance level, respectively.

EFFECT OF HIGH RATES OF ROW-APPLIED UREA ON SPRING WHEAT AND SPRING BARLEY

J.A. Lamb and R.K. Severson

OBJECTIVE: This study was conducted to evaluate the effects of high application rates of urea with the spring wheat and barley seed on population, quality and yield.

MATERIALS AND METHODS: This study was conducted at the Northwest Experiment Station during the summer of 1985. Marshall wheat and Robust barley were grown with five row-applied treatments of 0, 25, 50,75, and 100 lb N/ac as urea. These treatments were replicated four times. The soil NO_3^--N 0-2' was 50 lb/ac. The plots were planted with an 8 foot Melroe double disk drill on May 3, 1985. Population counts were made before tillering. Whole plant samples were taken at maturity, soft dough, August 7, 1985. The grain was harvested August 8 and August 16, 1985 for the barley and wheat, respectively.

RESULTS AND DISCUSSION: Table 1 contains the results for the wheat portion of the experiment.

Table 1. Spring wheat grain yield, quality, population, and dry matter for five rates of seed applied urea.

	Grain			Forage
N Rate	Yield	Test Weight	Population	Dry Matter
lb/ac	bu/ac	lb/bu	plants/ac	lb/ac
0	36	61	683892	5056
25	51	59	649044	6565
50	57	59	606355	7915
75	57	53	506167	8438
100	49	51	470448	8468
N Rate	**	**	**	**
C.V.	13.0	5.3	8.1	11.8

The maximum wheat yield was obtained at the 50 to 60 lb/ac rate. These yields were under the potential yield level for 1985. This was caused by a shortage of N plus the reduction of population. The recommended N rate would have 120 to 130 lb/ac of soil NO_3^--N plus fertilizer N. At 50 to 75 lb/ac rate, the total would have been 100 to 110 lb/ac. The plant populations were affected negatively by the increasing N rates. For optimum yield, a population of 700,000 plants per acre is needed. Table 1 shows that at 50 and 75 lb/ac the population was suboptimal. At rates above 50 lb/ac the test weight was economically affected decreasing below 58 lb/bushel.

The results from the barley portion of the experiment are reported in Table 2.

Although the yield did not decrease at the higher N rates, the maximum yield was obtained at the 75 lb N/ac rate. Like the wheat yields, the barley yields were not at the yield potential that was possible in 1985. The population was decreased by increasing N rates. This decrease of population was probably the reason for not obtaining higher yields.

The quality, % plumps and thins, were not affected by the seed application of N. The test weight was decreased but not seriously.

The amount of dry matter at maturity was increased by N rate even from the 100 lb/ac treatment.

Table 2. Spring barley grain yield, quality, population, and dry matter.

N Rate		Grain			Population	Forage Dry Matter
		Test Weight	Plumps	Thins		
lb/ac	bu/ac	lb/bu	- - - - %	- - -	plants/ac	lb/ac
0	39	48	88	10	557568	4157
25	57	48	87	12	545371	5857
50	60	47	88	10	466092	6968
75	63	47	90	9	402494	7131
100	64	46	88	9	370260	7541
N Rate	**	**	NS	NS	**	**
C.V.	9.9	1.2	3.5	28.2	11.2	12.1

INVESTIGATION OF SPRING WHEAT Cu-P UPTAKE INTERACTIONS ON PEAT SOILS IN NORTHWESTERN MINNESOTA

John A. Lamb

On May 20, 1985 a field study was established to determine the amount of phosphorus (P) and copper (Cu) uptake by spring wheat grown on peat soils and if an interaction occurs between P and Cu. Being unable to establish a Cu deficiency in the greenhouse, this study was conducted in the field.

MATERIALS AND METHODS: The field study was located on the Gust Kveen farm, Roseau, MN. The soil tested 39 lb/ac Bray-P, 188 lb/ac extractable K, and a pH of 7.1. The DTPA extractable Cu was 3.6 ppm. This is in the marginal soil test category of 2.6-5.0. Eighteen treatments arranged in a factorial design were used in this study. These treatments involve three rates of Cu (0, 6, and 12 lb/ac), two rates of P (0 and 20 lb/ac), two sources (chelate and sulfate), and two methods of placement (broadcast and row). Marshall spring wheat was planted May 20, 1985. The treatments were applied shortly before or during planting. Plant samples were taken at Feekes stage 3 (tillering), 8 (jointing), 10 (boot), and 11 (maturity) for Cu and P analyses. Grain yields were taken September 27, 1985.

RESULTS AND DISCUSSION: Wheat yields increased 8.7 bu/ac with the application of 6 lb/ac of Cu ($P \geq 0.001$). Increasing the Cu to 12 lb/ac had no additional effect on yield. The increase in yield from Cu fertilization in this study was not as large as has been recorded in the past. This may be explained by the higher soil level of Cu at this site. The Cu fertilization recommendation for a soil test of 3.6 ppm DTPA extractable Cu is 6 lb/ac Cu which agrees with the results of this study.

The broadcast method of application produced 7 bu/ac more grain than row application ($P > .001$). A possible explanation was an increase of root interception of Cu with the broadcast application. Earlier studies reported mixed results comparing broadcast vs. row application. There was a significant interaction between rate of Cu and method of application ($P > .03$, Table 1). Increasing the Cu rate with the broadcast application increased grain yield. With the row placement, the grain yield decreased with increasing Cu rate.

The chelated source of Cu had a 1.7 bu/ac larger yield than the sulfate source ($P > .13$). A significant source by method of application interaction occurred ($P > 0.02$, Table 2). For row application the chelate form performed better. The sources performed equally for the broadcast application. The economic choice would be the sulfate source.

The results in Table 3 are from the first three plant sampling stages. The fourth sampling stage, Feekes 11, is being analyzed at the time of writing.

The analysis of variance of the plant uptake data did not indicate a significant Cu by P interaction. To detect a Cu-P interaction, where the Cu content is low in the plant, the P content is high and as the Cu content increased the P content would decrease, the correlation analysis would have to produce a negative correlation coefficient. This study does not support a Cu-P interaction. The marginal soil Cu content (3.6 ppm) could explain this. In earlier studies, the DTPA extractable Cu was <2.0 ppm. The soil copper content may have to be <2.0 ppm for a Cu-P interaction to occur.

SUMMARY: The results from this study did not find a Cu-P uptake interaction. There was a significant increase in yield from a 6 lb/ac application of Cu. A producer growing spring wheat on peat soils with a marginal soil test content, 2.5 to 5.0 ppm DTPA extractable Cu, should consider broadcast application of 6 lb Cu/ac as copper sulfate for the best results.

Table 1. Grain yields as affected by rate and method of Cu application.

Rate		Method: Broadcast	Method: Row	$\bar{X}$
lb/ac		bu/ac		
0		14.6		14.6
6		25.8	20.8	23.3
12		28.2	18.4	23.6
	$\bar{X}$	27.0	19.7	

Table 2. Grain yields as affected by source of Cu fertilizer and method of application.

Source	Method: Broadcast	Method: Row	$\bar{X}$
	bu/ac		
Chelate	26.7	21.7	24.3
Sulfate	27.4	17.7	22.6
$\bar{X}$	27.0	19.7	

Table 3. Uptake values for Cu and P for three sampling dates (Feekes 3, 8, and 10), three Cu rates (0, 6, and 12), and two P rates (0 and 20 lb/ac).

	Feekes 3				Feekes 8				Feekes 10			
	Cu Uptake		P Uptake		Cu Uptake		P Uptake		Cu Uptake		P Uptake	
Cu Rate	0P	20P	0P	20P	0P	20P	0P	20P	0P	20P	0P	20P
	lb/ac											
0	.0008	.0006	0.72	1.08	.0033	.0035	3.37	5.14	.0052	.0101	10.77	12.74
6	.0010	.0007	1.02	0.73	.0046	.0059	3.93	5.25	.0096	.0092	11.96	12.60
12	.0009	.0009	0.71	0.95	.0060	.0051	4.33	4.80	.0091	.0105	11.43	12.27

TIMING OF NITROGEN APPLICATION ON SUGARBEET

John A. Lamb

OBJECTIVE: Evaluate the effect of application timing of N fertilization on yield and quality.

PROCEDURES: The plots were established at the Northwest Experiment Station, Crookston, MN. Anhydrous ammonia was used to apply N at four dates, April 20, May 20, June 10, and July 1. The total N applied was 120 lb/ac as NH_3 and 28 lb/ac in the soil. The treatments were applied as 120 lb/ac in several combinations over the four dates as shown in Table 1. The treatments were aranged in a randomized complete block design with four replications. The plots were seeded April 25 with variety Dippe II. The final population was 125 plants/100 ft row. The beets were harvested September 20, 1985 with the quality measured by the American Crystal Tare Lab at East Grand Forks.

RESULTS AND DISCUSSION: Table 1 shows the yield, sugar, recoverable sugar, and impurities.

The yield was not significantly affected by the application of nitrogen. A trend of yield depression with later application of the nitrogen fertilizer was indicated. Evidentally, to maximize yield, nitrogen must be available early in the growing season. The later application does not produce maximum yield.

The sugar content was affected by nitrogen treatments ($P \geq 0.10$). The sugar content decreases with the later application of nitrogen. This is similar to the yield. Studies in the past have reported if the nitrate content in the sugarbeet is above 1000 ppm within 6 weeks of harvest, the sugar content will be decreased. The later N applications along with N mineralized from the soil, probably keep the petiole NO_3^--N levels above 1000 much later than the earlier applications. At this time the petiole NO_3^--N samples taken have not been analyzed to confirm this but will be at some time this spring.

The impurity index was significantly affected by treatment. This was because the N application affected the Amino N component of the impurity index.

Recoverable sugar was significantly increased from nitrogen fertilization when applied earlier in the growing season. If N was applied later, the amount of sugar recovered was less than the check treatment. This integrates the effects of results discussed earlier.

In summary, the split applications where the one of the applications are late in the season caused lower recoverable sugar. The best treatments were when all of the N fertilizer was applied by June 1. This conclusion is specific for 1985 and may not hold for years with different weather conditions.

Table 1. Yield, quality and soil test data for N timing study.

Study Date				Yield	Sugar	Recoverable Sugar			Impurities Na	K	Amino N	
4/20	5/20	6/10	7/1	t/ac	%	lb/ac	%	lb/ton	- - - ppm	- - -		Index
0	0	0	0	16.0	16.3	4839	.93	301	205	1795	280	487
30	30	30	30	17.9	15.6	4980	.90	280	268	1835	528	677
60	60	0	0	19.1	16.0	5536	.90	289	218	1793	538	646
60	0	60	0	17.7	16.1	5130	.90	288	240	1880	580	691
60	0	0	60	15.6	14.9	4103	.88	263	310	1908	583	769
0	60	60	0	19.2	15.7	5429	.90	282	240	1815	540	675
0	60	0	60	16.4	15.9	4675	.90	286	273	1750	540	659
0	0	60	60	17.5	15.0	4723	.89	265	318	1885	585	765
120	0	0	0	15.9	15.8	4561	.90	286	228	1800	505	638
0	120	0	0	19.7	15.6	5550	.90	282	268	1868	480	652
0	0	120	0	17.9	16.0	5228	.91	292	240	1835	438	599
0	0	0	120	17.0	15.4	4661	.90	276	290	1880	503	685
Treatment				NS	++	NS	**	*	NS	NS	**	**
CV				13.6	4.0	15.1	1.3	4.9	26.7	5.1	16.3	11.6
LSD (.05)				3.4	0.80	1070	.016	20	99	133	119	110
LSD (.10)				2.8	0.75	891	.014	17	82	111	99	92

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

	Soil Test	
NO_3^--N	28 lb/ac	0-2'
P	10 lb/ac	0-6"
K	170 lb/ac	0-6"

STARTER PHOSPHORUS FERTILIZER EFFECT ON SUGARBEET

John A. Lamb

OBJECTIVE: Determine if the fertilizer needs for a sugarbeet can be met with a starter fertilizer application alone.

PROCEDURES: Four locations were chosen for this study in 1985. Two in West Central Minnesota in the Holoway-Milan area and two near Crookston. Table 1 gives the soil test data. Four treatments were 10-34-0 broadcast or row applied at planting at 3 or 6 gallon rates. Three treatments involved preplant application of the Minnesota recommendations (Table 2) alone, or with 3 and 6 gallons of row-applied 10-34-0. An unfertilized check was also included making a total of eight treatments. At each site there were four replications in a randomized complete block design. One replication had to be abandoned at the Peterson site because of poor plant population.

The West Central Minnesota locations were planted May 8, 1985. The Northwest Experiment Station and Peterson locations were planted May 20, 1985, respectively. The plots were harvested between September 16 and September 28, 1985. Quality was determined by the American Crystal Tare Lab in Grand Forks.

RESULTS AND DISCUSSION:

ARNOLD LOCATION: The yield was increased by fertilization (Table 3). The largest yield occurred with the Minnesota recommendation plus 6 gallons of 10-34-0. The treatments with the Minnesota recommendations did better than the treatments without.

The sugar content was also greater in the Minnesota recommendation treatments. Recoverable sugar on the pound per acre basis was increased by fertilization. The Minnesota recommendation treatments with starter had the highest yield. The MN Rec + 3 gal 10-34-0 produced the same yield as MN Rec + 6 gal 10-34-0.

The largest recoverable sugar on a pound per ton of sugarbeet was the Mn Rec treatment. All the Mn Rec treatments did better than the starter alone.

JOHNSON LOCATION: Table 4 shows the yields for the Johnson location. No treatments affected yield. Except for the Mn Rec treatment, sugar content was decreased by fertilization. The recoverable sugar on a pound per acre was not affected by the treatments. Because of the reduction in sugar content the recoverable sugar on a pound per ton basis was decreased by fertilization except for the Mn Rec which was the same as the check.

NWES LOCATION: Fertilizer application increased the yield at the NWES location (Table 5). The Mn Rec + 3 gal 10-34-0, and Mn Rec + 6 gal 10-34-0 treatments performed better than the check, 3 gal 10-34-0 row, and 6 gal 10-34-0 row.

The sugar content was less than the check with the 3 gal 10-34-0 broadcast and 6 gal 10-34-0 broadcast. The Mn Rec, Mn Rec + 3 gal, Mn Rec + 6 gal, 3 gal 10-34-0 row and 6 gal 10-34-0 row are similar to the check.

The recoverable sugar on a pound per acre basis was greatest with the Mn Rec treatments. The other starter alone treatments were not different from the check. Recoverable sugar on a pound per ton of sugarbeet basis was the greatest with the 6 gal 10-34-0 row starter treatment. This was not significantly different from the check.

PETERSON LOCATION: The only significant yield differences occurred between the row and broadcast starter treatments (Table 6). The sugar content was not affected by any treatment. The recoverable sugar pound per acre was increased by the fertilizer treatments where the Mn Rec treatments on the average did better than the row starter treatments. Recoverable sugar on the pound per ton basis was not affected by the treatments.

SUMMARY: In most instances the Mn Rec treatment performed better than the starter treatments. The weather conditions observed in the 1985 season would tend to reduce the advantage attributed to starter fertilizers because of the above-normal May temperatures. In three of the four locations, the greatest recoverable sugar pound per acre basis was with the Mn Rec + 3 or 6 gal 10-34-0 treatment. On the pound per ton basis, the Mn Rec treatment did better than the row starter treatment at all but the NWES location. These results are from one years data and may be different under different weather situations. This study will be conducted over more years in hopes to evaluate these treatments under different weather conditions.

Table 1. Soil test information.

	Site			
	Arnold	Johnson	NWES	Peterson
NO_3^--N 0-2' lb/ac	59	40	28	59
P 0-6" lb/ac	11	25	10	11
K 0-6" lb/ac	400	410	170	200
pH	7.8	6.7	8.2	8.0
OM, %	4.4	3.1	4.0	3.0

Table 2. Minnesota recommendations for each site in starter study.

	Site			
	Arnold	Johnson	NWES	Peterson
	lb/ac Applied			
N	61	80	92	61
P_2O_5	30	0	70	30
K_2O	0	0	40	0

Table 3. Yield and quality data for Arnold site, 1985.

Treatment	Yield t/ac	Sugar %	Index	Recoverable Sugar lb/ac	Recoverable Sugar lb/t
Check	15.4	15.5	575	4353	282
3 gal Broadcast	17.5	15.8	540	5079	291
6 gal Broadcast	20.8	15.6	513	5967	287
3 gal Row	21.7	15.4	596	6083	281
6 gal Row	21.7	15.8	528	6309	291
Mn Rec	22.1	16.2	495	6629	301
Mn Rec + 3 gal Row	24.3	16.1	484	7239	298
Mn Rec + 6 gal Row	24.9	16.0	555	7271	293
Treatment	**	+	NS	**	+
C.V.	9.3	3.0	11.7	9.2	3.7

** and + are 0.01 and 0.20 significance levels, respectively

Table 4. Yield and quality data for Johnson site, 1985.

Treatment	Yield t/ac	Sugar %	Index	Recoverable Sugar lb/ac	Recoverable Sugar lb/t
Check	21.1	15.8	518	6152	292
3 gal Broadcast	20.6	15.7	489	6003	291
6 gal Broadcast	22.2	15.3	563	6224	280
3 gal Row	24.1	15.3	576	6715	279
6 gal Row	21.7	15.2	549	6066	280
Mn Rec	25.3	15.8	549	7341	290
Mn Rec + 3 gal Row	24.2	15.4	560	6825	282
Mn Rec + 6 gal Row	24.3	15.6	609	6849	283
Treatment	NS	+	*	NS	+
C.V.	12.4	2.5	7.5	12.1	3.0

* and + are 0.05 and 0.20 significance levels, respectively.

Table 5. Yield and quality data for NWES site, 1985.

Treatment	Yield t/ac	Sugar %	Index	Recoverable Sugar lb/ac	Recoverable Sugar lb/t
Check	13.5	15.5	564	3844	283
3 gal Broadcast	13.8	14.1	689	3499	253
6 gal Broadcast	13.3	15.0	620	3591	273
3 gal Row	14.4	15.2	590	3988	277
6 gal Row	15.0	15.9	551	4374	291
Mn Rec	17.0	15.5	629	4830	281
Mn Rec + 3 gal Row	17.4	15.9	601	5009	288
Mn Rec + 6 gal Row	17.6	15.4	657	4887	277
Treatment	**	++	+	**	++
C.V.	8.8	4.7	10.6	9.8	5.6

**, ++ and + are 0.01, 0.10, and 0.20 significance levels, respectively.

Table 6. Yield and quality data for Peterson site, 1985.

Treatment	Yield t/ac	Sugar %	Index	Recoverable Sugar lb/ac	Recoverable Sugar lb/t
Check	15.4	16.0	737	4341	285
3 gal Broadcast	16.2	16.3	712	4744	293
6 gal Broadcast	14.2	15.7	821	3901	276
3 gal Row	15.6	16.2	760	4476	287
6 gal Row	17.7	16.4	736	5122	291
Mn Rec	16.9	16.8	692	5083	301
Mn Rec + 3 gal Row	17.4	16.6	740	5138	295
Mn Rec + 6 gal Row	16.8	16.2	761	4826	287
Treatment	+	NS	NS	*	NS
C.V.	9.2	3.3	11.0	9.0	4.2

* and + are 0.05 and 0.20 significance levels, respectively.

EFFECT OF PHOSPHORUS AND POTASSIUM FERTILIZATION ON YIELD AND QUALITY OF SUGARBEET GROWN IN WEST CENTRAL MINNESOTA

John A. Lamb

OBJECTIVE: To determine the effect of P and K fertilization on sugarbeet yield and quality in the corn and soybean production area of West Central Minnesota.

PROCEDURES: The study was established at the Dale Johnson farm near Milan, MN and the Dan Arnold farm near Holoway, MN. Soil test information is listed in Table 1.

The treatments were a factorial arrangement of N, P and K fertilizer and replicated 4 times in a randomized block design. Each element was applied at 3 rates (0, 50, 100 lb N/ac; 0, 20, 40 lb P/ac; and 0, 25, 50 lb K/ac). The fertilizer was a dry material (Urea, 0-44-0 and 0-0-60) broadcast and incorporated before planting.

The variety KW3394 was planted May 8, 1985 and thinned later to 125 plants/100 ft of row. Harvest occurred September 20, 1985 with quality determined by the American Crystal Tare Lab located in Grand Forks, ND.

RESULTS AND DISCUSSION:

Arnold Location: Yield was significantly increased from the application of both N and P (Table 2 and 3). The soil test would indicate a high probability of response to these inputs and not K. The maximum tonnage yield was not obtained from the high rates of N or P.

The sugar content was decreased by the 100 lb/ac rate of N. The P and K did not affect sugar content.

Nitrogen did not affect the amount of sugar recovered on a per acre basis but it did decrease the amount recovered per ton of sugarbeet processed at the high rate of N. Phosphorus increased the amount of recoverable sugar per acre but did not affect the amount recovered per ton.

The maximum recovered per ton of sugarbeet occurred at 50 lb N/ac or approximately 110 lb of fertilizer + soil N. This corresponds closely with the suggested recommendations. A surprising factor was that the addition of K fertilizer to a soil with high soil test K (400 lb) did not affect the K level in sugarbeet and thus not increasing the impurities in the sugar production.

Johnson Location: The yield was increased by N and K fertilization (Table 4 and 5). The N effect was expected but the K effect was not predicted from the soil value (410 lb/ac).

There was a significant interaction of P and K on yield. As the rate of P increased, the yield increase from K fertilization was greater (Table 7).

The sugar content was affected by N and P. The N response was positive up to 50 lb/ac and then decreased at the highest N rate. The decrease in sugar from the first 20 lb P/ac and then increase at 40 lb P/ac is not explainable.

Nitrogen increased the recoverable sugar per acre past the 100 lb/ac rate. The maximum amount recovered per ton of beet was at the 50 lb/ac rate or a soil + fertilizer N level of 90 lb/ac. This is a lower rate than would be expected. A depression of both recoverable sugar per acre and per ton occur at the 20 lb P/ac. The soil test would indicate the probability of a yield increase from P fertilization would be small. The surprise result was the increased recoverable sugar per acre at the 50 lb K/ac rate. The soil test would not have predicted a yield increase from K application. Table 7 also indicates a P by K interaction for recoverable sugar per acre similar to the interaction for yield.

The soil test listed in Table 1 is from a spring sample. The farmer's fall sample results indicate a K soil test of 195 lb/ac. At this soil test the probability of an increase in recoverable sugar per acre is higher than a soil test of 400 lb/ac. An explanation could lie in the accuracy of the soil sampling and the moisture content of the soil. Originally this difference was thought to be from the different sampling practices and areas sampled. The fall sample was taken on a field size area with a hydraulic corer. The spring sample came from the plot area and was taken by a hand sampler. Past literature indicates that soil moisture can affect the K soil test level considerably. The fall sample was taken under drier soil moisture conditions than the spring sample. This location will be resampled to determine the correct K value.

Potassium application did not affect the recoverable sugar per ton of sugarbeet. Similar to the Arnold site, K did not increase the amount of potassium in the beet and thus did not increase the impurities in the beet.

The help of Dr. James Widner and Ken Dahl in locating these sites is greatly appreciated.

Table 1. Soil Test Information.

	Site	
	Arnold	Johnson
NO_3^--N 0-2' lb/ac	59	40
P 0-6" lb/ac	11	25
K 0-6" lb/ac	400	410
pH	7.8	6.7
OM	4.4	3.1

Table 2. Yield and quality data for Arnold site, 1985.

N Rate lb/ac	Yield t/ac	Sugar %	Index	Recoverable Sugar lb/ac	Recoverable Sugar lb/t
0	21.7	15.8	547	6304	290
50	22.8	15.9	541	6683	293
100	23.3	15.6	619	6603	284
	+	++	**	NS	**
P Rate lb/ac					
0	20.9	15.8	683	6042	289
20	22.5	15.8	566	6493	289
40	24.4	15.8	560	7056	289
	**	NS	NS	**	NS
K Rate lb/ac					
0	22.4	15.7	571	6440	287
25	22.5	15.8	570	6504	289
50	22.9	15.9	567	6646	290
	NS	NS	NS	NS	NS

Table 3. Statistics for Arnold location.

Source	Yield	Sugar	Index	Recoverable Sugar lb/ac	Recoverable Sugar lb/ton
Nitrogen Rate (N)	+	++	**	N.S.	**
Linear	*	+	**	N.S.	*
Phosphorus Rate (P)	**	N.S.	N.S.	**	N.S.
Linear	**	N.S.	N.S.	**	N.S.
Potassium Rate (K)	N.S.	N.S.	N.S.	N.S.	N.S.
Linear	N.S.	N.S.	N.S.	N.S.	N.S.
N * P	N.S.	N.S.	N.S.	N.S.	N.S.
N * K	N.S.	N.S.	N.S.	N.S.	N.S.
P * K	N.S.	N.S.	N.S.	N.S.	N.S.
N * P * K	N.S.	N.S.	N.S.	N.S.	N.S.
C.V.	14.9	3.2	14.4	16.1	4.3

**, *, ++ and + are 0.01, 0.05, 0.10, and 0.20 significance levels, respectively.

N.S. is not significant (P $\geq$ 0.20).

Table 4. Yield and quality data for Johnson site, 1985.

N Rate lb/ac	Yield t/ac	Sugar %	Index	Recoverable Sugar lb/ac	Recoverable Sugar lb/t
0	19.4	15.4	537	5499	283
50	22.8	15.7	529	6577	289
100	24.4	15.5	591	6914	283
	**	*	**	**	*
P Rate lb/ac					
0	22.4	15.6	551	6401	286
20	21.8	15.4	561	6170	282
40	22.4	15.6	545	6419	287
	NS	++	NS	+	+
K Rate lb/ac					
0	21.7	15.5	561	6158	283
25	21.7	15.5	549	6159	285
50	23.2	15.6	546	6663	287
	**	NS	NS	**	NS

Table 5. Statistics for Johnson location.

Source	Yield	Sugar	Index	Recoverable Sugar lb/ac	Recoverable Sugar lb/ton
Nitrogen Rate (N)	**	*	**	**	*
Linear	**	N.S.	**	**	N.S.
Phosphorus Rate (P)	N.S.	++	N.S.	+	+
Linear	N.S.	N.S.	N.S.	N.S.	N.S.
Potassium Rate (K)	**	N.S.	N.S.	**	N.S.
Linear	**	++	N.S.	**	+
N * P	N.S.	N.S.	N.S.	N.S.	N.S.
N * K	N.S.	N.S.	N.S.	N.S.	N.S.
P * K	*	N.S.	N.S.	+	N.S.
N * P * K	N.S.	N.S.	N.S.	N.S.	N.S.
C.V.	9.4	3.0	11.1	10.0	3.7

**, *, ++ and + are 0.01, 0.05, 0.10, and 0.20 significance levels, respetively.

N.S. is not significant (P $\geq$ 0.20).

Table 6. Interaction means for Johnson site, 1985.

lb P/ac	Yield (lb K/ac) 0	25	50
0	22.9	21.4	22.9
20	21.5	21.6	22.4
40	20.8	22.0	24.3
	Recoverable Sugar (lb/ac) 0	25	50
0	6420	6152	6631
20	6058	6109	6344
40	5997	6249	7013

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

J.A. Lamb and R.K. Severson

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

METHODS AND MATERIALS: Four sites were located for this study in 1985. The N fertilizer (urea) treatments (0, 30, 60, 90 and 120 lb N/ac) and inoculation treatment (none and inoculated) were applied and the plots planted to McCall soybean May 23, 24, 28 and 28 for the Marshall County, NWES, East Polk County and Norman County sites, respectively. The most recently matured trifoliate leafs were sampled July 25 through 28. The East Polk location was abandoned at that time because of a weed control problem. The plots were harvested by hand the first week of October.

RESULTS AND DISCUSSION: Tables 1, 2 and 3 list the grain yields, trifoliate N, and statistical analyses for 1985. The Marshall County site had an increased yield from inoculation. Application of N fertilizer did not affect yields. With a soil test of 50 lb NO_3^--N/ac 0-2 ft, a yield response was expected. The trifoliate data showed no effect of inoculation but did have an increase in N concentration with increasing rates of N. Some other factor was limiting yield response to N.

Yields at the NWES site were increased by both inoculation and N application. The trifoliate N concentration was increased by N application but not inoculation. It took over 60 lb N/ac applied to noninoculated soybean to equal the yield of inoculated soybean with no N applied. At the soil NO_3^--N level of 50 lb/ac 0-2 ft a response similar to this would be expected. The N fertilizer continues to increase yield up to the 90 lb/ac rate for inoculated soybean and up to the 120 lb N/ac rate for the noninoculated treatment.

The Norman County site had a soil NO_3^--N test 0-2 ft of 80 lb/ac. Inoculation did not affect yield and N application decreased yield except for the 120 lb N/ac treatment. The nonresponse would be expected because of the high soil NO_3^--N level. Trifoliate N analyses for the Norman County site were not available at the time of this report.

SUMMARY: Unlike 1984, the nodule formation in the inoculated plots was good. The noninoculated soybean did not set nodules. A good job of inoculating seed may be the most important aspect to getting soybean to produce nodules.

Table 1. Grain yields for 1985.

	Marshall County 50 lb NO_3^--N 0-2'			NWES 50 lb NO_3^--N 0-2'			Norman County 80 lb NO_3^--N 0-2'		
N Rate	O	I	$\bar{X}$	O	I	$\bar{X}$	O	I	$\bar{X}$
lb/ac	bu/ac								
0	19.5	18.6	19.1	15.1	19.2	17.2	26.9	25.8	26.3
30	15.4	19.0	17.2	17.3	20.1	18.7	25.6	24.8	25.2
60	16.2	18.4	17.3	18.7	20.8	19.8	23.7	24.8	24.3
90	15.7	20.9	18.3	22.0	23.8	22.9	23.9	22.6	23.3
120	15.9	19.6	17.8	24.1	24.7	24.4	26.5	27.4	26.9
$\bar{X}$	16.6	19.3	17.9	19.4	21.7	20.6	25.4	25.1	25.2

O and I are noninoculated and inoculated, respectively.

Table 2. Most recently matured trifoliate N concentration at 1/2 bloom, 1985.

	Marshall County			NWES		
N Rate	O	I	$\overline{X}$	O	I	$\overline{X}$
0	4.41	4.41	4.41	3.30	3.43	3.36
30	5.22	5.05	5.13	4.37	4.09	4.23
60	5.58	5.52	5.55	4.72	4.58	4.65
90	5.67	5.40	5.54	4.67	4.68	4.67
120	5.81	5.63	5.72	4.94	4.62	4.78
$\overline{X}$	5.34	5.20	4.46	4.40	4.28	4.34

O and I are noninoculated and inoculated, respectively.

Table 3. Statistical analyses for soybean study, 1985.

	Marshall County		NWES		Norman County
	Yield	Trifoliate N	Yield	Trifoliate N	Yield
I	*	NS	*	NS	NS
N	NS	**	**	**	*
N lin	NS	**	**	**	NS
N quad	NS	**	NS	**	**
I*N	NS	NS	NS	NS	NS
	16.7	4.5	7.5	5.6	9.2

I and N are inoculation and nitrogen rate, respectively.
**, * and NS are 0.01, 0.05, and > 0.20 significance levels, respectively.

AVAILABILILTY OF RESIDUAL NITRATE-N TO CORN

Lamberton, 1985

G. W. Randall and W. W. Nelson

Application of fertilizer N at rates exceeding crop removal can result in rather significant amounts of residual N left in the soil for the succeeding crop. For instance, after a very dry season, the quantity of residual N may be such that crop response the following year to added fertilizer may not be obtained. The purpose of this study is to determine crop response to residual NO_3-N and to measure loss of this N to tile lines.

EXPERIMENTAL PROCEDURES

Nitrogen fertilizer was applied as urea annually from 1973-1979 to tile drained plots each measuring 45' x 50' and lined with plastic at Lamberton. Rates of 18, 100, 200, and 400 lb N/A were replicated three times. An additional treatment (200 lb N/A as soybean meal) was applied to isolated plots which were not within the original replications. Consequently, statistical analyses have been performed only on the former four treatments.

Corn has been grown continuously from 1973 thru 1985. The grain has been removed and all remaining residue plowed down annually. Nitrogen removal in the grain has been measured. In addition, N losses thru the tile lines have been determined by measuring flow rate and NO_3-N concentrations when tile flow occurred. Each fall (when possible) soil samples have been taken to a 10-foot depth to determine residual NO_3-N in the soil.

Because some of the N treatments exceeded the N removal rates, substantial amounts of NO_3-N accumulated from 1973-1979. Consequently, no fertilizer N has been applied to the plots since May 1979. Research efforts since 1979 have attempted to monitor the availability of the residual NO_3-N to corn and to follow the movement of NO_3-N either in the soil or into the tile lines. Results from 1980-82 and 1983-84 can be found in University of Minnesota Agr. Exp. Stn. Misc. Pub 2 (revised) - 1983 (pp. 78-81) and 1985 (pp. 46-51), respectively.

In 1985, 125 lb N/A as anhydrous ammonia was applied to an isolated 6-row strip between the plots so that crop response to the residual N could be compared to this annual application. Weeds and insects were controlled adequately on all plots by pesticides. All plots have been moldboard plowed each fall.

RESULTS

Corn yields shown in Table 1 were good due to the favorable growing conditions (above normal rainfall). Grain yields from all of the previous N treatments were excellent considering that N had not been applied since 1979 but were below the yield of 145.8 bu/A obtained from the 6-row strip where N was applied in 1985. Grain yields were significantly increased over the 18- and 100-lb treatments by the residual N remaining from the 400-lb N treatment. Grain N concentration, although quite low, was also increased by the 400-lb treatment but was markedly less than the 1.25% N found in the grain from the 6-row strip. Silage yields were increased significantly (P=93% level) by the 400-lb treatment. As a result of higher yields and N concentrations, N removed in the grain and total N uptake in the silage were both increased significantly by the 400-lb treatment over all other treatments. Final population and N concentrations in the fodder and leaf at silking were not affected by the residual N. Results from the 200-lb organic N rate (soybean meal) were similar to the 200-lb rate applied as urea.

Table 1. Corn production and N utilization in 1985 as influenced by residual NO_3-N from annual N applications from 1973-1979 at Lamberton.

Annual N rate	Final population	Leaf N	Fodder N	Silage Yield	Silage N uptake	Grain Yield	Grain N	Grain N removal
lb N/A	ppA x 10^3	%	%	T DM/A	lb N/A	bu/A	%	lb N/A
18	22.1	2.54	.44	4.57	64.4	101.9	1.01	48.8
100	21.6	2.58	.45	4.82	68.1	106.2	1.01	50.8
200	22.2	2.45	.45	4.83	69.1	109.1	1.01	52.0
400	23.5	2.57	.50	5.69	86.5	124.5	1.08	63.4
Signif. Level (%):1/	42	06	81	93	99	95	97	97
BLSD (.05) :					12.4	16.6	0.05	9.8
CV (%) :	7.3	12.2	6.8	8.6	8.3	7.1	2.4	8.7
200 org.	22.5	2.30	.40	5.10	70.3	113.7	1.01	54.2

1/ Probability level that a difference among the four means listed above is significant.

Tile lines flowed from April thru mid-July and from September thru early November. Flow was highest in April, May, and September. Tile flow averaged 15.3 acre-inches for the 6-month flow period. Average flow-weighted NO_3-N concentrations ranged from 12.2 to 25.4 mg/L (Table 2). Average concentrations remained approximately the same as in 1984 except with the 400-lb rate which dropped from 33.0 mg/L.

Nitrate-N losses in the tile discharge were again quite sizeable (Table 2). The large flow volumes coupled with concentrations between 12 and 25 mg/L resulted in losses ranging from 44 lb/A with the 18-lb treatment to 100 lb/A with the 400-lb rate. These data indicate: (1) relatively high losses of NO_3^- even when no N fertilizer has been applied over the last 15 years, (2) little residual N is now being lost thru the tile lines with rates of 200 lb/A or less, and (3) substantial amounts of residual NO_3^- are still being lost to the tile lines six years after the last 400-lb N application.

Table 2. Tile line flow, average NO_3-N concentrations, and total NO_3-N losses into the tile lines in 1985 as related to annual N application rates from 1973-1979 at Lamberton.

Annual N rate	Total tile flow	Nitrate-N Avg. concentration	Nitrate-N Losses
lb N/A	acre-inches	mg/L	lb/A
18	15.94	12.2	44.0
100	14.56	13.9	45.9
200	13.31	16.2	48.7
400	17.31	25.4	99.5
200 org.	15.53	14.8	52.0

Residual NO_3-N remaining in the soil profile from the two high N rates is shown in Table 3. With the exception of the slight accumulation between 1 and 3' in the 200-lb treatment most of the NO_3^- was below 6-feet in both treatments. Nitrate-N concentrations were highest between 6 and 10 feet deep. Nitrates at these depths have little chance of being moved up into the profile for crop uptake and, thus, are extremely susceptible to leaching down into the groundwater.

SUMMARY - 1985

Residual N still remained from the 400-lb annual treatment applied from 1973-79. As a result grain yield, N concentration, and N removal in the grain were significantly increased. At the same time, more than twice as much NO_3-N was lost from the tile lines with this treatment. At the end of the 1985 season, little NO_3^- remained in the soil above the tile lines. Most of the NO_3^- had been moved to the 5 to 15' depth.

Table 3. Residual NO_3-N in the 0-20' soil profile in October, 1985 as influenced by previous N application at Lamberton.

Profile depth	Annual N rate (lb/A)[1/]	
	200	400
feet	---------- ppm ---------	
0-1	2.3	4.5
1-2	7.3	1.6
2-3	7.1	2.3
3-4	1.6	1.8
4-5	2.4	5.3
5-6	4.2	9.4
6-7	6.2	13.0
7-8	7.5	13.0
8-9	9.9	11.6
9-10	7.0	11.6
10-11		10.1
11-12		9.2
12-13		6.7
13-14		7.5
14-15		6.9
15-16		5.7
16-17		3.9
17-18		2.1
18-19		2.0
19-20		No sample
Total lb NO_3-N in 10-foot profile	222	296

1/ Annual application over 7-year period (1973-79).

13-YEAR TILE DRAIN SUMMARY

Total NO_3-N losses via tile discharge water are presented in Table 4 for the fertilized period (1973-79) and for the residual period (1980-85). Due to higher precipitation in the last 6 years, approximately three-quarters of the 13-year tile flow occurred in the 6-year residual period. Nitrate-N losses during the residual phase of the study approximated the losses during the 7-year fertilizer application period. From 29 to 44% of the fertilizer applied at the 200- and 400-lb N/A rates (the recommended rate is 140 lb N/A) were lost from the soil thru the tile lines during this 13-year period.

Table 4. Summary of NO_3-N losses thru tile discharge from 1973-85 at Lamberton.

Total Applied N (1973-79)[1/]	Nitrate-N Lost Thru Tiles[2/]			Percent of applied N lost
	1973-79	1980-85	1973-85	
lb N/A	------------ lb NO_3-N/A ------------			%
126	80	131	211	--
700	161	184	345	23
1400	299	287	586	29
2800	639	737	1376	44

1/ Does not include the 40-lb rate applied in 1984.
2/ 20.8 acre-inches tile drainage in 1973-79, 56.6 acre-inches in 1980-85.

WEST CENTRAL EXPERIMENT STATION - MORRIS

WEATHER SUMMARY - 1985

Month	Period	Precipitation 1985	Precipitation 100-yr. av.	Precipitation Dev. from av.	Temperature 1985	Temperature 100-yr. av.	Temperature Dev. from av.	Soil Temperature (10 cm depth) 1985	Soil Temperature (10 cm depth) 10-yr. av.
January	1-31	0.28	0.68	-0.40	5.1	8.0	-2.9	14.8	20.7
February	1-28	0.47	0.67	-0.20	10.1	12.8	-2.7	14.1	23.9
March	1-31	2.74	1.13	+1.61	33.4	26.7	+6.7	31.2	29.2
April	1-10	0	0.57	-0.57	37.9	38.0	-0.1	36.7	
	11-20	0.03	0.64	-0.61	53.9	44.4	+9.5	43.2	
	21-30	2.10	1.05	+1.05	52.8	48.3	+4.5	42.0	
Total or av.		2.13	2.26	-0.13	48.1	43.6	+4.5	42.3	41.4
May	1-10	0.87	0.77	+0.10	61.2	52.0	+9.2	52.4	
	11-20	3.00	0.95	+2.05	58.3	55.8	+2.5	56.3	
	21-31	2.87	1.25	+1.62	62.4	60.0	+2.4	58.8	
Total or av.		6.74	2.97	+3.77	60.7	56.1	+4.6	55.8	57.1
June	1-10	T	1.29	-1.29	59.7	63.0	-3.3	57.7	
	11-20	2.29	1.30	+0.99	61.0	66.3	-5.3	59.9	
	21-30	0.71	1.37	-0.66	64.7	68.1	-3.4	57.5	
Total or av.		3.00	3.96	-0.96	61.8	65.8	-4.0	58.3	69.3
July	1-10	0.12	1.44	-1.32	71.0	70.1	+0.9	70.5	
	11-20	0.22	1.06	-0.84	68.6	71.4	-2.8	70.9	
	21-31	2.14	1.01	+1.13	65.9	71.4	-5.5	69.9	
Total or av.		2.48	3.51	-1.03	68.4	70.9	-2.5	70.4	76.7
August	1-10	0.80	1.04	-0.24	68.2	70.4	-2.2	69.1	
	11-20	1.65	0.93	+0.72	59.9	69.0	-9.1	62.5	
	21-31	2.17	1.04	+1.13	63.2	66.9	-3.7	63.3	
Total or av.		4.62	3.01	+1.61	63.8	68.7	-4.9	64.7	73.9
September	1-30	3.25	2.20	+1.05	55.7	59.0	-3.3	56.8	61.5
October	1-31	1.58	1.74	-0.16	43.2	47.2	-4.0	42.0	47.8
November	1-30	1.62	0.97	+0.65	19.2	29.7	-10.5	30.6	33.6
December	1-31	1.00	0.68	+0.32	4.1	15.2	-11.1	23.7	23.4
April-August Growing Season		18.97	15.71	+3.26	60.6	61.0	-0.4	58.3	63.8
January-December Annual		29.91	23.78	+6.13	39.6	42.0	-2.4	42.1	46.7

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

Morris, 1985

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-(1982-85). Manure was applied in 1970 and 1971 only. Fertilizer has been applied to the fertilized checks each year.

I. Planting Information

The plots were planted with Pioneer 3901 on May 6, 1985, @ 24,300 seeds/acre. Counter was applied @ 12 lbs/acre (1.8 lbs/acre active ingredient) in the row to the entire area at planting. The fertilized plots received 120 + 50 + 50 + 10 ($N + P_2O_5 + K_2O + Zn$) lbs/acre on November 16, 1984. Lasso @ 3 lbs/acre and Bladex @ 2.2 lbs/acre were broadcast on May 8. Silage samples were taken by hand on September 26 and the grain harvest was taken with a plot combine on October 14.

II. Soil Sampling and Analysis

A. 1985 Measurements

Only three nutrients (P, K and Zn) were measured in the plow layer samples in the fall of 1985 (Table 1). The levels of the LH treatments are approaching the fertilized check levels. The SB and LB are generally higher than the fertilized check except for Zn where all treatments are significantly less.

Table 1. Soil test values in the 0 to 8-inch zone for P, K, Zn and pH in a Tara soil 15 years (Fall 1985) after the application of high rates of manure.

	Elements				
Treatment	P Bray	P Olsen	K	Zn	pH
	- - -	lbs/acre	- - -	ppm	
CK	14	10	272	0.6	7.7
FE	48	35	303	4.9	7.0
SB	125	104	666	2.1	7.5
LB	152	187	591	2.7	6.9
LH	101	81	389	3.2	7.3
Signif. level (%)	>99	>99	>99	>99	88
BLSD (.05)	52	57	75	1.1	0.7
CV (%)	31.9	37.4	9.6	23.3	4.5

III. Plant Tissue Analysis

The nutrient concentrations in the ear leaves at silking in 1985 are given in Table 2. There are significant effects on many elements. The LH treatment was in the deficient range in N and was also significantly less than the fertilized check in N, Fe and Zn. SB and LB were significantly less than the fertilized check in Mg and Zn.

Table 2. Summary of analysis of corn leaves at silking - 1985.

Treatment	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	Elements									
	- - - - -		%	- - - - -		- - - -		ppm	- - - -	
CK	2.00	0.21	1.71	0.55	0.37	90.3	16.7	5.6	101.0	5.7
FE	2.99	0.32	1.93	0.50	0.33	128.5	32.2	5.2	83.1	5.7
SB	2.81	0.34	2.11	0.49	0.22	129.4	16.4	6.4	126.7	6.0
LB	2.62	0.43	2.22	0.47	0.22	131.3	19.3	5.5	88.1	5.7
LH	2.21	0.34	2.06	0.45	0.26	108.6	23.2	5.7	93.8	5.7
Signif. level (%)	>99	>99	>99	99	>99	>99	>99	20	84	2
BLSD (.05)	0.44	0.07	0.14	0.05	0.07	18.4	6.2	NS	42.9	NS
CV (%)	9.1	11.4	3.9	5.0	13.4	8.3	15.5	20.1	20.2	12.5

IV. Yield Measurements (Table 3)

A. Grain - The LH treatment had a significantly lower grain yield than the fertilized check.

B. Silage - None of the treatments were significantly different from the fertilized check.

Table 3. Summary of plant measurements - 1985.

Treatment	Early plant height	Early plant (10) dry weight	Grain: Moisture at harvest	Grain: Yield @ 15.5% M	Silage: Dry matter at harvest	Silage: Silage yield (D.M.)	Silage: Ear wt. as a % of silage wt.
	inches	- grams -	- % -	-Bu/A-	- % -	-lb/A-	- % -
CK	19.0	35.4	46.2	43.0	41.0	8766	53.8
FE	23.5	64.9	35.0	124.9	42.8	15875	54.6
SB	25.4	92.5	35.3	113.9	44.7	14983	57.6
LB	24.0	71.6	36.6	105.9	41.0	13197	58.9
LH	23.7	74.4	37.8	97.0	46.6	13287	57.1
Signif. level (%)	98	98	>99	>99	87	97	87
BLSD (.05)	3.3	28.6	3.8	19.0	5.1	4314	5.0
CV (%)	7.4	21.5	5.4	10.9	5.5	16.3	4.1

V. Summary

The last manure treatments were applied in 1970 and 1971. The LH treatment has had a significantly lower grain yield than the fertilized check the last two years, probably due to lower available nitrogen in the soil. The other two manures are slightly lower yielding than the fertilized checks.

MANURE RATE STUDY

Morris, 1985

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. Results from previous years are given in Soils Series 91, 95, 97, 99, 103, 105, 107, 109, and Misc. Publ. 2-(1982-85). 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 6, 1985, @ 24,300 seeds/acre. Counter was applied @ 12 lbs/acre (1.8 lbs/acre active ingredient) in the row to the entire area at planting. The fertilized plots received 120 + 50 + 50 + 10 (N + P_2O_5 + K_2O + Zn) lbs/acre on November 16, 1984. Lasso @ 3 lbs/acre and Bladex @ 2.2 lbs/acre were applied broadcast on May 8. Silage samples were taken by hand on September 26 and the grain harvest was taken with a plot combine on October 14.

II. Soil Sampling and Analysis

A. 1985 Measurements

Only three nutrients (P, K and Zn) were measured in the plow layer samples in the fall of 1985 (Table 1). The levels of all nutrients of the LB1 treatment were slightly below the fertilized check. The remainder of the treatments continued to have P and K levels significantly greater than the fertilized check, with the SB3 treatment having the highest levels. The Zn level of the fertilized check was significantly greater than all treatments except SB2 and SB3.

Table 1. Effect of two types of beef cattle manure and commercial fertilizer on P, K, Zn and pH values of a Tara Soil (0-8") - Fall 1985.

Treatment	Elements			pH
	Bray P	K	Zn	
	- lbs/acre -		ppm	
CK	10	279	0.6	7.3
FE	29	299	3.6	7.3
SB1	110	607	2.3	7.6
SB2	322	1172	4.5	7.0
SB3	462	1657	6.7	6.8
LB1	22	287	0.7	7.6
LB2	68	344	1.3	7.6
LB3	164	479	2.1	6.5
Signif. level (%)	99	99	99	96
BLSD (.05)	28	138	1.1	0.9
CV (%)	11.9	13.5	25.6	5.8

III. Plant Tissue Analysis

The nutrient concentrations in the ear leaves at silking in 1985 are given in Table 2. Significant effects were measured on all elements except Ca, Cu and Mn. The treatments which showed high soil tests of P and K also showed high levels of P and K in the leaf tissue. The N level of LB1 was in the deficient range. Solid beef manure generally decreased the levels of Mg, Cu and Mn as the rate was increased. Liquid beef manure decreased Ca, Mg, Mn and B and increased Fe as the rate increased.

Table 2. Summary of analysis of corn leaves at silking - 1985.

Treatment	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	Elements									
	- - - - - - - - - % - - - - - - - -					- - - - - - - - - ppm - - - - - -				
CK	1.97	0.20	1.54	0.51	0.36	85.6	15.2	3.4	87.5	5.8
FE	2.92	0.28	1.73	0.51	0.34	107.1	26.1	3.9	107.9	4.9
SB1	2.72	0.29	1.95	0.45	0.25	133.5	17.3	4.6	105.6	4.9
SB2	2.79	0.35	2.12	0.47	0.21	148.0	14.4	3.8	96.6	5.1
SB3	2.96	0.41	2.13	0.46	0.18	140.2	16.8	3.4	98.5	4.8
LB1	2.25	0.27	1.70	0.53	0.33	91.3	15.1	3.5	105.2	6.0
LB2	2.45	0.28	1.84	0.49	0.26	104.1	16.2	4.3	101.3	5.1
LB3	2.70	0.35	1.98	0.44	0.23	129.9	16.0	4.4	88.2	4.6
Signif. level (%)	>99	>99	>99	57	>99	>99	>99	68	8	98
BLSD (.05)	0.39	0.04	0.23	NS	0.07	21.5	13.2	NS	NS	0.8
CV (%)	8.6	7.9	7.1	10.8	14.3	10.8	10.4	18.6	22.8	8.3

IV. Yield Measurements (Table 3)

A. Grain - No treatments were significantly less in yield than the fertilized check in 1985, but the LB1 and LB2 were both significantly less than the SB2 treatment. In 1984 LB1 and LB2 were both less than the fertilized check.

B. Silage - The LB1 treatment yielded significantly less than the fertilized check.

Table 3. Summary of plant measurements - 1985.

Treatment	Early plant height	Early plant (10) dry weight	Grain: Moisture at harvest	Grain: Yield @ 15.5% M	Silage: Dry matter at harvest	Silage: Silage yield (D.M.)	Silage: Ear Wt. as a % of silage wt.
	inches	- grams -	- % -	- Bu/A -	- % -	lbs/A	- % -
CK	19.5	42.9	40.8	65.5	45.0	8660	57.7
FE	22.9	70.0	38.9	121.3	41.1	16297	58.1
SB1	25.3	99.5	35.2	125.6	45.0	17706	58.1
SB2	29.6	111.6	33.0	149.0	43.3	18278	61.1
SB3	26.0	69.6	36.2	136.0	42.1	18161	60.4
LB1	21.5	57.9	40.2	87.3	41.4	12571	60.7
LB2	23.2	72.0	37.4	94.5	45.8	15492	62.3
LB3	24.3	79.6	35.4	118.7	41.8	16625	57.9
Signif. level (%)	99	91	95	99	66	>99	29
BLSD (.05)	4.4	54.1	5.6	41.5	NS	3177	NS
CV (%)	10.0	33.5	7.4	19.9	6.7	12.1	6.5

V. Summary

The 1985 season was the seventh since manure had been applied. The LB1 and LB2 treatments appear to no longer be adequate for grain yields, as compared to other treatments.

CONTINUOUS CORN SILAGE
Morris, 1985
S. D. Evans

I. Experimental Description

In 1965 an experiment was initiated on a McIntosh silt loam to determine the effect of removal of continuous corn silage and fertilizer on 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. 1985 Operations

In 1985 the variety was Dekalb T950 and was planted @ 24,300 seeds/acre. Counter was applied @ 12 lbs/acre at planting on May 23. Lasso @ 3 lbs/acre and Bladex @ 2.2 lbs/acre were applied broadcast on May 23. Silage yields were taken on October 8 and grain yields on October 28. Following harvest, plow layer soil samples were taken from each plot.

III. Silage Yields - Dry matter, tons/acre

Treatment	1985 Yield	1966-85 Yield
Silage, low fertility	4.20	5.60
Silage, high fertility	5.22	6.10
Grain, low fertility	4.66	5.65
Grain, high fertility	5.70	5.98

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

	1985 Yield	1966-85 Yield
Grain, low fertility	78.9	89.9
Grain, high fertility	96.6	94.1

V. Check Yields

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

	1985 Yield	1966-85 Yield
Grain (0 + 0 + 0)	31.3	45.7
Silage (0 + 0 + 0)	2.02	3.59

VI. Soil Test Results

Treatment	pH	Bray P	Olsen P	Exch. K	Zinc
		- - - lbs/acre		- - -	ppm
Silage, low fertility	8.1	23	26	261	2.1
Silage, high fertility	8.1	55	41	292	2.0
Grain, low fertility	8.1	29	17	332	2.2
Grain, high fertility	8.1	58	48	397	2.2
Check	8.1	9	7	280	1.9

VII. Discussion

A. In 1985 a severe soil surface crust decreased stands, however, the trends of past years continued. The grain high fertility silage yields were significantly higher than the grain low fertility or silage low fertility treatments. The silage high fertility plots had significantly higher silage yields than did the silage low fertility plots.

B. The 20-year average yields show very little difference between silage and grain plots, but there is a slight advantage for the higher fertility level.

C. Soil test results show a large difference in soil P and K levels due to fertilizer treatment. The P levels on plots receiving only 50 lbs/acre of P_2O_5 annually are in the medium range. Soil K levels are considerably higher where only the grain has been removed compared to removing corn silage.

SOIL TEST LAB COMPARISON

Morris, 1985

S. D. Evans and G. A. Regimbal

In west central Minnesota there are several laboratories where soil samples are analyzed and fertilizer recommendations given. Recommendations of commercial laboratories sometimes differ greatly from the University of Minnesota Soil Testing Laboratory. In order to develop educational material for extension soils specialists, trials were started at the West Central Experiment Station in 1980 on a corn-wheat rotation. Results from 1980-84 trials were summarized previously (Soil Series 109 and Misc. Publ. 2-1982 to 1985).

In the fall of 1984 soil samples from the plow layer and 0-2 foot zone (corn only) were taken from all plots except the check. The soil from the four replications was combined to make two samples (plow layer and 0-2 foot) from each treatment. The samples were dried thoroughly, mixed, subdivided and sent to the appropriate laboratory. Recommendations were requested from five laboratories 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 foot samples for 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 Harris Labs (Lab C). Harris Labs gave no indication that the 0-2 foot sample was used for the nitrogen recommendation on wheat. Labs will be

Table 1. Soil test results and the suggested fertilizer program for wheat in 1985.

	Soil Test Results				
Test	Lab A	Lab B	Lab C	Lab D	Lab E (UM)
pH	7.7	7.5	7.8	7.9	7.6
P (Bray 1), ppm	-	23H	-	13	21
(NaHCO3), ppm	15(H)	-	14	13	16
K, ppm	125(H)	149M	183	155	147
O.M., %	4.4	4.0H	4.1	4.0	M
Ca, ppm	3750	2060M	4544	3760	-
Mg, ppm	570	573VH	644	510	-
Na, ppm	12	-	18	72	-
S, ppm	3L	4L	3	9	-
Fe, ppm	14.1H	20.0H	18.1	13.0	-
Mn, ppm	9.1VH	15.0H	12.4	8.8	-
Zn, ppm	1.45H	2.1M	2.1	1.7	2.0
Cu, ppm	.60H	1.0M	0.8	0.66	-
B, ppm	-	1.0M	0.7	3.3	-
ENR (lb/A)	-	89	-	-	-
Nitrate-N (lb/A)	96	-	11	38	50
C.E.C. (meq/100 g)	23.8	15.5	28.6	24	-
Soluble salts (mmhos/cm)	.35	-	.19	-	-

	Suggested Fertilizer Program[1]				
Nutrient	Lab A	Lab B	Lab C	Lab D	Lab E (UM)
			lb/A		
Nitrogen	56	120	98	76	70
Phosphorus (P_2O_5)	41	35	50[2]	45	0
Potassium (K_2O)	51	115	130[2]	95	30
Sulfur	0	12	15	20	0
Zinc	0	1.5	0	5	0
Boron	0	0	0-1	0	0
Iron	0	0	0	3	0

[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.

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

labeled as follows: Lab A = Agvise, B = A & L, C = Harris, D = Eco-gri (Tests for treatment D were analyzed by Willmar Testing Lab, Willmar, MN from 1980-83. Tests in the fall of 1984 for the 1985 crop were by Eco-Agri Testing Laboratories, Willmar, MN), and E = U of M.

Table 2. Soil test results and the suggested fertilizer program for corn in 1985.

Test	Soil Test Results				
	Lab A	Lab B	Lab C	Lab D	Lab E (UM)
pH	8.0	7.9	8.0	8.1	7.9
P (Bray 1), ppm	-	11.0L	-	6.0	5
(NaHCO3), ppm	8(L)	-	8.0	11	8
K, ppm	109(H)	120M	131	118	112
O.M., %	3.5	3.7H	3.5	3.9	M
Ca, ppm	4650	2730H	5143	3920	-
Mg, ppm	555	476VH	524	625	-
Na, ppm	11	-	16	72	-
S, ppm	3L	4L	3	9.0	-
Fe, ppm	11.4H	14M	14.5	12	-
Mn, ppm	7.0VH	10M	8.8	6.92	-
Zn, ppm	1.26H	1.7M	1.3	1.4	1.4
Cu, ppm	.62H	1.0M	0.8	.66	-
B, ppm	-	0.9M	0.7	3.4	-
ENR (lb/A)	-	85	-	-	-
Nitrate-N (lb/A)	-	-	-	-	-
C.E.C (meq/100 g)	28.2	17.9	30.5	25	-
Soluble salts (mmhos/cm)	.36	-	.19	-	-

Nutrient	Suggested Fertilizer Program[1]				
	Lab A	Lab B	Lab C	Lab D	Lab E (UM)
	lb/A				
Nitrogen	132	150	185	165	120
Phosphorus (P_2O_5)	98	85	108[2]	105	90
Potassium (K_2O)	59	130	243[2]	170	40
Sulfur	0	15	20	20	0
Zinc	0	2.5	3	8	0
Copper	0	0	0	4	0
Manganese	0	1.0	0	0	0
Boron	0	0	0-1	0	0
Iron	0	0	0	3	0

1 All values indicate pounds of nutrient suggested per acre for a yield goal of 130 bushels per acre for corn.
2 Value include maintenance plus 1/2 of suggested buildup.

General

The experimental design is a randomized complete block with four replications on each crop. Two blocks, each with 24 plots, are adjacent and alternate between wheat and corn. The plot size is 15 feet by 40 feet. Row spacing on the corn is 30 inches.

Wheat

The fertilizer was applied by hand on November 7, 1984. All plots were then moldboard plowed. In the spring the plots were field cultivated and dragged. On April 30, 1985, the plots were seeded to Era wheat @ 1 3/4 Bu/A. Bromate was applied @ 1 pt/A on June 4. The plots were harvested with a plot combine on August 15.

Corn

The fertilizer was applied by hand on November 8, 1984. All plots were then moldboard plowed. In the spring the plots were field cultivated and dragged. On May 2, 1985, the plots were planted to Dekalb-Pfizer T950 @ 24,300 seeds/acre. Counter was applied at planting @ 12 lbs/acre. Lasso @

3 lbs/A and Bladex @ 2.2 lbs/A were applied broadcast on May 2. The plots were harvested on October 14 with a plot combine.

Results and Discussion of the Wheat Trial

The soil tests and fertilizer recommendations are shown in Table 1. The soil test results were somewhat variable between labs. The recommended amounts of N, P and K had wide variations and A & L, Harris and Eco-Agri labs suggested applying sulfur. A & L and Eco-Agri recommended zinc, Eco-Agri also recommended iron and Harris recommended boron. There were no significant differences between labs in plant lodging, plant height, grain yield or grain moisture (Table 3).
U of M had the lowest fertilizer cost ($19.80) and the highest return over fertilizer ($225.90), while Harris had the highest fertilizer cost ($52.47) and the lowest return over fertilizer ($168.73) (Table 4).

Table 3. Effect of fertilizer recommendations on various plant measurements - 1985.

Lab	Wheat: Plant Lodging	Wheat: Plant Height at Harvest	Wheat: Grain Yield	Wheat: Grain Moisture	Corn: Grain Yield	Corn: Grain Moisture
	-Score[1]-	-inches-	Bu/A	%	Bu/A	%
A (Agvise)	3.5	34.5	62.7	14.6	114.2	39.6
B (A & L)	4.0	35.8	63.9	14.4	106.0	39.1
C (Harris)	4.3	35.5	63.2	14.3	100.8	40.7
D (Eco-Agri)[2]	3.3	35.3	67.9	14.5	100.3	41.2
E (UM)	3.0	34.5	70.2	14.3	107.3	41.6
Check	1.0	29.8	39.8	14.3	66.8	43.2
Signif. level (%)	98	>99	>99	21	>99	94
BLSD (.05)	1.9	2.8	9.8	NS	13.8	3.2
CV (%)	36.6	5.3	10.9	3.3	9.6	4.5

1 Lodging score: 1 = No lodging, 9 = Flat.
2 Tested by Willmar, 1980-83.

Table 4. Economic return over fertilizer costs - 1985.

Lab	Wheat: Value of Crop @ $3.50/Bu	Wheat: Fertilizer Cost[1]	Wheat: Return over Fertilizer	Wheat: Return over Check	Corn: Value of Crop @ $2.07/Bu	Corn: Fertilizer Cost	Corn: Return over Fertilizer	Corn: Return over Check
	$/A							
A (Agvise)	219.45	27.15	192.30	53.00	236.39	58.16	178.23	39.95
B (A & L)	223.65	50.77	172.88	33.58	219.42	72.05	147.37	9.09
C (Harris)	221.20	52.47	168.73	29.43	208.66	99.08	109.58	-28.70
D (Eco-Agri)[2]	237.65	45.28	192.37	53.07	207.62	87.94	119.68	-18.60
E (UM)	245.70	19.80	225.90	86.60	222.11	51.70	170.41	32.13
Check	139.30	0	139.30	-	138.28	0	138.28	-

1 Values used ($/lb) were: N = $0.24, P_2O_5 = $0.21, K_2O = $0.10, S = $0.21, Zn = $0.40, Mn = $1.05, B = $2.30, Fe = $0.63.
2 Tested by Willmar 1980-83.

Results and Discussion of the Corn Trial

The soil tests and fertilizer recommendations are shown in Table 2. Once again recommendations varied for N, P, K and micro-nutrients. Sulfur was recommended by A & L, Harris, and Eco-Agri. Also recommended were: manganese by A & L, boron by Harris and iron by Eco-Agri.

Table 3 shows a significant difference between Agvise and Eco-Agri in grain yield. There are no significant differences in corn grain moisture between labs.

Fertilizer costs ranged from $51.70 (U of M) to $99.08 (Harris) (Table 4). Economic return over fertilizer had a range of $109.58 (Harris) to $178.23 (Agvise).

Five-Year Summary

The combined average return per year for 1980-85 shows a range of $39.46 (A & L) to $80.94 (U of M) over the check (Table 5). For wheat, Harris shows the smallest return over the check, while U of M shows the greatest. For corn, Harris and A & L are showing negative returns over the check, while after six years, U of M has returned $101.64 over the check. The extremely high rates of N and K by A & L, Harris and Eco-Agri are not increasing yields and result in a much higher fertilizer cost. In addition it appears that the recommendations of some labs for sulfur and micronutrients are not resulting in significantly higher yields over those which do not; consequently, economic returns over fertilizer are less.

Table 5. Six-year summary of yields and economic returns 1980-1985.

Lab	Wheat[1]				Corn[2]				Combined Average Return per Year
	Total 6-year Yield	Total 6-year Fertilizer Cost	Economic Return over Fertilizer	Return over Check	Total 6-year Yield	Total 6-year Fertilizer Cost	Economic Return over Fertilizer	Return over Check	
A (Agvise)	374.7	164.52	1302.93	305.23	687.1	308.69	1447.40	98.54	67.30
B (A & L)	384.3	255.00	1250.25	252.55	669.4	372.08	1333.08	-15.78	39.46
C (Harris)	382.6	287.63	1211.17	213.47	685.0	425.71	1332.59	-16.27	32.87
D (Eco-Agri)[3]	370.5	206.83	1241.22	243.52	678.2	379.04	1361.34	12.48	42.67
E (UM)	387.3	132.43	1381.67	383.97	679.4	255.42	1450.50	101.64	80.94
Check	254.4	0	997.70	-	525.4	0	1348.86	-	-

[1] Wheat valued at $4/Bu, 1980-84 and $3.50/Bu for 1985.
[2] Corn valued at $3.00, $2.40, $2.00, $3.00, $2.80, and $2.07/Bu in 1980, 1981, 1982, 1983, 1984, and 1985, respectively.
[3] Tested by Willmar, 1980-83.

EFFECTS OF NITROGEN AND PHOSPHORUS APPLICATION METHODS ON SPRING WHEAT - 1985

Morris, 1985

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 fifth 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

Initial soil sample results by rep are given in Table 1. The broadcast 0-46-0 was applied by hand on May 3, 1985. The anhydrous ammonia and 10-34-0 were applied with a dual applicator the same day. The material was placed at about an 8-inch depth with a knife spacing of 12 inches. On May 3 the plots were field cultivated and drug. The study was seeded to Era wheat @ 1 3/4 Bu/acre.

Whole plant samples were collected on July 30 and were used to calculate forage yield and N and P uptake. The plots were harvested on August 15 with a plot combine.

Table 1. Soil test results spring 1985.

Rep	P Soil Test Olson	P Soil Test Bray	Exch. K	Soil pH	NO_3-N[1]
	- - lb/A	- -	-lb/A-		-lb/A-
1	11	15	237	7.8	12.8
2	6	7	290	8.1	
3	7	10	248	8.1	12.4
4	20	5	276	8.2	
Mean	11	9	263	-	12.6

[1] Nitrate samples (0-2') are an average of reps 1-2 and 3-4.

Yield and Nutrient Uptake

The nutrient uptake and yield results are given in Table 2. There are no large placement or P rate effects. The major significant difference is between the check vs. the other treatments. It also appears that surface placement of nitrogen (treatments 8, 9 and 11) was inferior to the other treatments in dry matter yield and grain yield. There appears to be no consistent advantage of any placement method. The response to P is small or non-existent indicated by a dry matter yield of 7467 lbs/acre and a grain yield of 68.4 bu/acre for treatment 10 where only N was applied.

Table 2. The effect of N and P application on spring wheat.

	Treatment Description				Whole Plants @ Soft Dough Stage						
		Fertilizer Treatment									
Trt. No.	Placement	Source[1]	N	P_2O_5	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	4480	0.234	10.5	1.18	53.5	36.6	12.3
2	Dual NP, Knife	AA,APP	100	20	7167	0.221	15.9	1.64	117.9	68.9	14.0
3	Dual NP, Knife	AA,APP	100	40	7559	0.189	14.3	1.43	107.9	71.5	13.8
4	N Knife, P BCST	AA,TSP	100	20	7574	0.179	13.7	1.36	103.2	71.3	13.8
5	N Knife, P BCST	AA,TSP	100	40	8075	0.179	14.5	1.36	109.1	70.6	14.1
6	N Knife, NP1 Drill[2]	AA,UR,TSP	100	20	7657	0.194	14.9	1.52	116.5	70.7	13.7
7	N Knife, NP2 Drill[3]	AA,UR,TSP	100	40	7395	0.191	14.2	1.43	105.3	70.5	14.2
8	N & P BCST	UR,TSP	100	20	7043	0.188	13.5	1.27	89.5	66.8	13.2
9	N & P BCST	UR,TSP	100	40	7081	0.188	13.5	1.22	87.1	70.6	13.0
10	N Knife	AA	100	0	7467	0.180	13.3	1.48	110.0	68.4	13.4
11	N BCST	UR	100	0	6739	0.188	12.9	1.39	93.5	66.4	13.5
Signif. level (%)					>99	90	44	>99	>99	>99	91
BLSD (.05)					1136	0.050	NS	0.21	21.5	7.0	1.6
CV (%)					11.1	13.5	21.1	9.9	15.1	7.7	6.0

[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 + 20 P_2O_5 at seeding with drill.

[3] NP2 Drill = 10 N + 40 P_2O_5 at seeding with drill.

EFFECT OF LIQUID STARTER RATE AND ANALYSIS ON CORN GROWTH AND YIELD

Morris, 1985

S. D. Evans

With the increase in reduced tillage systems, many new types of fertilizer placement devices have been developed to overcome the adverse effects of plant residues on operation of fertilizer placement disks or knives outside the seed opener area. One of these devices is a knife mounted inside the double disk opener on minimum tillage row crop planters. This device supposedly places the liquid fertilizer 1/2 to 3/4 inch to the side and 1/2 to 1 inch below the seed. The close proximity to the seed may cause seedling damage at high starter rates. This study was set up to examine the effect of two liquid fertilizers (10-34-0 and 7-22-5) at three rates (10, 20, and 30 gal/A) with two seed placements (the device described above and a 2" x 2" placement with a single disk opener).

Experimental Procedures

The study was located on a Tara silt loam planted to corn in 1984 and moldboard plowed in the fall. Nitrogen as anhydrous ammonia was applied with a field cultivator in the spring of 1985 to provide 120 lbs/A of N. The area was field cultivated a second time in preparation for planting. The soil tests were: pH = 7.9, O.M. = High, Olsen P = 22 lbs/A, and exchangeable K = 237 lbs/A.

A randomized complete block experiment with four replications was used. Treatments consisted of two liquid starters (10-34-0 and 7-22-5), three rates (10, 20, and 30 gal/A), and two placement methods (near the seed and 2" to the side and 2" below the seed) plus no starter checks with each placement device.

Corn (Pioneer 3906) was planted in 30" rows with a Hiniker minimum tillage planter with Kinze planter units at 24,300 plants per acre on May 30. The liquid materials were applied with a John Blue squeeze pump near the seed (NSd) or 2" x 2" with a Hiniker single disk opener. Counter was applied at 13 lbs/A for corn rootworm control. Chemical weed control consisted of 3 qt. of Lasso and 2.2 qt. of Bladex applied on May 30. The fertilizer pump drive chain came off when planting the 7-22-5, NSd, 10-gal treatment requiring replanting this treatment to get on the proper fertilizer. This treatment was not used in the early emergence measurements.

Plant counts to obtain emergence rate and final stand were taken every two days from 2 rows each 40' long for 10 days beginning on the 11th day after planting. Harvest population was taken on the same area. Grain yield was determined by harvesting each plot with a modified JD 3300 combine.

Table 1. Daily precipitation and average soil temperature (2" depth) in the 2-week period following planting.

Days after planting	Avg. Soil temperature (2")	Precipitation
	- °F -	- inches -
1	59	2.53
2	60	trace
3	54	0
4	54	0
5	52	trace
6	52	0
7	58	0
8	56	0
9	63	0
10	64	0
11	62	trace
12	60	0.88
13	56	0.63
14	60	0

Results and Discussion

The experiment was planted late in the season because of wet soil conditions. The evening of the day the corn was planted a heavy rain of 2.53" fell (Table 1). This left the area saturated and possibly diluted the fertilizer bands eliminating any possibility of salt damage. The next significant rain was recorded on the 12th and 13th day after planting. Temperatures at the 2" depth were above 50^{o}F for the entire period.

Salt values (Table 2) ranged from 11.6 lbs/A at the low rate of 10-34-0 to 39.6 lbs/A at the high of 7-22-5. The 20- and 30-gal rates of both materials exceed the maximum N + K_2O guideline in Minnesota of 15-20 lbs/A.

Table 2. Salt rate as influenced by starter fertilizer material and rate of application.

Application rate	Liquid fertilizer 10-34-0	7-22-5
gal/A	- lb N + K_2O -	
10	11.6	13.2
20	23.2	26.4
30	34.8	39.6

Emergence rate was significantly affected by placement (Table 3) with the NSd treatments emerging before the 2" x 2" treatments. Analysis of material and rate of material did not affect emergence rate.

There was no significant differences on emerged population.

Table 3. Influence of liquid starter fertilizer material, application rate, and placement on emergence rate, emerged population, and early plant height of corn.

Material	Treatment Knife	Rate	Days after planting 11	13	15	18	20	Emerged Population (6-19-85)
		gal/A	- % of final stand -					ppA x 10^{-3}
Check	NSd	0	35	72	91	98	100	20.6
Check	2" x 2"	0	31	68	88	96	100	20.6
10-34-0	NSd	10	55	86	98	100	100	22.5
10-34-0	2" x 2"	10	33	69	91	97	100	20.9
7-22-5	NSd	10[1]	-	-	-	-	-	- -
7-22-5	2" x 2"	10	22	70	86	96	100	20.5
10-34-0	NSd	20	53	86	97	100	100	22.4
10-34-0	2" x 2"	20	25	64	88	97	100	19.4
7-22-5	NSd	20	38	79	96	100	100	20.7
7-22-5	2" x 2"	20	30	64	90	96	100	21.5
10-34-0	NSd	30	58	83	89	100	100	20.8
10-34-0	2" x 2"	30	33	69	89	100	100	20.8
7-22-5	NSd	30	37	79	93	99	100	21.3
7-22-5	2" x 2"	30	34	69	85	96	100	19.1
Significance level (%)			>99	99	95	46	0	73
BLSD (.05)			9	9	13	NS	NS	NS
CV (%)			25	13	6	4	0	8

[1] Mistake made in planting this treatment so early stand counts not valid.

The NSd treatments were significantly taller than the 2" x 2" treatments as measured on July 1 (Table 4). The only material x rate combination showing a decrease in height with increasing rate was the 2" x 2" placement with 10-34.0. The height was 14.7" at 10-gal, decrease to 13.8" at 20-gal, and decreased to 12.8" at the 30-gal rate.

Table 4. Plant height on 7-1-85 as affected by liquid starter material, application rate, and placement.

Placement Method	Rate	Material 10-34-0		7-22-5
	gal/A	- height (in.) -		
NSd	0	- -	12.6	- -
NSd	10	15.2		14.6
NSd	20	16.0		13.8
NSd	30	15.8		12.8
2" x 2"	0	- -	11.7	- -
2" x 2"	10	14.7		12.6
2" x 2"	20	15.2		13.4
2" x 2"	30	15.8		14.2

Grain yield was significantly affected by treatment (Table 5). The NSd treatments averaged 72.2 bu/A and the 2" x 2" treatments 65.4 bu/A. The two materials were significantly different in yield: 10-34-0 = 72.6 bu/A and 7-22-5 = 64.5 bu/A. There was a significant effect of starter (68.8 bu/A) vs. no starter (57.6 bu/A). There was no significant effect of rate on yield.

There were some significant treatment effects on grain moisture (Table 5). One major effect was starter (38.2%) vs. no starter (44.6%). The other major effect was 10-34-0 = 36.6% vs. 7-22-5 = 39.8%.

Table 5. Influence of liquid starter fertilizer material, application rate, and placement on harvest population, grain moisture, and corn grain yield.

Material	Treatment Knife	Rate	Harvest Population	Grain Moisture	Grain Yield
		gal/A	- ppA x 10^{-3} -	- % -	bu/A
Check	NSd	0	20.1	43.5	60.3
Check	2" x 2"	0	20.3	45.8	54.8
10-34-0	NSd	10	21.8	37.4	71.6
10-34-0	2" x 2"	10[1]	20.5	36.4	73.5
7-22-5	NSd	10	22.8	40.3	69.3
7-22-5	2" x 2"	10	20.6	42.2	58.6
10-34-0	NSd	20	22.5	35.1	82.0
10-34-0	2" x 2"	20	19.5	38.9	64.1
7-22-5	NSd	20	20.1	37.9	63.9
7-22-5	2" x 2"	20	21.0	40.8	62.6
10-34-0	NSd	30	22.0	35.1	77.8
10-34-0	2" x 2"	30	20.5	39.8	66.9
7-22-5	NSd	30	21.8	36.7	68.9
7-22-5	2" x 2"	30	19.7	38.0	66.6
Significance level (%)			95	>99	>99
BLSD (.05)			2.8	3.4	9.5
CV (%)			7.2	6.2	9.8

[1] Mistake made in planting this treatment so early stand counts not valid.

ALFALFA FERTILITY-MANAGEMENT STUDY

Morris, 1985

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

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

Experimental Procedures

The experiment was set up in 1983 on a Tara silt loam site that tested medium in Bray P (19 lbs/acre) and high in exchangeable K (234 lbs/acre). The experiment was direct seeded on May 23-24, 1983. The design was a split-split plot with four replications. The main plots were cutting schedule. The first split was P and K fertilizer and the second split was variety. In 1983 the area was harvested but no yields were taken and no fertilizer applied. In 1984 and 1985 the cuttings were taken as scheduled. Fertilizer was applied by hand after the first cutting except for the 300- and 400-lb K rates where 200 lbs/acre was applied after the first cutting and the remainder after the second cutting. The 4-cut schedule was harvested on June 6, July 1, July 30, and September 6. The 3-cut schedule was harvested on June 12, July 12, and August 20. Yields were taken with a small flail chopper, weighed and a moisture sample collected from each plot. Samples of the Answer variety were saved for chemical analysis. Soil samples were taken of the 0 to 2-inch and 2- to 8-inch zones in early September.

Results and Discussion

After two crop years no significant difference in total seasonal yield has occurred between the two varieties used (Tables 1 and 2). There were some significant differences between varieties for individual cuttings (Table 4), but the no variety was consistently higher yielding and the maximum difference was 0.1 ton/acre. In 1985 the 3-cut schedule significantly outyielded the 4-cut schedule (Table 3). The addition of P fertilizer has increased yields significantly in both years, while the addition of K fertilizer has not affected yields (Tables 1 and 2).

Table 1. Effect of cutting schedules, P and K fertilization and varieties on alfalfa yields at Morris in 1985.

Fertilizer Rate		1/2 Bud (4 cuttings)			1/10 Bloom (3 cuttings)			Average
		Variety			Variety			over
P_2O_5	K_2O	Vernal	Answer	Average	Vernal	Answer	Average	Fertilizer
- - lb/A - -		Dry Matter (T/A)						
0	200	2.81	2.70	2.75	3.51	3.41	3.46	3.11
50	200	4.47	4.53	4.50	5.19	5.32	5.25	4.88
100	200	4.54	4.91	4.73	5.57	5.67	5.62	5.17
50	0	4.25	4.55	4.40	5.04	5.00	5.02	4.71
50	100	3.89	4.03	3.96	5.32	5.16	5.24	4.60
50	200	4.65	4.58	4.62	5.02	5.17	5.09	4.85
50	300	4.43	4.61	4.52	5.39	5.23	5.31	4.92
50	400	4.68	4.75	4.71	5.30	5.20	5.25	4.98
Average		4.21	4.33	4.27	5.04	5.02	5.03	4.65

CV =5.3%

Dry matter percentage (Table 5) was significantly affected by PK treatment in all of the cuttings. In all cases the No-P treatment was drier than the 50-P and 100-P treatments.

Statistical analysis of the soil tests show many significant fertilizer effects on the 0 to 2-inch soil zone (Table 6). In all cases increasing either P or K fertilizer increased the P soil test and K soil tests, respectively (Tables 7 and 8). Fertilizer did not affect soil tests in the 2- to 8-inch zone. All P and K soil tests were lower than one year ago except the K soil test on plots receiving 400 lbs/acre of K_2O annually.

Table 2. Effect of P and K fertilization and variety on alfalfa yields at Morris in 1985.

Fertilizer Rate		Varieties	
P_2O_5	K_2O	Vernal	Answer
- - lb/A - -		Dry Matter (T/A)	
0	200	3.16	3.05
50	200	4.83	4.93
100	200	5.06	5.29
50	0	4.64	4.77
50	100	4.60	4.59
50	200	4.83	4.87
50	300	4.91	4.92
50	400	4.99	4.98
Average		4.63	4.67

CV = 5.3%

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

Variable	Std. Error	Signif. level[1]
	- T/acre -	- % -
Cutting Schedule (CS)	.54	93
PK Treatment (PK)	.65	99
CS x PK	.18	27
Variety (V)	.03	71
CS x V	.07	88
PK x V	.07	35
CS x PK x V	.11	35

1 Probability that differences are not due to chance.

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

Variable	3-cut Schedule			4-cut Schedule			
	1st	2nd	3rd	1st	2nd	3rd	4th
	- - - - - - Signif. level (%)[1] - - - - - - - -						
PK Treatment	99	>99	>99	>99	>99	>99	>99
Variety (V)	>99	96	91	42	74	>99	80
PK x V	95	4	61	41	19	46	4

1 Probability that differences are not due to chance.

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

Variable	3-cut Schedule 1st	2nd	3rd	4-cut Schedule 1st	2nd	3rd	4th
	- - - - Signif. level (%)[1] - - - -						
PK Treatment (PK)	>99	>99	>99	98	>99	>99	>99
Variety (V)	14	22	86	91	38	55	49
PK x V	83	27	74	94	61	88	30

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

Table 6. Effect of cutting schedule and P and K fertilization on Answer only on soil test levels in September 1985.

	Soil Tests (lbs/acre)					
	Bray P		Olsen P		Exch. K	
Variable	0-2"	2-8"	0-2"	2-8"	0-2"	2-8"
	- - - - - - - Probability[1] (%) - - - - - - - -					
Cutting Schedule (CS)	88	20	92	15	1	28
PK Treatment (PK)	>99	68	>99	62	>99	80
CS x PK	46	59	18	41	26	57

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

Table 7. Effect of P rate on Answer only on soil test P of the 0-2 inch soil zone in September 1985.

Fertilizer Rate P_2O_5	K_2O	Bray P	Olsen P
- lbs/acre -		- - lbs/acre - -	
0	200	9	5
50	200	20	17
100	200	40	33

Table 8. Effect of K rate on Answer only on soil test K of the 0-2 inch soil zone in September 1985.

Fertilizer Rate P_2O_5	K_2O	Exch. K
- lbs/acre -		lbs/acre
50	0	228
50	100	279
50	200	346
50	300	416
50	400	756

INVESTIGATIONS OF TILLAGE, N RATE, AND CORN HYBRID ON A PACHIC UDIC HAPLOBOROLL (TARA, SILT LOAM)

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

Morris, 1985

The purpose of this study was to investigate (1) the interaction of corn hybrid and N response, (2) the effect of tillage on rate of N transformation of applied N and·its availability, and (3) the effect of tillage on corn hybrid performance.

EXPERIMENTAL PROCEDURES

The experimental site is located in west central Minnesota on a Pachic Udic Haploboroll (Tara, silt loam) soil. The experimental disign is a split-plot with tillage as main plots, N rates as subplots, and hybrids as sub-subplots. There are four replications.

Treatments are summarized in Table 1. The site was too wet in the fall of 1984 to apply ammonia and carry out the tillage operations. The nitrogen was applied as anhydrous ammonia on May 10. The moldboard plow and chisel plow treatments were carried out on May 20. The moldboard plow plots were disked twice and field cultivated once before planting. The chisel plow plots were disked once before chiseling and disked once after chiseling. The plots were planted on May 24 with a Hiniker planter with Kinze units. The planted population was 30,100 seeds/acre.

Weed control was obtained by Alachlor (Lasso) 3 lbs/A + Cyanazine (Bladex) 2.2 lbs/A applied preemergence on May 25. There was excellent weed control. Row fertilizer was applied at planting (9.4 gal/A of 7.4-25-0). The moldboard , chisel, and no till treatments were not cultivated. The ridge till plots were cultivated twice (June 24 and July 8) to form ridges.

Stand counts were made on a 30-foot section of the two center rows. Tasseling and silking dates were estimated visually as the date 50% of the plants tasseled or silked.

Silage yields were taken by hand on October 1 from one 20-foot border row of each plot. The ears and stover were weighed separately and samples were saved for moisture and chemical analysis.

Grain yields were taken on October 21 with a modified JD 3300 combine. The two center rows of each plot 30 feet long were harvested and weighed on the combine. A grain sample was saved for moisture and chemical analysis.

RESULTS AND DISCUSSION

Heavy rains (2.53 inches on May 30) and cool temperatures (minimum daily temperatures 6.3^{o} F below normal the first 14 days after planting) resulted in some herbicide damage from the Lasso + Bladex. Very few plants were lost, but there was some tissue damage.

Yields

The grain and silage yields were quite low (Table 3) due to the late planting and cool season. There were significant effects of tillage, nitrogen, and hybrid on yield (Tables 2 and 3). The chisel treatment was superior in both grain and silage yield. The grain yields of the other 3 treatments were not different. Silage yields of moldboard and ridge till were low while no till was intermediate. The grain yields reached a maximum at 120 N while silage yields peaked at 80 N. Pioneer 3906 outyielded Dekalb XL8 in both grain and silage yields.

Moisture Stress

Moisture stress was measured on August 7th and 8th. There was a relatively low level of moisture stress at that time. The evaporative demand was relatively high under clear, dry conditions. There was no measurable effect of tillage on moisture stress (Table 6). There was a consistent difference in moisture stress due to hybrid. Pioneer 3906 showed lower stress than Dekalb XL8 (Table 7). This is consistent with the 1984 findings, although there was a significant tillage effect in that year.

Table 1. Treatment summary at Morris, MN, 1985.

Treatment	
Tillage:	Spring moldboard plow Spring chisel plow Ridge till No till
N Rate:	0, 40, 80, 120, and 160 lbs/A applied May 10,1985 prior to tillage as anhydrous ammonia
Hybrid:	Pioneer 3906 Dekalb XL 8

Table 2. Significance levels of treatment effects on measured variables.

Variable	Residue Cover After Planting	Emerged Population	Tassel Date	Silk Date	Grain Yield	Silage Yield	Harvest[2] Index
	Significance level[1] (%)						
Tillage (T)	>99	99	91	91	99	98	95
Nitrogen (N)	80	52	>99	>99	>99	>99	>99
T x N	86	65	78	79	58	8	73
Hybrid (H)	97	>99	10	21	>99	>99	>99
T x H	60	92	97	96	7	12	95
N x H	95	42	38	26	44	82	98
T x N x H	90	1	52	54	18	31	88

[1] [2] Harvest index is defined as ear dry matter as a percent of the total dry matter.
Probability that differences are not due to chance.

Table 3. Main effects of tillage, N rate, and hybrid on grain yield, silage yield, and harvest index.

Tillage	N Rate	Hybrid	Grain Yield	Silage Yield	Harvest Index
	- lb/A -		- bu/A -	- lbs/A -	- % -
Moldboard			68.4	9856	46.8
Chisel			79.3	11352	45.1
Ridge till			69.3	9690	45.7
No till			65.8	10199	43.7
BLSD (.05)			6.6	1099	2.3
	0		38.8	7291	42.0
	40		72.2	9806	45.2
	80		77.6	11272	46.4
	120		82.9	11416	46.5
	160		82.9	11587	46.5
	BLSD (.05)		4.3	746	2.4
		P 3906	78.8	10949	46.8
		D XL8	62.7	9599	43.8
CV (%)			12.7	15.3	9.4

Table 4. The effect of tillage and hybrid on residue cover, emerged population, and harvest index.

Tillage	Residue Cover[1] After Planting		Emerged Population		Tassel Date		Harvest Index	
	P 3906	D XL8	P 3906	D XL8	P 3906	D XL8	P 3906	D XL8
	- - - % - - -		- ppA x 10^{-3} -		days after 8/1		- - - % - - -	
Moldboard	10.1	9.2	24.2	22.0	5.2	4.7	46.7	46.8
Chisel	37.5	43.0	25.4	24.3	3.9	4.0	46.6	43.6
Ridge till	64.1	70.9	24.6	22.0	4.6	4.6	48.2	43.2
No till	70.8	74.2	24.4	23.6	4.8	5.0	45.8	41.6

1 Only 40 N and 120 N rates were counted.

Table 5. The effect of nitrogen and hybrid on residue cover and harvest index.

N Rate	Residue Cover[1] After Planting		Harvest Index	
	P 3906	D XL8	P 3906	D XL8
- lbs/A -	- - - % - - - -		- - - - % - - - -	
0	-	-	45.7	38.4
40	42.8	49.9	47.3	43.1
80	-	-	46.6	46.1
120	48.4	48.8	47.5	45.5
160	-	-	47.1	45.8

Table 6. The effect of tillage on moisture stress at Morris, MN, 1985 (n=8).

Date	Time	Tillage				Significance[1] Level
		Moldboard	Chisel	Ridge till	No till	
		- - - - - - - - - - - (-bars) - - - - - - - - - - -				- - - % - -
8/7/85	1400	7.85	7.90	7.05	7.20	52
8/8/85	0800	1.77	2.05	1.81	2.17	50
8/8/85	1330	4.78	4.74	4.70	4.55	6

1 Probability that differences are not due to chance.

Table 7. The effect of corn hybrid on moisture stress at Morris, MN, 1985 (n=8).

Date	Time	Hybrid		Significance[1] Level
		Pioneer 3906	Dekalb XL8	
		- - - - - - (-bars) - - - - - -		- - - % - -
8/7/85	1400	6.81	8.12	99
8/8/85	0800	1.65	2.25	99
8/8/85	1330	4.44	4.95	91

1 Probability that differences are not due to chance.

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

George Rehm, Mike O'Leary, Greg Cremers, Brian Anderson

Background and Justification:

In Minnesota, there is potential for a requirement for the use of fertilizer boron (B) in the production of both corn and alfalfa. The potential for a response of B is highest where these crops are grown on sandy soils with a low organic matter content.

The need for the addition of B to a fertilizer program has been the subject of previous studies but the results have not been conclusive. Annual applications of B did increase the yield of an alfalfa-grass mixture in northeastern Minnesota. Broadcast applications of B increased corn yield but had little effect on production of alfalfa in north-central Minnesota. At this experimental site, excessively high rates of fertilizer B reduced the yield of both corn and alfalfa. At the Becker Experimental Field, the application of fertilizer B had no effect on yield.

Boron, like nitrogen (N) and sulfur (S), is considered to be a mobile nutrient in soils. The early trials in northeastern and north-central Minnesota showed that there was substantial downward movement of applied B through the soil profile. Management programs have been developed, which, if followed, minimize the movement of nitrate-nitrogen (NO_3-N) to the groundwater. In Minnesota, no research efforts have been directed to the development of management systems which will minimize the loss of fertilizer B.

In past studies, the B used in the fertilizer program has been broadcast and incorporated before planting. Perhaps some of the B applied in this way was lost and this might explain some of the erratic responses noted to date. This study was designed to evaluate the effect of rate of applied B as well as frequency of application on production of both alfalfa and corn grown on an irrigated sandy soil.

Experimental Procedures:

This study was conducted at the Irrigation Research Center at Staples, Minnesota. The soil is classified as a Hubbard sandy loam. Relevant soil properties are listed in Table 1.

Trials were conducted with both corn and alfalfa. Prior to treatment application, soil samples were taken from each corn plot at depths of 0-6, 6-12, 12-24, and 24-36 inches (Table 2). Samples were collected in early November from the same depths to monitor changes in the B concentration in the soil. The hot water soluble procedure was used to extract B from the soil.

Four rates of B (0, 1, 2, 4 lb./acre) in either single or split application were broadcast to an established stand of alfalfa. When split applications were used, 1/2 was applied in early spring and 1/2 after the second cutting. Adequate S (as gypsum) and K (as 0-0-60) were applied to all plots. Three cuttings were taken starting in early June and whole plant samples were taken from each plot at each cutting. A total of 11.45 inches of irrigation water was applied during the growing season.

Table 1. Relevant soil properties of the experimental site (0-6 in.).

pH	7.0
P, lb./acre (Bray & Kurtz #1)	89
K, lb./acre 1 N NH_4 $C_2H_3O_2$)	206
Mg, lb./acre	340
S, ppm	4
B, ppm	.24
O.M., %	2.4

Table 2. Boron concentration in corn experimental area with depth as influenced by rate and frequency of application.

Treatment	Depth	Sampling Time Spring	 Fall
	inches	------------ppm B-----------	
control	0-6	.28	.23
	6-12	.20	.20
	12-24	.13	.13
	24-36	.10	.10
1 lb.B/acre	0-6	.23	.30
	6-12	.20	.28
	12-24	.15	.13
	24-36	.10	.10
2 lb. B/acre	0-6	.23	.30
	6-12	.20	.35
	12-24	.13	.18
	24-36	.10	.10
.5 + .5 lb. B/acre (split)	0-6	.23	.30
	6-12	.20	.33
	12-24	.13	.15
	24-36	.10	.10
1 + 1 lb. B/acre (split)	0-6	.25	.43
	6-12	.20	.55
	12-24	.10	.13
	24-36	.10	.10

Three rates of B (0, 1, 2 lb./acre) in either single or split application were broadcast for corn. Single applications were applied before planting. For split applications, 1/2 was applied before planting and 1/2 was applied at the 8-leaf stage. All plots received broadcast S (gypsum) and K (0-0-60). The N rate for all treatments was 200 lb./acre with 1/2 half applied before planting and 1/2 applied at the 8-leaf stage. In addition, all plots received a starter (8-10-41) at a rate of 100 lb./acre.

Other management practices needed to achieve high yields in the area were used. A total of 8.70 inches of irrigation was water applied during the growing season.

Ear leaf samples were collected at silking, dried and analyzed for B. Both grain and stover yields were recorded. Stover samples were analyzed for B to calculate B removal by the corn crop.

Results and Discussion:

In 1985, neither rate nor frequency of B applied had a significant influence on alfalfa yield (Table 3). This was true for individual cuttings as well as for total yield. Apparently the inherent B in the soil as well as the B released from the mineralization of organic matter during the growing season was sufficient to meet the B needs of this crop.

As was the situation for alfalfa, neither rate nor frequency of B applied had a significant effect on both the grain and stover yield of corn (Table 4). Again, the soil was able to supply the needed B during the 1985 growing season. Yields were hindered by cool temperatures and were lower than anticipated. Perhaps a response to fertilizer B could be achieved at higher yield levels.

The B concentration in the mature stover was not significantly affected by treatment. The high CV associated with this measurement illustrates the problem with sample collection and analysis of samples of mature corn stover. As would be expected, B uptake by the crop was not significantly influenced by treatment.

The B concentration in the ear leaf tissue was affected by treatment (Table 4). Compared to the control, use of B increased the concentration in this tissue. The highest concentration resulted from the situation where 2 lb. B/acre was split into 2 equal applications. These data would indicate that split applicatinos may be useful under irrigated conditions in situations where soil B is more limiting than at this experimental site.

The concentration of boron in the soil was also influenced by the treatment applied (Table 2). Compared to the control, the concentration in the 0-6 and 6-12 inch levels was increased when B was applied. The major changes occurred in the 6-12 inch depth. Greatest changes were measured when the 2 lb. B/acre rate was applied in 2 equal increments.

Compared to values recorded before B was applied, there was little or no change in B concentration in the 12-24 and 24-36 inch depths. It should be noted that the percentage of fine textured materials in the soil increases at the 12-24 inch depth. This fine textured material apparently prevents leaching of fertilizer B through the profile.

The amount of irrigation water used was higher than the normal amount that would be used. Based on data from one year it would appear that leaching of applied B would be a minor concern for these irrigated soils.

Table 3. Effect of rate and frequency of boron application on the yield of alfalfa.

Treatment	Cutting 1	Cutting 2	Cutting 3	Total
	---------ton dry matter/acre-------			
control	2.1	1.2	1.3	4.6
1 lb. B/acre (single)	1.8	1.1	1.3	4.2
2 lb. B/acre (single)	2.0	1.1	1.3	4.4
4 lb. B/acre (single)	1.8	1.1	1.3	4.2
.5 + .5 lb. B/acre (split)	2.0	1.2	1.3	4.5
1 + 1 lb. B/acre (split)	1.9	1.1	1.3	4.3
2 + 2 lb. B/acre (split)	2.1	1.2	1.3	4.6

Table 4. Effect of rate and frequency of boron application on the stover and grain yield of corn, B concentration in ear leaf and stover and B uptake by corn.

Treatment	Yield: Grain	Yield: Stover	B Conc.: Ear leaf	B Conc.: Stover	B Uptake
	bu./acre	ton D.M./acre	--------ppm B-----		lb./acre
control	136.4	6.17	8.1	5.2	.064
1 lb.B/acre (single)	143.4	6.02	9.3	6.1	.073
2 lb.B/acre (single)	140.6	6.34	9.8	5.0	.063
.5 + .5 lb.B/acre (split)	141.7	6.18	9.6	5.8	.072
1 + 1 lb.B/acre (split)	142.7	6.03	11.7	6.0	.072
CV: %	3.8	6.3	6.2	18.2	17.7
BLSD (.10)	NS	NS	.8	NS	NS

CORN - SOYBEAN ROTATION

H. Meredith, Mel Wiens and Mike O'Leary

The corn-soybean rotation experiment initiated in 1981 at the Staples Station to evaluate corn yield under a regime of continuous corn and corn following soybean continues.

Objective: To determine potential corn and soybean yields under intensive management.

Discussion: Moisture and nutritional requirements are frequently the two most limiting features of crop production on these typically coarse textured soils. Other management practices as early planting, population, seed selection, pest control, etc. frequently limit yields. This study is an application of the best management practices available to the commercial farmer variation in yield from year to year are attributed to growing conditions rather than changing management. All treatments have four replications.

1985 Management Practices

Date of Planting: Corn - April 26
Soybeans - May 21

Population: Corn - 29,900 seeds/A
Soybeans - 57 lbs/A (9 seeds/ft)

Herbicide: Lasso @ 4 lbs/A

Insecticide: Corn-Counter @ 6 lbs/A

Fertilizer: Corn - 9-11-72-11 Sulfur @ 100 lbs/A 180 lbs at planting N as urea applied on 6/4, 7/8, and 8/2 in 60 lb increments
Soybeans - 17-10-30 @ 142 lbs/A at planting

Harvest: Corn forage 9/26
Corn grain 10/15
Soybeans 9/26

Water Use: 5/3-9/19 19.27 in. total
Irrigation 6.5 in.
6/21-8/8 8.85 in. or .18 in/day

Variety Corn: Pioneer 3881 90 day (relative maturity)
Pioneer 3906 95 day
Pioneer 3953 80 day
Soybean: Clay

Table 1 contains yield and corresponding features associated with corn production in 1986.

Table 1. Corn Yield and Related Information Pertaining to Corn Production at the Staples Station in 1986

Treatment	Yield Bu/A	Harvest Population (X1000)	% Moisture	Grain Yield T/A(DM)	Stover Yield T/A(DM)	Grain Stover Ratio	Silage Tons/A (DM)
(1) C-C 3881	125.4	27.0	29.8	2.97	2.04	.60	5.01
(2) C-C 3906	123.9	23.3	31.0	2.94	2.55	.54	5.49
(4) SB-C 3881	122.7	24.7	30.3	2.91	2.49	.54	5.40
(7) CC-3953	115.1	26.7	20.3	2.73	2.00	.58	4.72
Sig Level	91	88	99	91	91	81	98
BLSD (.05)	9.6	NS	2.06	.23	.63	NS	.53
C.V. ½	4.3	8.7	4.8	4.3	15.10	7.5	6.0

Table 2. Nutrient Removal in Corn Grain - lbs/A

Treatment	N	P_2O_5	K_2O	Ca	Mg	MN	Zn	Cu	B
(1)	98.0	43.7	31.1	.18	8.5	.031	.13	.004	.016
(2)	95.1	41.4	27.1	.24	8.8	.035	.12	.005	.016
(4)	94.7	43.6	29.8	.16	8.5	.030	.13	.004	.014
(7)	79.9	35.5	24.8	.20	7.2	.025	.14	.005	.012

Table 3. Nutrient Removal in Corn Stover - lbs/A

Treatment	N	P_2O_5	K_2O	Ca	Mg	MN	Zn	Cu	B
(1)	13.5	8.03	129.2	15.2	7.08	.20	.13	.019	.029
(2)	30.9	12.32	139.8	20.4	9.43	.23	.12	.021	.037
(4)	24.0	10.19	128.8	16.7	8.09	.22	.11	.022	.031
(7)	17.7	7.15	108.0	14.5	7.73	.13	.10	.011	.025

Table 4. Total Nutrient Removal in Corn Grain and Stover - lbs/A

Treatment	N	P_2O_5	K_2O	Ca	Mg	MN	Zn	Cu	B
(1)	111.5	51.7	159.4	15.4	15.6	.23	.27	.023	.046
(2)	126.0	53.8	166.9	20.6	18.2	.27	.24	.026	.053
(4)	118.7	53.8	158.6	16.9	16.6	.25	.24	.026	.046
(7)	97.6	42.6	132.8	14.7	14.9	.16	.24	.016	.037

Table 5. Leaf Tissue Analyses of Corn at Silking

	Percent						PPM			
Treatment	N	S	P	K	Ca	Mg	MN	Zn	Cu	B
(1)	3.18	.22	.31	2.5	.66	.28	88	31	5.5	5.2
(2)	3.14	.23	.30	2.5	.70	.29	68	26	5.4	5.2
(4)	3.06	.22	.31	2.5	.68	.28	92	27	5.5	4.5
(7)	3.14	.21	.31	2.7	.71	.25	64	28	5.2	5.0

Table 6. Analyses of Corn Grain

	Percent					PPM			
Treatment	N	P	K	Ca	Mg	MN	Zn	Cu	B
(1)	1.65	.32	.42	.003	.14	5.3	22.5	.70	2.7
(2)	1.62	.31	.38	.004	.15	6.0	21.3	.87	2.7
(4)	1.63	.32	.43	.003	.14	5.2	22.6	.66	2.5
(7)	1.46	.28	.38	.004	.13	4.7	25.2	.84	2.3

Table 7. Analyses of Corn Stover

	Percent					PPM			
Treatment	N	P	K	Ca	Mg	MN	Zn	Cu	B
(1)	1.11	.22	1.33	.15	.15	22.8	26.4	2.31	4.6
(2)	1.15	.21	1.26	.19	.17	24.3	22.2	2.37	4.8
(4)	1.10	.22	1.22	.16	.15	23.3	22.6	2.42	4.2
(7)	1.04	.20	1.18	.16	.16	16.9	25.2	1.69	4.0

Table 8. Leaf Analyses/Soybean Leaves at Initiation of Blossom, Staples Station

Percent					PPM			
S	P	K	Ca	Mg	MN	Zn	Cu	B
.29	.51	2.6	1.2	.46	112	50	4.6	40

Yield of clay soybeans averaged 36.4 bu/A. However, the yield from plots planted to soybeans the previous year was 34.2 bu/A while yield following corn the previous year was 37.7 and 37.4 as averages from four replications. There appears to be a slight yield increase in soybean yields where corn is grown as an inter crop.

Table 9. Summary of Corn Yields of the Corn-Soybean Rotation Plots, Staples Station 1982-1985

Treatment	1982	1983	1984	1985	Ave.
	-------------------	Corn Yields -	Bu/A	-------------------	
C-C	168 1/	135.2 1/	130.5 1/	125.4 4/	139.8
C-C	166 2/	150.4 2/	127.7 2/	123.9 2/	142.0
SB-C	170 1/	148.2 2/	139.6 1/	122.7 4/	145.1
SB-C	168 1/	147.3 1/	137.4 1/	---	150.9
C-C	--	155.0 2/	131.8 1/	115.1 3/	134.0

1/ Pioneer 3978 (85 day RM)
2/ Pioneer 3906 (95 day RM)
3/ Pioneer 3953 (80 day RM)
4/ Pioneer 3881 (90 day RM)

Table 10. Summary of Soybean Yields of the Corn Soybean Rotation Plots, Staples Station 1982-1985

------ Soybean Yields Bu/A --------

1982	1983	1984	1985	Ave.
47.0	47.0	37.6	36.4	42.0

LUPIN BEAN STUDY

H. L. Meredith, Mel Wiens and Mike O'Leary

Lupinus Alba (white lupin), an herb cultivated from ancient times, is ideally suited for well drained, slightly acidic soils. A seemingly low fertility requirement, cold tolerance, relatively high yields, high palatability and high protein content all tend to confirm the desirability of this ancient crop.

A lupin experiment was initiated in the spring of 1984 to determine the feasibility of lupinus as a seed and forage crop. Potential yield and fertility requirements are of high interest.

Early planting is essential to permit blossom and pod set prior to the onset of high summer temperatures. This crop should be planted with the earliest spring crops or about the same time as oats.

Yield from two years field experience appears in Table 1.

Table 1. Ultra Lupin Yields at the Staples Station 1984 and 1985. Yields are Based on 13.5 Percent Moisture Basis.

Treatment	Yield, bu/Acre 1984	Yield, bu/Acre 1985	Forage Dry Matter 1985 (Lbs/A)
No fertilizer	39.1 1/	71.4 2/	9108
100# 8-32-16 3/	39.4	64.1	9719
25# sulfur	43.2	71.2	7667
300# K_2O	40.5	63.8	7996
PKS 4/	39.4	68.8	8595
NPKS 4/	41.5	64.9	8317

1/ 30-inch rows

2/ 6-inch graindrill

3/ Changed to 160# N in 1985, split applications

4/ 60# N and 60# P_2O_5 where indicated

There were no significant differences in yield as a result of any fertility treatments. The more variable yield in 1985 was attributed to plant count differential.

Yield data in Table 1 were taken from the same plots, therefore, lupins were grown two years on the same plots. A variety trial at another location on the station resulted in higher yields and demonstrates the yield capability of this crop.

Table 2. Yield of Lupin Varieties, Staples Station, 1985. Yields Adjusted to 13.5 Percent Moisture.

Variety	Yields, Bu/Acre
Kiev	83.7
Ultra	94.7
Hamburg	45.9
Multilupin	33.1

Plant population on these plots, especially Kiev and Ultra, was excellent. Neither the Hamburg nor Multilupin would be recommended. These varieties are "forage" varieties but are coarse, woody, and require a longer growing season than the Kiev or Ultra.

Lupins are susceptible to root disease. Seeding rates of 180 pounds per acre are highly recommended.

Table 3. Soil Test Data Staples Station from Site Used for Lupin Production, 1985.

Treatment	Soil Texture	Organic Matter	Soil pH	Bray P Lbs/A	K Lbs/A	Mg Lbs/A	S PPM	Zn PPM
(1) No Fert	LS	1.4	6.3	44	81	292	1	0.4
(2) 100# 8-32-16	LS	1.5	7.0	52	129	281	3	0.4
(3) 25# Sulfur	LS	1.6	6.9	52	93	297	2	0.6
(4) 300# K_2O	LS	1.5	6.7	45	223	299	2	0.6
(5) K+S + 60# P_2O_5	LS	1.3	6.8	62	229	280	2	0.4
(6) P_2O_5+K+S+60# N	LS	1.6	6.7	60	155	264	2	0.5

Table 4. Tissue Values of Lupin Grown on the Staples Site, 1985. Samples Taken at the Bloom Stage.

Treatment	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B
	(%)						(PPM)			
1	5.36	.28	.36	1.33	1.04	.22	.94	17.1	3.64	17.8
2	5.29	.29	.41	1.74	.88	.22	1.00	17.5	3.09	12.6
3	5.27	.30	.39	1.47	.99	.24	.95	21.3	3.46	15.2
4	5.27	.29	.35	1.71	.91	.18	.91	15.3	2.71	12.1
5	5.47	.29	.35	1.66	.96	.18	.88	12.4	2.44	12.8
6	5.25	.28	.38	1.74	.96	.22	1.01	16.3	3.04	13.8

Table 5. Nutrient Content of Lupin Beans, Staples Station, 1985.

Treatment	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B	Al	Fe	Na
				(%)					(PPM)				
1	5.36	.23	.41	1.03	.22	.18	1.4	39.3	4.7	13.0	8.5	28.1	52.7
2	5.35	.23	.44	1.10	.23	.19	1.3	36.6	3.9	10.5	6.6	26.4	43.4
3	5.65	.30	.43	1.17	.23	.19	1.2	41.4	4.9	12.4	6.3	27.0	51.7
4	5.57	.26	.42	1.17	.23	.18	1.6	39.9	4.8	11.4	6.6	28.6	54.3
5	5.67	.29	.44	1.24	.23	.20	1.1	35.6	4.1	9.3	13.6	34.3	52.0
6	5.59	.31	.43	1.20	.24	.19	1.4	39.5	4.2	12.0	10.0	28.1	61.8
Ave.	5.53												

Table 6. Nutrient Content of Lupin Forage, Staples Station, 1985.

Treatment	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B
				(%)					(PPM)	
1	2.63	.12	.20	1.06	.59	.22	1.4	21	2.8	13.8
2	2.58	.12	.20	1.21	.56	.22	1.3	19	2.4	11.4
3	2.25	.15	.17	1.26	.62	.22	1.1	19	2.7	13.2
4	2.50	.12	.17	1.51	.60	.20	1.4	19	2.6	12.6
5	2.58	.14	.19	1.45	.49	.19	1.0	17	2.4	10.2
6	2.72	.16	.21	1.46	.59	.21	1.3	22	2.2	11.8

Table 7. Lupin Bean Nutrient Removal, Staples Station, 1985.

Treatment	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B
					(Lbs/A)					
1	200	8.5	15.3	38.3	8.4	6.6	5.3	.14	.017	.05
2	180	7.6	14.5	36.9	7.6	6.3	4.2	.12	.013	.04
3	210	11.0	15.9	43.4	8.7	6.9	4.5	.15	.018	.05
4	185	8.7	13.9	38.6	7.6	6.0	5.2	.13	.016	.04
5	202	10.5	15.8	44.6	8.2	7.1	4.0	.12	.014	.03
6	189	10.3	14.6	40.8	8.2	6.4	4.7	.13	.014	.04

Table 8. Lupin Forage Nutrient Removal, Staples Station, 1985.

Treatment	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B
					(Lbs/A)					
1	238	10.6	17.8	98	53	20	12.8	.19	.026	.12
2	250	11.2	19.6	118	53	21	12.7	.18	.023	.11
3	175	11.4	13.8	97	48	17	8.4	.15	.021	.10
4	197	9.9	13.6	122	48	16	10.9	.15	.021	.10
5	220	12.3	16.3	125	42	16	9.1	.14	.020	.09
6	220	13.1	16.9	122	50	18	10.7	.18	.019	.10

Summary. Lupins appear to offer great potential as an alternate protein source where growing soybeans is not practical. The protein content is about 35 percent. Soybeans require heat treatment to deactivate the trypsin inhibitors and ureases which decrease digestibility of the dietary protein; lupins can be fed directly on the farm without heat treatment.

It is noted that yields such as the 94.5 bushel per acre yield obtained in 1985 would contain about 270 pounds of nitrogen. It is absolutely essential that lupin be carefully inoculated with Rhizobium lupini when planting to ensure adequate nitrogen fixation. Seemingly this bacteria is capable of excellent survival in a soil environment which is slightly acidic. A pH of 5.7 to 7.0 appears to be ideally suited for the growth of lupins. Strains are being developed for growth on higher pH soils. Iron and possibly Zinc deficiency appear to be common problems when grown on high pH soils, (above pH 8.0).

No response to fertility treatments was noted. However, additional studies must be conducted to more adequately describe the nutritional requirements of this crop.

Cold tolerance, relatively early maturing varieties, low to moderate nutrient requirements and on-farm usage are all factors which may be appealing qualities for many heretofore marginal soybean growing areas. Consideration of the lupin as a potential forage crop should not be overlooked.

Lupins have been shown to substitute 100 percent for soybean meal on a protein equivalent basis to obtain the same rate of daily gain. Lupins have also been substituted up to 30 percent in nonruminant rations. Pet ration also offer a strong potential for the use of lupins.

Snacks, macaroni, or pasta preparations, flour, etc. are also being test marketed through health-food stores. The high protein and fiber are especially attractive to the health-conscious user. The lupin, when prepared directly like other bean dishes, does not cause intestinal flatulence as some other beans.

Finally, it might be stated this ancient seed may fill a broad-based modern need.

Triticale Studies

H. Meredith, Melvin Wiens and Mike O'Leary

Triticale is a cross between durum wheat and rye. Triticum for wheat and secale for rye, hence the name. Although triticale is an old crop (first reported in 1876) improvements are destined to make the old crop better.

The early severe cold temperatures in the fall of 1984 convinced many growers that the crop does not have sufficient winter hardiness. Both winter and spring varieties are available.

In the fall of 1984 trial plots were established at the Staples Station which included triticale varieties I-18, 239, and double crop, a variety developed especially for forage production.

All three varieties winter killed. These varieties were replanted at the Staples Station in the fall of 1985. Excellent growth was observed prior to heavy snowfall. Unless unusual weather conditions prevail in the spring of 1986, a crop should be forthcoming.

A spring variety, Nutricale, was established and excellent yields were obtained in 1985. This variety will also be planted in 1986. Nitrogen treatments are to be established on all of the varieties to determine optimum yield levels.

Table 1 lists the chemical data for triticale forage (whole plant) growen at Staples in 1985.

Table 1. Chemical Data of Double-Crop Triticale, a Forage Variety. Whole Plant Data, Late Dough Stage, Staples Station, 1985.

Sample	N	S	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
	Percent						PPM						
1	1.49	.10	.25	1.6	.28	.11	41	77	17	84	34	2.0	2.4
2	1.56	.13	.28	1.8	.30	.12	38	100	27	62	52	2.7	2.4

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

Well Water Analyses

H. Meredith and Melvin Wiens

For several years the irrigation wells on the Staples Station have been monitored to determine any changes in the water quality.

The data from water samples taken in 1984 appear in Table 1.

Table 1. Analysis of Well Water, Staples Station, Sampled Fall 1984.

No.	SO_4-S PPM	Total Alkalinity mg/L $CaCO_3$	Specific Conductance Micromhos @25°C
I	2.5	131	240
II	11.7	112	350
III	7.3	133	--
IV	2.1	133	--
V	9.9	126	350
VI	11.7	108	335
VII	9.9	120	345
VIII	1.0	141	255
IX	0.8	139	245

Table 2. Water Sample Results From Water Samples Obtained in 1985, Staples Station.

No.	SO_4-S PPM	Total Alkalinity mg/L $CaCO_3$	K	Ca	Mg	Na	Mn	B
			PPM					
C-1	3.6	237	1.5	74	21	2	.2	.02
C-2	3.7	230	1.4	75	22	2	.2	.02
D-1	2.5	231	1.1	71	21	2	.3	.01
D-2	2.4	244	1.6	71	20	2	.3	.02
SWP-1	0.5	117	1.1	28	9	.8	.01	--
SWP-2	0.6	96	.6	27	9	.5	.01	--

Note: Phosphorus, Zinc, Copper, and other elements were essentially too low to determine.

SOUTHERN EXPERIMENT STATION - WASECA

WEATHER DATA - 1985

Month	Period	Precipitation 1985	Precipitation Normal1/	Avg. Air Temp. 1985	Avg. Air Temp. Normal1/	Growing Degree Days 1985	Growing Degree Days Normal1/
		----inches-----		------°F-------			
January	1-31	0.69	0.84	8.1	10.0		
February	1-29	0.24	0.99	13.7	16.4		
March	1-31	5.61	1.99	35.4	27.6		
April	1-30	3.33	2.64	49.9	44.7		
May	1-10	0.20		63.6		147.0	
	11-20	1.01		60.5		119.0	
	21-31	0.60		64.1		159.5	
	Total	1.81	3.76	62.7	57.7	425.5	334
June	1-10	0.17		63.6		138.5	
	11-20	1.80		59.9		105.5	
	21-30	0.59		67.9		177.0	
	Total	2.56	4.48	63.8	67.1	421.0	518
July	1-10	0.09		71.7		206.0	
	11-20	0.19		71.3		211.5	
	21-31	2.23		67.3		190.5	
	Total	2.51	4.02	70.1	71.2	608.0	641
August	1-10	0.18		68.3		183.5	
	11-20	2.41		61.0		124.5	
	21-31	2.62		63.5		149.0	
	Total	5.21	3.99	64.3	68.8	457.0	579
September	1-30	5.40	3.36	59.0	59.8	335.5	311
October	1-31	2.71	2.08	46.0	48.9	0.0	38
November	1-30	1.84	1.43	23.0	32.5		
December	1-31	2.04	1.02	4.7	18.0		
Year	Jan-Dec	33.95	30.60	41.7	43.6	2247.0	2421
Growing Season	May-Sep	17.49	19.61	64.0	64.9	2247.0	2383

1/ 30-year normal from 1951 - 1980.

Notes:

1) Highest temperature on June 9 -- 102°.
2) Rainfall for the May-June period was 47% below normal and was 6th driest May-June period since records began in 1914.
3) Rainfall for May-July period was 44% below normal and also was 6th driest May-July period on record.
4) Highest 24-hour precipitation on July 25 -- 1.57".
5) Last spring frost -- April 10.
6) First fall frost -- September 26.
7) Solar radiation recorded for May and July set record highs. Only 3 cloudy days in July.

ROTATION NITROGEN STUDY

Waseca, 1985

G. W. Randall, P. L. Kelly, and M. P. Russelle

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 plan a vital role in the conservation of N. The purposes 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 1985, anhydrous ammonia was applied on April 19 to all corn plots. Wheat received 50 lb N/A as urea before planting. All plots were moldboard plowed in the fall of 1984 after receiving a broadcast application of 0 + 50 + 150 lb $N+P_2O_5+K_2O$/A.

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 1. Furadan was applied to all corn plots at 1 lb/A to control rootworms. Wheat ("Wheaton") was planted on April 30. Hardin soybeans were planted in 15" rows on May 13.

Weeds were chemically controlled along with one cultivation of the corn. A combination of 3½ qt Lasso plus 3½ lb Bladex/A was applied preemergence to corn. Soybeans received 3½ 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 1984 harvest and again in the spring prior to N application, soil samples were taken to a depth of 5' from the 0 and 160-lb N treatments which were applied to the continuous corn (grain) and continuous corn (silage) rotations. Soil samples were also taken from the 0-lb N treatments in the plots where soybeans, wheat, and corn following soybeans were the 1984 crops. Two cores were taken/plot, divided into 1-foot increments, composited/rep, dried, crushed, and analyzed for NO_3-N by the Univerity of Minnesota Soil Testing Laboratory.

RESULTS

Nitrate-N remaining in the soil profile after the 1984 crop which was available to the 1985 corn, is presented in Table 1. When no fertilizer N was applied in 1984 (except the blanket 50-lb rate to wheat) very little difference in residual NO_3-N appeared among the five crop sequences.

Samples taken from these 0-N plots the following spring showed slight increases in NO_3-N compared to the fall sampling. Again, differences among the crop sequences were minimal. Approximately 40% of the residual NO_3-N was found in the top foot of the 5-foot profile with all five crops. When the 160-lb rate of N was applied to continuous corn (grain and silage), a substantial amount of residual N was found throughout the 5-foot profile in the fall. Samples taken the following April from these same plots showed approximately a 50% decline in NO_3-N throughout the profile. Reasons for this decrease are thought to be due to either denitrification or leaching.

Table 1. Effect of time, crop, and N rate applied to corn in the crop sequence on residual NO_3-N remaining in the 0-5' profile in the fall of 1984 and the beginning of the 1985 growing season.

	Octber, 1984					April, 1985			
	1984 Crop								
Profile depth	Corn (grain)	Corn (silage)	Soybeans	Wheat	Corn after Soybeans	Corn grain	Corn silage	Soybeans	Wheat
feet	lb NO_3-N/foot								
					0 lb N/A				
0-1	33	ND[1/]	37	48	28	30	44	51	37
1-2	12		14	15	11	26	17	24	28
2-3	10		12	11	9	14	10	15	19
3-4	11		15	10	13	13	16	15	14
4-5	12		17	11	16	13	13	14	9
Total(lb NO_3-N/5')	77		95	95	77	96	100	119	107
					160 lb N/A				
0-1	61	68				37	56		
1-2	67	67				22	34		
2-3	57	59				24	27		
3-4	60	67				21	26		
4-5	52	61				21	25		
Total(lb NO_3-N/5')	297	322				125	168		

1/ Not determined

Corn grain yield, leaf N, grain N, grain N removed, and grain moisture at harvest are shown in Table 2 for each of the treatments. All data are an average of five replications. Averages and statistical interpretations for each of the main factors and the two-way interactions are shown in Table 3.

Grain yield

Corn yields were excellent in 1985 considering the moisture stress encountered in July. As in previous years crop sequence had a substantial effect on corn yield. Yields following soybeans or wheat were significantly higher (15 to 24 bu/A) than when following corn (either for grain or silage) when averaged over N rates and hybrids. Second year corn yields following soybeans were intermediate between continuous corn and corn after soybeans or wheat. When averaged over N rates and hybrids corn yields following wheat were significantly higher than when following soybeans. Yields were economically maximized with the 160-lb N rate when averaged over crop sequence and hybrids. Contrary to 1984, yields were significantly higher with P3732. The lower yields with P3906 more than likely could be attributed to the dry, stress conditions during the pollination of this hybrid. P3732 which pollinated 5 days later (July 22) was aided by 1.57" of rain on July 25.

Closer examination of the interactions reveals additional information. The sequence x N rate interaction was highly significant (P=99% level) when averaged across hybrids. For the CC(g), CC(s), C-Sb, C-W, and Sb-C-C systems, highest yields were obtained statistically at the 120, 120, 120, 80, and 160-lb N rates, respectively, and were economically maximized at the 160, 160, 160, 80, and 160-lb rates, respectively. Yield responses of 68.2, 51.5, 60.2, 48.8, and 92.6 bu/A were obtained with the maximum economic rate of N for each of the respective crop sequences. Yields with the 0-16 N rate were lowest with the CC(g) and Sb-C-C systems, intermediate with the CC(s) and C-Sb systems, and highest with the C-W system. These data indicate that the higher amounts of plant residue incorporated from the 1984 CC(g) and Sb-C-C systems probably immobilized greater amounts of N than from the lower residue crop systems.

Contrary to 1984, the sequence x hybrid interaction was not significant indicating that the two hybrids behaved identically across all sequences. On the other hand, a highly significant N rate x hybrid interaction was found. At the 0-lb N rate only a 3.9 bu/A advantage was shown for P3732. As the N rates increased, yield advantages for P3732 increased up to a maximum of 16.2 bu/A at the 200-lb rate when averaged over sequences. No three-factor interaction was found.

Corn yield responses to N with each of the sequences did not appear to show any consistent relationship to the residual soil NO_3-N levels shown in Table 1. This is consistent with past years.

Table 2. Corn grain yield, leaf N, grain N, grain N removed, and grain moisture as influenced by previous crop, N-rate and hybrid at Waseca, 1985.

		N-rate (lb/A)					
Previous Crop	Hybrid	0	40	80	120	160	200
		Yield (bu/A)					
Cont. Corn (grain)	3906	85.0	111.0	133.4	140.5	148.9	149.8
	3732	89.9	120.3	145.8	159.8	162.3	162.9
Cont. Corn (silage)	3906	95.8	120.4	141.8	147.5	146.5	147.4
	3732	109.2	128.5	149.9	152.9	161.5	164.3
Soybeans	3906	102.2	132.7	145.8	152.8	158.9	156.9
	3732	109.6	146.5	164.5	170.5	173.3	173.6
Wheat	3906	125.6	148.7	164.0	157.0	159.7	164.1
	3732	116.6	158.3	175.8	176.3	177.6	173.8
Corn after soybeans	3906	78.9	116.2	148.4	154.6	164.6	153.4
	3732	81.8	121.3	152.9	168.6	181.1	177.7
		Leaf N (%)					
Cont. Corn (grain)	3906	1.58	1.68	2.18	2.41	2.61	2.61
	3732	1.33	1.55	2.08	2.35	2.52	2.57
Cont. Corn (silage)	3906	1.44	1.85	2.21	2.44	2.47	2.57
	3732	1.33	1.77	2.11	2.42	2.61	2.59
Soybeans	3906	1.48	2.12	2.35	2.45	2.55	2.66
	3732	1.44	1.99	2.31	2.50	2.60	2.70
Wheat	3906	1.69	2.13	2.37	2.45	2.73	2.78
	3732	1.86	2.22	2.45	2.70	2.73	2.76
Corn after soybeans	3906	1.24	1.51	2.13	2.32	2.63	2.69
	3732	1.30	1.58	2.09	2.39	2.66	2.58
		Grain N (%)					
Cont. Corn (grain)	3906	1.27	1.24	1.43	1.57	1.56	1.63
	3732	1.10	1.04	1.19	1.35	1.36	1.37
Cont. Corn (silage)	3906	1.28	1.30	1.45	1.55	1.58	1.63
	3732	1.12	1.12	1.21	1.39	1.37	1.40
Soybeans	3906	1.26	1.31	1.41	1.55	1.55	1.54
	3732	1.07	1.10	1.20	1.32	1.33	1.32
Wheat	3906	1.27	1.47	1.49	1.53	1.57	1.59
	3732	1.12	1.27	1.27	1.29	1.33	1.34
Corn after soybeans	3906	1.21	1.23	1.38	1.53	1.57	1.62
	3732	1.05	1.02	1.18	1.25	1.35	1.37
		Grain N Removed (lb/A)					
Cont. Corn (grain)	3906	51.5	65.0	89.9	104.0	110.3	115.2
	3732	47.1	59.0	82.0	102.1	104.7	105.3
Cont. Corn (silage)	3906	58.1	73.7	97.2	108.3	109.5	113.4
	3732	57.7	68.5	86.0	100.0	105.0	108.3
Soybeans	3906	60.8	82.2	97.3	112.1	116.7	113.9
	3732	55.4	76.1	93.8	106.5	109.5	108.7
Wheat	3906	76.0	103.5	115.4	113.8	118.2	123.4
	3732	62.2	94.7	105.9	107.1	111.6	109.8
Corn after soybeans	3906	45.2	68.1	96.8	111.8	122.0	117.7
	3732	40.8	58.5	85.5	99.9	115.6	115.0
		Grain Moisture (%)					
Cont. Corn (grain)	3906	25.3	24.0	24.5	25.0	24.8	24.8
	3732	31.0	29.5	29.5	29.9	29.6	29.6
Cont. Corn (silage)	3906	25.4	24.2	24.4	24.6	25.1	24.6
	3732	30.7	30.0	29.6	30.0	30.2	29.7
Soybeans	3906	24.8	24.3	24.2	24.9	24.5	24.3
	3732	30.8	29.2	28.6	29.5	29.1	29.6
Wheat	3906	25.0	24.8	24.7	25.2	25.0	25.5
	3732	30.5	29.6	29.2	29.8	29.1	29.5
Corn after soybeans	3906	24.9	23.8	24.4	24.6	24.6	24.8
	3732	30.8	29.2	29.0	28.3	28.7	29.2

Table 3. Main factor and two-factor interaction averages for corn yield, moisture, N, and grain N removal and leaf N in 1985

Source		Grain Yield	Grain Moisture	Grain N	Grain N removed	Leaf N
		bu/A	------- %	-------	lb/A	%
MAIN FACTORS						
Sequence						
Cont. corn (grain)		134.1	27.3	1.34	86.3	2.12
Cont. corn (silage)		138.8	27.4	1.37	90.5	2.15
Sb-C		149.0	27.0	1.33	94.4	2.26
Wht-C		158.1	27.3	1.38	103.5	2.41
Sb-C-C*		141.6	26.8	1.31	89.8	2.09
Signif. Level (%):		99	64	90	99	99
BLSD(.10) :		8.7	---	.05	6.6	.08
BLSD(.05) :		10.2	---	---	7.8	.09
N Rate (lb/A)						
0		99.5	27.9	1.17	55.5	1.47
40		130.4	26.8	1.21	75.0	1.84
80		152.2	26.8	1.32	95.0	2.23
120		158.1	27.2	1.43	106.6	2.44
160		163.4	27.1	1.46	112.3	2.61
200		162.4	27.1	1.48	113.1	2.65
Signif. Level (%):		99	99	99	99	99
BLSD(.10) :		3.4	.3	.02	2.4	.04
BLSD(.05) :		4.0	.3	.02	2.7	.05
Hybrid						
P 3906		138.4	24.7	1.45	96.4	2.21
P 3732		150.2	29.6	1.24	89.4	2.20
Signif. Level (%):		99	99	99	99	36
INTERACTIONS						
Sequence x N Rate						
CC(g)	0	87.4	28.1	1.18	49.3	1.46
	40	115.6	26.7	1.14	62.0	1.61
	80	139.6	27.0	1.31	85.9	2.13
	120	150.2	27.5	1.46	103.0	2.38
	160	155.6	27.2	1.46	107.5	2.57
	200	156.4	27.2	1.50	110.2	2.59
CC(s)	0	102.5	28.0	1.20	57.9	1.38
	40	124.4	27.1	1.21	71.1	1.81
	80	145.8	27.0	1.33	91.6	2.16
	120	150.2	27.3	1.47	104.1	2.43
	160	154.0	27.7	1.48	107.3	2.54
	200	155.9	27.2	1.51	110.8	2.58
Sb-C	0	105.9	27.8	1.16	58.1	1.46
	40	139.6	26.8	1.20	79.1	2.06
	80	155.2	26.4	1.31	95.6	2.33
	120	161.7	27.2	1.43	109.3	2.48
	160	166.1	26.8	1.44	113.1	2.57
	200	165.2	26.9	1.43	111.3	2.68
Wht-C	0	121.1	27.7	1.20	69.1	1.78
	40	153.5	27.2	1.37	99.1	2.17
	80	169.9	27.0	1.38	110.6	2.41
	120	166.6	27.5	1.41	110.5	2.57
	160	168.6	27.0	1.45	114.9	2.73
	200	169.0	27.5	1.46	116.6	2.77

Source		Grain Yield	Grain Moisture	Grain N	Grain N removed	Leaf N
		bu/A	------- % -------		lb/A	%
Sb-C-C*	0	80.3	27.8	1.13	43.0	1.27
	40	118.7	26.5	1.13	63.3	1.54
	80	150.7	26.7	1.28	91.1	2.11
	120	161.6	26.5	1.39	105.8	2.35
	160	172.9	26.6	1.46	118.8	2.64
	200	165.6	27.0	1.49	116.4	2.64
Signif. Level (%):		99	08	99	99	99
BLSD(.05) :		9.0		0.05	5.8	0.14
Sequence x Hybrid						
CC(g)	3906	128.1	24.7	1.45	89.3	2.18
	3732	140.2	29.8	1.23	83.3	2.07
CC(s)	3906	133.2	24.7	1.46	93.4	2.16
	3732	144.4	30.0	1.27	87.6	2.14
Sb-C	3906	141.6	24.5	1.43	97.2	2.27
	3732	156.3	29.5	1.22	91.7	2.26
Wht-C	3906	153.2	25.0	1.49	108.4	2.36
	3732	163.0	29.6	1.27	98.6	2.45
Sb-C-C*	3906	136.0	24.5	1.42	93.6	2.08
	3732	147.2	29.2	1.20	85.9	2.10
Signif. Level (%):		49	94	25	77	99
BLSD(.10) :		---	.4	---	---	.06
BLSD(.05) :		---	---	---	---	.08
N rate x Hybrid						
0	3906	97.5	25.1	1.26	58.3	1.48
	3732	101.4	30.7	1.09	52.6	1.45
40	3906	125.8	24.2	1.31	78.5	1.86
	3732	135.0	29.5	1.11	71.4	1.82
80	3906	146.7	24.5	1.43	99.3	2.25
	3732	157.8	29.2	1.21	90.6	2.21
120	3906	150.5	24.9	1.55	110.0	2.41
	3732	165.6	29.5	1.32	103.1	2.47
160	3906	155.7	24.8	1.57	115.3	2.60
	3732	171.2	29.3	1.35	109.3	2.62
200	3906	154.3	24.8	1.60	116.7	2.66
	3732	170.5	29.5	1.36	109.4	2.64
Signif. Level (%):		99	99	99	15	50
BLSD(.10) :		3.3	.3	.02	---	---
BLSD(.05) :		3.9	.4	.03	---	---
Seq. x N rate x Hybrid						
Signif. Level (%):		78	08	03	23	27
CV(%) :		5.4	2.8	3.9	6.4	6.7

* = Position in sequence for which measurements taken.

Contrary to 1984, the sequence x hybrid interaction was not significant indicating that the two hybrids behaved identically across all sequences. On the other hand, a highly significant N rate x hybrid interaction was found. At the 0-lb N rate only a 3.9 bu/A advantage was shown for P3732. As the N rates increased, yield advantages for P3732 increased up to a maximum of 16.2 bu/A at the 200-lb rate when averaged over sequences. No three-factor interaction was found.

Corn yield responses to N with each of the sequences did not appear to show any consistent relationship to the residual soil NO_3-N levels shown in Table 1. This is consistent with past years.

In summary, corn yields (averaged over hybrids) from the 160-lb rate were approximately 8% higher when following either soybeans or wheat compared to continuous corn (grain or silage). This advantage was slightly below the advantages shown in previous dry years. Also, contrary to reports from Purdue University, P3732 continued to respond to increasing N rates up to 160 lb N/A. This same N rate also maximized the P3906 yield when averaged over sequences.

Grain Moisture

Grain moisture at harvest was unaffected by crop sequence but was reduced from the 0-lb rate by all rates $\geq$ 40 lb N/A. The shorter season hybrid (P3906) had significantly less moisture.

Interactions between crop sequence and N rate or hybrid were not significant at the 95% level. The highly significant interaction between N rate and hybrid was due to the greater difference in grain moisture between the two hybrids at the 0-lb rate (5.6%) compared to differences (<4.7%) at N rates of 80-lb or more.

Grain N

Grain N concentrations were not influenced by the crop sequence when averaged over N rates and hybrids, but were increased signficantly by N rates up through 160 lb/A when averaged over sequences and hybrids. The P3906 hybrid averaged 0.21% higher grain N or 1.3% higher protein than P3732 when averaged over sequence and N rate. The significant sequence x N rate interaction was due to the higher N rate (160-lb) required to optimize grain N with the Sb-C-C rotation compared to the other sequences where 120 lb N/A was adequate. Also, grain N was lowest with the 0-lb N rate when in the Sb-C-C rotation. The N response curve was least when corn followed wheat. No sequence x hybrid interation was found. The significant N rate x hybrid interaction was due to the greater difference in grain N concentrations between the two hybrids as the N rate increased.

Grain N removed

Nitrogen removed in the grain crop was closely associated with both grain yield and grain N concentration. Highest grain N removal was when wheat was the previous crop, when the 160-lb N rate was applied, and when P3906 was grown even though grain yields were higher with P3732.

Nitrogen efficiency, as measured by grain N removed divided by fertilizer application rate, averaged 45, 38, 43, 52, and 47% for the N rates giving the highest yields (statistically) for the CC(g), CC(s), C-Sb, C-W, and Sb-C-C sequences, respectively. At the N rates where yields were maximized economically, the efficiency values were 36, 31, 34, 52, and 47%, respectively. Efficiency was consistently maximized at 60, 52, and 47% for the 80, 120, and 160-lb N rates, respectively, with the Sb-C-C rotation.

Leaf N

Concentrations in the earleaf at silking were significantly higher when corn followed either soybeans or wheat compared to following corn when averaged over N rates and hybrids. Contrary to 1984, leaf N was not different between the two hybrids when averaged over sequences + N rates. The significant interaction between sequence and N rate was due to the much higher N concentration with the 0-lb N rate in the C-W sequence compared to the other sequences. The 160-lb N rate maximized leaf N concentration at between 2.54% and 2.73% N for all crop sequences. When averaged over N rates, leaf N of P3732 was lower when grown in the CC(g) sequence but was higher than P3906 when grown in the C-W sequence; hence, the significant interaction. A difference between the two hybrids was not found when grown in the CC(s), C-Sb, and Sb-C-C sequences. No N rate x hybrid interaction was found.

Silage production

Measurements were taken from the CC(s) crop sequence to determine fodder yield, fodder N concentration, fodder N uptake, silage yield, and total N uptake. Data shown in Table 4 indicate a significant effect of N up to the 120-lb rate on fodder yield. Similar to 1984, fodder yield of P3732 was significantly greater than P3906. Fodder N concentration was maximized at the 160-lb rate and contrary to 1984 was signficantly higher for P3906. Fodder N uptake was highest at the 160-lb N rate with no difference between hybrids.

Silage yields were increased significantly by N rates up to 120 lb/A and by the P3732 hybrid (similar to 1984). Total N removed in the silage was increased with increasing N rates up through 160 lb/A. More N was removed by the P3906 hybrid than by P3732. N efficiency with P3906 fertilized at the 160-lb rate was 58%.

Table 4. Silage production as influenced by N rate and hybrid in a silage corn rotation at Waseca, 1985.

N rate	Hybrid	Fodder Yield	Fodder N	Fodder N Uptake	Silage Yield	Silage N Removal
lb/A		T DM/A	%	lb N/A	T DM/A	lb N/A
0	3906	1.82	.41	14.9	4.38	65.1
	3732	2.05	.33	13.7	4.53	55.3
40	3906	1.91	.40	15.3	4.90	76.6
	3732	2.48	.33	16.9	5.52	70.6
80	3906	2.65	.43	22.7	6.53	111.5
	3732	2.84	.42	24.1	6.93	101.3
120	3906	2.74	.58	31.4	7.05	141.4
	3732	3.12	.54	33.2	7.64	133.2
160	3906	2.63	.72	37.9	6.90	157.4
	3732	2.91	.66	38.3	7.41	146.1
200	3906	2.57	.67	33.8	6.86	156.2
	3732	3.02	.62	37.5	7.62	145.8
Individual Factors						
N rate (lb/A)						
0		1.93	.37	14.3	4.46	60.2
40		2.20	.37	16.1	5.21	73.6
80		2.75	.43	23.4	6.73	106.4
120		2.93	.56	32.3	7.34	137.3
160		2.77	.69	38.1	7.15	151.7
200		2.80	.64	35.6	7.24	151.0
Signif. Level(%)1/:		99	99	99	99	99
BLSD(.05) :		.20	.06	3.8	.60	12.1
Hybrid						
3906		2.39	.53	26.0	6.10	118.0
3732		2.74	.48	27.3	6.61	108.7
Signif. Level(%)1/:		99	97	79	99	99
N rate x Hybrid IA:1/		60	06		44	03
CV (%) :		8.7	16.	14.	5.8	6.4

1/ Probability level of significance

Soybean production

To determine if N from the 1984 application to corn influenced the 1985 soybean yields, soybeans from the 0-and 200-lb N treatments were harvested. The data in Table 5 indicate no effect from the previous year's N treatment on either soybean yield or seed moisture at harvest.

Table 5. Soybean yield and moisture as influenced by N applied to corn in 1984.

N rate	Seed Yield	Seed Moisture
(lb/A)	bu/A	%
0	52.2	13.9
200	51.7	14.0
Signif. Level (%):	57	63
CV (%) :	1.8	1.1

Summary - 1985

Corn grain yields averaged about 8% higher when corn followed either soybeans or wheat compared to continuous corn (grain or silage). Highest yields with minimum N input were found when corn followed wheat and were maximized at the 80-lb N rate. Yields with both P3732 and P3906 were maximized at the 160-lb N rate with the CC(g), CC(s), C-Sb, and Sb-C-C crop sequences. Grain N concentrations and grain N removal were significantly higher with the P3906 hybrid. Leaf N at silking was maximized at between 2.54% and 2.73% with the 160-lb rate for all crop sequences. Soybean production was not affected by N application to the previous corn crop.

ELEVEN-YEAR YIELD SUMMARY

Average corn yields over this 11-year period have been optimized with 175, 140, and 120 lb N/A for the continuous corn, corn-soybean, and corn wheat sequences, respectively. At these N rates, yields for corn following soybeans and wheat were 17 and 14% higher than for continuous corn.

Table 6. Effect of previous crop on corn response to N from 1975-1985 at Waseca.

	Previous Crop		
N rate	Corn(g)	Soybeans	Wheat
lb N/A	-----------	bu/A	------------
0	76	110	106
40	100	134	132
80	115	146	147
120	124	152	150
160	131	157	152
200	134	157	154

SPLIT APPLICATION OF N FOR CORN ON A WEBSTER SOIL

Waseca, 1985

G. W. Randall and P. L. Kelly

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

EXPERIMENTAL PROCEDURES

A poorly drained Webster clay loam soil with lateral tile lines at 75-foot spacings was the experimental site. Corn, which had been fall moldboard plowed, was the previous crop. Soil tests of the site showed a pH = 6.7, OM = High, Bray P_1 = 52 lb/A (VH), and exchangeable K = 416 lb/A (VH).

Ten N treatments were applied in a randomized, complete-block design with six replications (Table 1). Each plot measured 10' wide (4-30" rows) by 60' long. Split treatments consisted of a 1/3-rate applied preplant with the remaining 2/3 sidedressed. The preplant treatments were applied on May 9. Anhydrous ammonia (AA) was injected while the urea-ammonium nitrate (UAN) was broadcast applied on the soil surface. Immediately afterwards the entire experimental area was field cultivated.

Corn (Pioneer 3906) was planted at 29900 ppA on May 10. No starter fertilizer was used. Furadan was used at a rate of 1 lb(a.i.)/A to control rootworms. Weeds were chemically controlled with a preemergence application of Lasso (3½ qt./A) plus Bladex (3½ qt./A). Rootworm and weed control was excellent.

The sidedress portions of the split treatments were applied at the 8-leaf stage (June 21). The AA was injected while the UAN was applied in bands to the soil surface using a bicycle sprayer with no. 55 orfices. Both materials were applied mid-way between the rows. The UAN was not incorporated. No rain occurred in the next 4 days, but was followed by 0.55" on the fifth day after application.

Ten randomly selected leaves opposite and below the ear were taken at silking (July 25). Stover and silage yields were obtained at physiological maturity by hand harvesting 15' of row. Grain yields were determined on October 16 by harvesting the center two rows with a modified JD 3300 plot combine. Chemical analyses on the leaves, stover, and grain were performed by the Research Analytical Laboratory, University of Minnesota.

RESULTS

Leaf N

Severe N deficiency symptoms were very apparent for the lower N rates and the sidedress UAN treatments at the tasseling stage. Leaf N concentrations given in Table 1 show all N treatments with significantly more N than the control. Factorial comparisons of the treatments show a linear response to N rate when averaged over source-time of application. When averaged over N rates significantly less leaf N was found with split applications (especially with UAN) compared to the single preplant application. The highly significant interaction between N rate and N time-source (P = 99% level) is shown by the lack of response with the 180 lb AA sidedress treatement. The severe N deficiency as shown by the split-applied UAN treatments was caused by the dry conditions between the June 21 application and tasseling. Only 0.87" of rain fell during this period and apparently was not sufficient to move the surface-applied N down into the active root zone. This positional unavailability was much less evident with the split-applied AA which was injected about 7" deep. Apparently this N was nitrified and moved into the root system.

Table 1. Leaf N, stover N, stover yield, and final population as influenced by split N application.

Nitrogen[1/] Rate	Time	Source	Leaf N	Stover N	Stover Yield	Final population
lbN/A			%	%	TDM/A	ppA x 10^{-3}
0	--	CHECK --	1.22	.38	1.74	28.9
60	PP	AA	1.92	.42	2.61	29.3
120	"	"	2.24	.42	2.71	30.2
180	"	"	2.57	.58	3.12	28.8
60	1/3PP+2/3SD	UAN(PP)+AA(SD)	1.92	.40	2.50	28.8
120	"	"	2.32	.50	2.68	29.3
180	"	"	2.25	.51	2.81	29.2
60	"	UAN	1.46	.41	2.51	28.7
120	"	"	1.61	.50	2.69	29.2
180	"	"	1.88	.52	2.69	28.7
Signif. Level (%):			99	99	99	42
BLSD (.05) :			.14	.06	.28	
CV (%) :			6.9	12.	9.8	4.2
FACTORIAL COMPARISONS						
Main Factors						
N Rate (lb/A)						
60			1.77	.41	2.54	28.9
120			2.06	.48	2.69	29.6
180			2.24	.54	2.87	28.9
Signif. Level (%):			99	99	99	79
BLSD (.05) :			.08	.04	.17	
N Time-Source (Method)						
PP - AA			2.24	.48	2.82	29.5
PP/SD - UAN/AA			2.16	.47	2.66	29.1
PP/SD - AA			1.65	.48	2.63	28.8
Signif. Level (%):			99	7	92	67
BLSD (.05) :			.08			
Interaction						
				Significance Level (%)		
N Rate x N Time-Source			99	98	64	23

[1/] PP = preplant, SD = sidedress applied at the 8-leaf stage.

Stover N

Nitrogen concentrations in the stover at physiological maturity were increased linearly by the N rates but were not different between the single and split applications (Table 1). The highly significant interaction between N rate and N time-source (P = 98% level) was due to the single preplant application at the 120-lb rate which for some unexplainable reason did not respond over the 60-lb rate. These results indicate that the sidedress application of UAN became available to the plants after silking due to the above normal rainfall during August and September.

Stover Yield

Stover yield was increased significantly over the check by all of the N treatments (Table 1). Highest stover yields were obtained at the 180-lb rate regardless of source or time of application. Slightly higher yields were found with the single preplant application than with the split applications (P = 92% level). No difference was observed between the sidedress applied AA vs UAN.

Final Population

None of the treatments affected the final population (Table 1).

Grain Yield

Grain yields were increased significantly over the control by all N treatments (Table 2). Highest yields were obtained at the 180-lb rate for all application methods. When averaged over N rates, there was no difference between the single preplant and the split application when AA was the sidedressed material. However, at the 120-lb rate the split application with AA gave a significantly higher yield than the single preplant application. Yields were approximately 10% lower when UAN was the sidedressed material. This more than likely was due to the dry weather causing the positional unavailability described under Leaf N.

Grain Moisture

Grain moisture at harvest was reduced by all N treatments and was lowest with the 120- and 180-lb N rates (Table 2). Moisture differences were not found among the N source-time of application treatments.

Grain N

Grain N was increased significantly by all N treatments except the 60-lb single preplant application (Table 2). A linear grain N response was obtained with increasing N rate when averaged over methods of application. Split application of both N sources resulted in significantly higher levels of N in the grain than the single preplant application. The significant interaction between N rate x method of application was due to the 120-lb split application using AA which showed a grain N level higher than the other 120-lb treatments and not less than the 180-lb treatments.

Grain N removal

Grain N removal (product of grain yield times grain N concentration was increased significantly by all N treatments (Table 2). Highest grain N removals were associated with the 180-lb rate with the single application and with the 120 and 180-lb rates with the split application when AA was the sidedressed material. When averaged over N rates, highest N removal was found with the spilt application using AA.

Nitrogen efficiency based on grain N removal minus that removed by the check averaged 60, 49, and 40% for the 60, 120, and 180-lb rates, respectively. When averaged over N rates, methods of application ranked according to highest efficiency were: split with AA (51%) > single (45%) = split with UAN (43%).

Silage Yield

Similar to grain yields, silage yields were increased significantly by all N treatments (Table 2). Highest silage yields were obtained with the 180-lb rate and with the single preplant application. Silage yields were significantly lower with the split application when UAN was sidedressed.

Total N Uptake

Total N uptake by the corn can be calculated from multiplying the stover N concentration times stover yield and adding it to grain N removal. Similar to grain N removal total N uptake was highest when the 180-lb rate was applied as either a single preplant application or as a split application using AA. When averaged over N rates, total N uptake was highest with the spilt application using sidedressed AA.

Nitrogen efficiency based on total N uptake minus that removed in the check averaged 73, 59, and 50% for the 60, 120, and 180-lb rates, respectively. When averaged over N rates, efficiency was 61, 57, and 53% for the split application with AA, single application, and split application with UAN, respectively.

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

Nitrogen Rate	Nitrogen Time	Nitrogen Source	Grain Yield	Grain H_2O	Grain N	Grain N Removal	Silage Yield	Total N Uptake
lb/A			bu/A	---- % ----		lb/A	TDM/A	lb/A
0	--- CHECK ---		66.2	30.7	1.18	36.6	3.73	49.9
60	PP	AA	119.6	29.2	1.24	70.5	6.32	92.5
120	"	"	144.5	28.4	1.32	90.1	6.95	113.2
180	"	"	157.0	28.2	1.50	111.9	7.81	148.1
60	1/3PP+2/3SD	UAN+AA	119.9	29.4	1.32	75.0	6.20	95.1
120	"	"	152.0	28.1	1.50	107.5	7.04	134.0
180	"	"	157.0	28.2	1.50	111.8	7.27	140.4
60	"	UAN	113.5	29.2	1.34	72.2	6.00	93.0
120	"	"	132.2	28.2	1.43	89.4	6.66	116.4
180	"	"	144.9	29.0	1.52	104.2	6.86	132.2
Signif. Level (%):			99	99	99	99	99	99
BLSD (.05) :			6.8	0.8	0.07	7.0	0.50	8.9
CV (%) :			5.0	2.6	5.1	7.7	7.3	7.7
FACTORIAL COMPARISONS								
Main Factors								
N Rate (lb/A)								
60			117.7	29.3	1.30	72.6	6.17	93.5
120			142.9	28.2	1.41	95.7	6.89	121.2
180			153.0	28.5	1.51	109.3	7.31	140.2
Signif. Level (%):			99	99	99	99	99	99
BLSD (.05) :			4.0	0.5	0.04	4.1	0.30	5.3
N Time - Source (Method)								
PP - AA			140.4	28.6	1.36	90.8	7.03	117.9
PP/SD - UAN/AA			143.0	28.6	1.44	98.1	6.84	123.2
PP/SD - UAN			130.2	28.8	1.43	88.6	6.51	113.9
Signif. Level (%):			99	37	99	99	99	99
BLSD (.05) :			4.1		0.04	4.4	0.33	6.0
Interaction								
					Significance Level (%)			
N Rate x N Time-Source			83	50	99	99	63	99

CONCLUSIONS

Based on this 1-yrs data corn yields were not improved significantly by split applications of N on this Webster soil. Split applications with 2/3 of the N applied at the 8-leaf stage showed decreased leaf N concentrations at silking but resulted in higher grain N concentrations than the single preplant application. Grain and silage yields were consistently lower with the split applications of UAN. The abnormally dry period from May thru late July undoubtedly affected these results and pointed to the need for injecting sidedress applications of N.

NITROGEN SOURCES FOR CORN WITH CONSERVATION TILLAGE IN SOUTHERN MINNESOTA

1985

G. W. Randall and C. Zadak

Conservation tillage, which leaves plant residues on the soil surface, is frequently being practiced in southern Minnesota. These residues have been shown to affect N losses. Hence, best management practices, including proper N sources, are necessary to minimize loss of N and maximize economic return. The purpose of this study was to evaluate various N sources for corn production with conservation tillage on two contrasting soils in southern Minnesota.

EXPERIMENTAL PROCEDURES

Two sites which had been planted to corn in 1984 were selected for this study. One location was on a Mount Carroll silt loam (Mollic Hapludalf) on the Roger Kleese 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 (Typic Haplaquoll) 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 Co. site consisted of fall chisel plowing and then spring field cultivating prior to planting. The site in Waseca Co. was ridge-planted in both 1984 and 1985. Soil tests for the Goodhue and Waseca sites follow: pH = 6.2 and 7.1; Bray extractable P_1 = 48 and 42 lb/A (both Very High); exchangeable K = 374 and 427 lb/A (both Very High); and extractable SO_4 - S = 7 and 8 ppm (both Medium), respectively, for the two locations. Nitrate-N totaled 130 lb/A in the 0-5' profile (83 lb NO_3 - N/A in 0-3' profile) at the Goodhue Co. site. Surface coverage by plant residues averaged 30 and 38% at the two sites, respectively. Ridge height averaged 5.2 inches at the Waseca site.

Sixteen N treatments were replicated three times at the Goodhue site while 13 treatments were replicated five times at the Waseca site. A randomized, complete-block design was used at each site. Each plot measured 10' wide (4-30" rows) x 35' long in Goodhue County and 10' wide x 60' long in Waseca County.

Corn (Pioneer 3737) was planted with a John Deere Max-Emerge planter at a population of 27700 plants/acre on May 2 in Goodhue Co. and on May 8 in Waseca Co. Excellent weed and corn rootworm control was obtained with proper chemicals at both sites.

Nitrogen treatments were broadcast applied on the soil surface on May 6 in Goodhue Co. and on May 8 in Waseca Co. Rainfall in the 10-day period following N application in Goodhue Co. totaled 0.48 inch with 0.08" on the 5th day and 0.23" on the 8th day following application. At Waseca, 1.01" rain occurred in the 10-day period with .06" on the 3rd day, .07" on the 4th, .26" on the 6th, and .50" on the 8th day following application. Three quarters of the N (90 lb/A) for the split application was sidedress applied on the soil surface at the 7-leaf state (June 12) at Goodhue Co. Two days later 0.38" of rain fell to dissolve the AN into the surface soil.

Ten randomly selected leaves opposite and below the ear were taken at silking for 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 stover and grain analyses were conducted on samples gathered at harvest. Chemical analyses were performed by the Research Analytical Laboratory, University of Minnesota.

Soil samples were taken at 1-foot increments to a depth of 8' from the 0, 60, 120, 180, and 240-lb AN treatments on November 12 at the Goodhue Co. site. These samples were dried, ground, and analyzed for NO_3 - N to determine the carryover and accumulations of NO_3^- in the soil profile.

RESULTS AND DISCUSSION

Rainfall during the 1985 growing season was considerably below normal in Goodhue Co. and slightly below normal in Waseca Co. (Table 1). Conditions were exceptionally dry during May, June, and July; rain did not occur in sufficient amounts immediately after application to leach the surface applied N into the soil profile. Thus, some volatilization could have occurred in the first 5 days at both locations.

Table 1. Rainfall during the May thru October growing season in Goodhue and Waseca Counties.

Month	Location	
	Goodhue	Waseca
	--------- inches	--------
May	1.58	1.81 (-1.95)[1/]
June	1.32	2.56 (-1.92)
July	1.64	2.51 (-1.51)
August	4.35	5.21 (+1.22)
September	3.09	5.40 (+2.04)
October	1.17	2.71 (+0.63)
TOTAL	13.15	20.20 (-1.49)

1/ Departure from 30-year normal.

Goodhue County

Because of the moderate levels of NO_3^- in the soil profile and the adverse growing conditions during the season, corn response to the N treatments was minimal (Tables 2 and 3). These small differences made it difficult to clearly establish the effects of the N sources and their interaction with rate of N application.

Nitrogen Concentrations

Leaf, stover, and grain N concentrations were generally increased over the control by the 120-lb N/A application rate but not by the 60-lb rate (Table 2). When averaged over N rate, differences among the N source were not significant at the P=95% level. At the 60-lb rate leaf and grain N were lowest with the urea + AS treatment. The 120-lb N rate averaged over the six sources increased leaf N and grain N significantly (P=99% level). Increasing the application rate of AN to 240-lb N/A increased leaf, stover, and grain N significantly. However, the split application of AN did not improve the N concentrations in the plant tissure over the single, preemergence application.

Significant (P = > 94% level) interactions between N source and N rate were found for leaf N, stover N, and grain N. The 120-lb rate resulted in a large increase in leaf N when the N source was urea + AS, modest increases with AN, AS, UAN + S, and urea, and no increase when UAN was used. Stover N was increased with the higher N rate when AS, UAN + S, and urea + AS were used but was unchanged when UAN or urea were used. Grain N was also increased substantially by the 120-lb rate of urea + AS, but was unaffected by N rate when UAN, UAN + S, or urea were used. Explanations for these significant interactions are not readily apparent at this time.

Yields

Although significant differences (P = 95% level) in stover, silage, and grain yields occurred among the 16 treatments, few yields were increased significantly over the check (Table 3). When averaged over N rates, highly significant differences were found among the N sources. Silage yields were lowest with the AS and urea treatments while grain yields were significantly lower with the AS and urea + AS treatments. For some unknown reason the yields from these treatements did not differ from the check. The 120-lb N rate significantly increased silage and grain yield over the 60-lb rate. Additional yield increases with the 180 and 240-lb rates were not found.

Significant (P = > 93% level) interactions between N source and rate of application were also found for stover, silage, and grain yields (Table 3). These were primarily due to the large yield increases with the 120-lb N rate of urea or urea + AS over the 60-lb rate while yield differences between the two N rates were minimal when using AN, AS, or UAN.

Table 2. Nitrogen concentration in corn tissue and final population as affected by N source and rate of application in Goodhue Co.

N Treatment: Source[1/]	Rate	N concentration in: Leaf	Stover	Grain	Final population
	lb N/A	%	%	%	ppA x 10^{-3}
CHECK	0	1.95	.60	1.32	24.0
AN	60	2.28	.83	1.37	24.5
"	120	2.35	.72	1.44	24.9
"	180	2.40	.91	1.47	24.4
"	240	2.65	.90	1.54	22.3
"	120 split	2.50	.82	1.44	23.1
AS	60	2.03	.63	1.36	23.9
"	120	2.26	.76	1.42	22.4
UAN	60	2.23	.76	1.43	23.8
"	120	2.29	.77	1.42	23.8
UAN+S	60	2.01	.67	1.40	24.0
"	120	2.25	.78	1.41	24.0
Urea	60	1.97	.81	1.38	24.3
"	120	2.20	.80	1.38	25.2
½UR+½AS	60	1.70	.73	1.33	25.0
"	120	2.38	.85	1.47	23.2
Signif. Level (%):		99	99	99	42
BLSD (.05) :		0.29	.11	0.10	
CV (%) :		7.8	8.4	3.8	6.3
INDIVIDUAL FACTORS					
N Source (60+120 lb)					
AN		2.32	.78	1.41	24.7
AS		2.14	.69	1.39	23.2
UAN		2.26	.76	1.42	23.8
UAN+S		2.13	.72	1.41	24.0
Urea		2.09	.80	1.38	24.7
½UR+½AS		2.04	.79	1.40	24.1
Signif. Level (%):		91	94	50	53
BLSD (.10) :		0.21	.08		
N Rate (lb/A)					
60		2.04	.74	1.38	24.2
120		2.29	.78	1.43	23.9
Signif. Level (%):		99	93	99	48
Interaction		Significance Level (%)			
Source x Rate		94	98	97	43

1/ AN = ammonium nitrate, AS = ammonium sulfate, UAN = urea-ammonium nitrate, UAN + S = UAN + 3% S as AS(25-0-0-3), and UR = urea.

2/ 30 lb at preemergence (May 6) and 90 lb at 7-leaf stage (June 12).

Table 3. Corn yields and N uptake as influenced by N source and rate of application in Goodhue Co.

N Treatment		Yields			Ear	N Uptake	
Source	Rate	Stover	Silage	Grain	Moisture	Grain	Total[1/]
	lb N/A	----- TDM/A ----		bu/A	%	--- lb N/A ----	
CHECK	0	1.98	5.62	137.0	40.7	86.0	109.7
AN	60	2.17	6.26	152.9	41.3	99.3	135.5
"	120	2.13	6.08	147.8	41.7	100.9	131.6
"	180	2.26	6.41	154.8	41.0	108.0	149.4
"	240	2.26	6.28	149.3	41.0	108.7	149.7
"	120 split	2.26	5.90	136.2	42.7	92.5	129.3
AS	60	2.03	5.62	134.8	40.7	86.4	112.0
"	120	2.16	5.83	137.2	41.3	92.4	125.2
UAN	60	2.34	6.23	145.2	41.0	98.3	134.1
"	120	2.08	6.16	151.7	40.3	102.0	134.0
UAN+S	60	2.16	5.98	143.0	40.3	95.1	124.0
"	120	2.24	6.32	152.7	40.7	102.2	137.0
Urea	60	1.79	5.48	137.8	41.7	89.8	118.6
"	120	2.19	6.33	155.1	40.3	101.6	136.5
½UR+½AS	60	2.04	5.34	123.9	41.7	78.1	107.8
"	120	2.10	6.04	147.3	42.0	102.7	138.3
Signif. Level (%):		96	99	99	97	99	99
BLSD (.05) :		0.35	0.58	15.7	1.6	14.0	17.4
CV (%) :		7.6	5.3	5.9	1.3	8.0	7.9
INDIVIDUAL FACTORS							
N Source (60+120 lb)							
AN		2.15	6.17	150.3	41.5	100.1	133.6
AS		2.10	5.72	136.0	41.0	89.4	118.6
UAN		2.21	6.19	148.4	40.7	100.1	134.1
UAN+S		2.20	6.15	147.8	40.5	98.6	130.5
Urea		1.99	5.90	146.4	41.0	95.7	127.6
½UR+½AS		2.07	5.69	135.6	41.8	90.4	123.1
Signif. Level (%):		80	98	99	95	98	95
BLSD (.05) :			0.40	10.2	1.0	8.4	12.7
N Rate (lb/A)							
60		2.09	5.82	139.6	41.1	91.2	122.0
120		2.15	6.13	148.6	41.1	100.3	133.8
Signif. Level (%):		72	99	99	17	99	99
Interaction				Significance Level(%)			
Source x Rate		95	96	93	79	94	96

1/ Grain + stover

N Uptake

Uptake of N (product of N concentration times either the grain or grain + stover dry matter yield) was increased significantly over the check by most of the 120-lb treatments (Table 3). Grain and total plant uptake of N was highest with the AN and UAN sources and lowest with the AS source when averaged over N rates. Again, the reason for this is not clear. Both grain and total plant uptake were increased by the 120-lb rate over the 60-lb rate. Grain N uptake was not increased by the AN rates greater than 120-lb N/A, whereas, total plant uptake was highest with the 180-lb rate. The significant N source by N rate interaction was due to higher grain and total plant uptake at the 120-lb rate with the AS, UAN + S, urea, and urea + AS sources, while with AN and UAN, uptake was not affected by rate. Reasons for this interaction are not known at this time, but may merely reflect the variability in the data.

Sulfur Concentrations

Even though S applications totaled 138, 69, and 14.4 lb S/A with the AS, UAN + S, and urea + AS treatments, leaf and stover S concentrations were not affected (Table 4). Due to the extremely low variability grain S was increased slightly but significantly by the 69 and 138-lb AS treatments. Sulfur uptake in the grain and the whole plant were not affected by the S treatments. Nitrogen:S ratios ranged from 13.8 to 15.8 for leaves, 10.6 to 11.8 for stover, and from 14.8 to 15.8 for the grain. In all cases, the lowest N:S ratio was with the 138-lb S treatment as AS.

Table 4. Sulfur concentrations and uptake by corn as influenced by N sources in Goodhue Co.

N Source[1/]	Leaf S	Stover S	Grain S	Sulfur Uptake Grain	Sulfur Uptake Total
	%	%	%	lb S/A	lb S/A
AN	.149	.063	.091	6.37	9.05
AS	.164	.072	.096	6.25	9.35
UAN	.155	.069	.091	6.55	9.44
UAN+S	.159	.071	.093	6.69	9.86
Urea	.155	.070	.088	6.46	9.52
½UR+½AS	.159	.072	.094	6.52	9.55
Signif. Level (%):	17	41	98	26	27
BLSD (.05) :			.004		
CV (%) :	8.4	9.9	2.5	5.6	6.5

1/ 120 lb N/A

Residual Nitrate - N

Samples taken to an 8-foot depth after harvest showed a linear increase corresponding to N application rate in NO_3^- remaining in the soil profile (Table 5). In the 0-8' profile an increase of 189 lb NO_3-N was noted with the 240-lb rate over the control The majority of the NO_3^- accumulated in the top 3' with some evidence of movement to 6' with rates of 120-lb and greater.

Table 5. Residual soil NO_3-N in the soil profile in November as influenced by N rate in Goodhue Co.

Profile depth	N Application Rate (lb/A) 0	60	120	180	240
feet	lb NO_3-N/foot				
0-1	14	22	27	52	55
1-2	11	19	43	61	90
2-3	4	18	31	31	47
3-4	12	18	19	16	26
4-5	14	18	22	20	22
5-6	15	16	23	24	20
6-7	16	13	18	18	16
7-8	14	12	14	14	13
Totals					
0-5'	55	95	142	170	240
5-8'	45	41	55	56	49
0-8'	100	136	197	226	289

Nitrogen Budget

A N budget can be obtained by adding the total N uptake shown in Table 4 to the residual NO_3-N shown in Table 5 for each treatment, and then subtracting out the uptake plus residual from the check treatment. From this one can calculate the precent recovery by dividing by the respective N application rate. Using this method, % recovery totaled 103, 99, 92 and 95% for the 60, 120, 180, and 240-lb N rates, respectively. These high recovery rates indicate that very little fertilizer N was lost from the soil or immobilized into the soil organic matter during the 1985 season.

Waseca County

Nitrogen Concentrations

Leaf N was increased significantly over the check by all N treatments except UAN at the 75-lb N rate (Table 6). Grain N was increased significantly by all of the 150-lb treatments and with the AA, AS, and urea sources at the 75-lb N rate. Stover N concentrations were not increased over the check by any of the N treatments due to the high variabililty (CV = 14.0). However, stover N concentrations averaged 40% lower at this site than at the Goodhue site.

When averaged over N rates, leaf N was significantly higher with the AA and AS treatments compared to the UAN and UAN + S treatments with the urea treatments being intermediate. Stover N was not influenced (P = 90% level) while grain N was highest with the AA and AS treatments (P = 92% level). When averaged over the six N sources, leaf and grain N were both increased significantly by the 120-lb N rate. Interactions between N source and N rate were not significant for either leaf or grain N.

Table 6. Nitrogen concentration in corn tissue and final population as affected by N source and rate of application in Waseca Co.

N Treatment		N concentration in			Final
Source[1/]	Rate	Leaf	Stover	Grain	population
	lb N/A		%		ppA x 10^{-3}
CHECK	0	1.68	.39	1.08	26.3
AA	75	2.47	.50	1.24	26.4
"	150	2.62	.42	1.38	26.5
AS	75	2.36	.50	1.28	26.6
"	150	2.54	.48	1.34	26.0
UAN	75	1.92	.40	1.13	27.2
"	150	2.37	.50	1.33	26.5
UAN+S	75	2.04	.41	1.14	26.8
"	150	2.29	.38	1.27	27.2
Urea	75	2.22	.42	1.25	27.2
"	150	2.52	.49	1.32	26.5
½UR+½AS	75	2.16	.46	1.13	26.8
"	150	2.38	.43	1.30	27.2
Signif. Level (%):		99	95	99	3
BLSD (.05) :		0.30	.12	0.13	
CV (%) :		9.3	14.	7.1	5.1
INDIVIDUAL FACTORS					
N Source					
AA		2.54	.46	1.31	26.4
AS		2.45	.49	1.31	26.3
UAN		2.14	.45	1.23	26.0
UAN+S		2.16	.39	1.21	27.0
Urea		2.37	.46	1.28	26.8
½UR+½AS		2.27	.45	1.21	27.0
Signif. Level (%):		99	88	92	18
BLSD (.05) :		0.21			
N Rate (lb/A)					
75		2.20	.45	1.19	26.8
150		2.45	.45	1.32	26.6
Signif. Level (%):		99	19	99	34
Interaction		Significance Level (%)			
Source x Rate		25	91	37	14

[1/] AA = anhydrous ammonia, AS = ammonium sulfate, UAN = urea-ammonium nitrate, UAN + S = UAN + 3% S as AS(25-0-0-3), and UR = urea.

Yields

Grain and silage yields were increased over the check by all of the N treatments (Table 7). Grain moisture at harvest was also decreased significantly by the N treatments. Stover yields were not affected by the treatments.

Table 7. Corn yields and N uptake as influenced by N source and rate of application in Waseca Co.

N Treatment		Yields			Grain	N Uptake	
Source	Rate	Stover	Silage	Grain	Moisture	Grain	Total[1/]
	lb N/A	----- TDM/A ----		bu/A	%	lb N/A	
CHECK	0	1.79	4.80	106.9	25.6	55.1	69.2
AA	75	2.29	6.61	147.9	23.0	87.0	109.9
"	150	2.14	6.61	149.9	22.4	97.6	115.7
AS	75	2.17	6.50	146.5	23.9	88.6	110.1
"	150	2.17	6.56	152.2	24.0	96.6	117.7
UAN	75	2.18	5.82	128.1	24.2	68.9	86.1
"	150	2.26	6.51	148.8	22.8	94.0	116.7
UAN+S	75	2.19	6.35	131.3	24.2	71.0	89.2
"	150	2.29	6.58	145.3	23.8	87.9	105.3
Urea	75	2.14	6.62	140.5	23.4	83.3	101.5
"	150	2.31	6.70	144.8	23.7	90.2	112.7
½UR+½AS	75	2.22	6.34	141.1	24.2	75.7	96.6
"	150	2.19	6.55	143.1	23.4	87.8	106.7
Signif. Level (%):		83	99	99	99	99	99
BLSD (.05) :			0.70	17.7	1.4	15.6	19.5
CV (%) :		9.8	7.5	8.5	3.8	13.	13.
INDIVIDUAL FACTORS							
N Source							
AA		2.21	6.62	148.9	22.7	92.3	112.8
AS		2.17	6.53	149.3	24.0	92.6	113.9
UAN		2.22	6.16	138.4	23.5	81.4	101.4
UAN+S		2.24	6.47	138.3	24.0	79.5	97.2
Urea		2.23	6.66	142.6	23.5	86.7	107.1
½UR+½AS		2.21	6.44	142.1	23.8	81.8	101.6
Signif. Level (%):		1	60	80	93	92	90
BLSD (.10) :					1.0	11.3	14.2
N Rate (lb/A)							
75		2.20	6.37	139.2	23.8	79.1	98.9
150		2.23	6.58	147.3	23.4	92.4	112.5
Signif. Level (%):		33	86	99	90	99	99
Interaction				Significance Level (%)			
Source x Rate		27	27	54	56	42	52

1/ Grain + stover

When averaged over N rate, significant differences (P = 90% level) in stover, silage, or grain yield were not found among the N source treatments. However, grain yields were 10% lower with the two UAN treatments compared to the AA and AS treatments. Grain yields were increased significantly by the 150-lb N rate over the 75-lb rate. Interactions between N source and N rate were not apparent.

N Uptake

Nitrogen uptake in both the grain and total plant (grain + stover) was increased (P = 95% level) over the check by all treatments except UAN at the 75-lb N rate (Table 7). When averaged over N rates, highest N uptake was achieved with the AA and AS sources while UAN + S resulted in lowest uptake. Uptake of N was significantly (P = 99% level) increased by the 150-lb N rate over the 75-lb rate when averaged over N sources. There was no N source by N rate interaction.

Sulfur Concentrations

Sulfur application rates with the AS, UAN + S, and urea + AS treatments totaled 170, 18, and 85 lb S/A, respectively. The 170-lb S rate consistently resulted in highest leaf, stover, and grain S (Table 8). Grain S was also increased with the 85-lb rate. The 18-lb rate applied with UAN did not affect leaf, stover, or grain S concentrations. Sulfur uptake in the grain and the total plant was only increased with the AS treatment (170 lb S/A). Nitrogen:S ratios ranged from 14.3 to 16.1 for leaves, 8.3 to 10.4 for stover, and 13.5 to 15.7 for grain. In all cases lowest N:S ratios were found with the 85 and 170-lb S rates as AS. Slight reductions in the N:S ratio were noted with the UAN + S treatment.

Table 8. Sulfur concentrations and uptake by corn as influenced by N sources in Waseca Co.

N Source[1/]	Leaf S	Stover S	Grain S	Sulfur Uptake Grain	Sulfur Uptake Total
	%			lb S/A	
AA	.163	.046	.088	6.23	8.22
AS	.178	.058	.098	7.10	9.61
UAN	.150	.048	.086	6.10	8.30
UAN+S	.144	.044	.088	6.04	8.08
Urea	.157	.049	.087	5.93	8.20
½UR+½AS	.154	.052	.096	6.50	8.77
Signif. Level (%):	94	99	99	91	92
BLSD (.10) :	.021	.006	.004	0.82	1.11
CV (%) :	9.2	9.0	3.8	8.8	8.8

1/ 150 lb N/A

SUMMARY

Although differences did exist among the N sources when averaged over N rates, these differences did not show a consistent advantage for any one particular source. In Goodhue Co. slight advantages appeared with AN and UAN, while AS resulted in the poorest yields. In Waseca Co., highest yields and N uptake were obtained with AA and AS while UAN resulted in the lowest yields. Corn production was maximized by the 120-lb rate in Goodhue Co. and by the 150-lb rate in Waseca Co.

Corn production was not enhanced by the sulfur in the N sources although S uptake was increased at Waseca. A nitrogen budget calculated from the plant N uptake and residual soil NO_3^- data in Goodhue Co. indicated N recovery to range from 92 to 103%, indicating little N loss in 1985.

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UAN AND S PLACEMENT FOR CORN WITH RIDGE TILLAGE IN SOUTHERN MINNESOTA

1985

G. W. Randall and C. Zadak

Ridge tillage is a conservation tillage method which is gaining popularity in the Corn Belt. With this system corn is planted on a previously built ridge which has had the residue removed by the planting operation. Thus, most of the plant residue remains in the valleys between the rows or on the ridge edges. Urea-ammonium nitrate (UAN) is also becoming a popular source of N in southern Minnesota. However, volatilization losses of N from surface-applied UAN to residue covered soils have frequently been reported in the literature. Recently North Dakota State University scientists reported that additions of ATS (ammonium thiosulfate) with UAN have reduced volatilization losses from surface-applied UAN. The purpose of this study was to determine the effect of placement of UAN (28% N) with and without sulfur (S) in a ridge tillage system in two southern Minnesota soils.

EXPERIMENTAL PROCEDURES

Two sites which had been ridge-planted to corn in 1984 were selected for this study. One location was on a Mount Carroll silt loam (Mollic Hapludalf) on the Paul Nesseth 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 (Typic Haplaquoll) 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.

Soil tests for the Goodhue and Waseca sites follow: pH = 6.0 and 7.9; OM = Med. and High; Bray $_1$ extractable P = 78 lb/A (VH) and Olsen's extractable P = 27 lb/A (H); exchangeable K = 297 lb/A(H) and 241 lb/A(MH); and extractable SO_4-S = 7 and 7 ppm (both medium), respectively, for the two locations. Nitrate-N totaled 83 lb/A (Low) in the 0-5' profile (54 lb NO_3-N/A in the 0-3' profile) at the Goodhue Co. site. Surface coverage by plant residues perpendicular to the rows averaged 48 and 33% at the two sites, respectively. Coverage on the ridges averaged 22 and 11% at the two sites, respectively. Ridge height averaged 4.2" at the Waseca site.

Ten N treatments were replicated four times at the Goodhue site and five times at the Waseca site. A randomized, complete-block design was used at each site. Each plot measured 10' wide (4-30") rows x 40' long in Goodhue County and 10' wide x 60' long in Waseca County.

Corn (Pioneer 3737) was planted with a John Deere Max-Emerge planter at a population of 26100 plants/acre on May 1 in Goodhue Co. and at 27700 on May 8 in Waseca Co. Excellent weed and corn rootworm control was obtained with proper chemicals at both sites.

Nitrogen treatments were applied on the soil surface on May 6 in Goodhue Co. and on May 8 in Waseca Co. The broadcast treatments were applied using 8006E nozzles. The 2-cm wide band application to the ridge-top was accomplished using no. 93 orfices. Rainfall in the 10-day period following N application in Goodhue Co. totaled 0.48 inch with 0.08" on the 5th day and 0.23" on the 8th day following application. At Waseca, 1.01" rain occurred in the 10-day period with .06" on the 3rd day, .07" on the 4th, .26" on the 6th, and .50" on the 8th day following application. The sidedress portion of the split application was applied in a band 6" to the side of the row at the 6-leaf stage on June 12 at the Goodhue Co. site and on June 17 at the Waseca Co. site.

Rain (0.36") occurred 2 days later in Goodhue Co. to move the UAN into the soil. The sidedress application was followed immediately by cultivation in Waseca Co.

Ten randomly selected leaves opposite and below the ear were taken at silking for N and S analyses. Fodder and grain yields were obtained at physiological maturity by hand-harvest techniques at the Goodhue location while grain yields were obtained by combine harvesting at Waseca. All stover 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

Rainfall during the 1985 growing season was considerably below normal at both locations. Conditions were exceptionally dry during May, June, and July. Only five 24-hr rainfall events greater than 0.10" occurred during this period in Goodhue Co. while 13 occurred in Waseca Co. Rain did not occur in sufficient amounts immediately after application to leach the surface-applied N into the soil profile. Thus, some volatilization could have occurred in the first 5 days at both locations.

Goodhue County

Due to the dry weather and the apparent carryover of residual N, crop response to the N treatments was limited. Check plot yields surpassed expectations. Moreover, yield response to the N treatments was marginal and was quite variable.

Nitrogen Concentrations

Leaf and stover N concentrations were not affected significantly (P=90% level) from the check by the N treatments (Table 1). Neither N source nor placement affected leaf and stover N concentrations. The significant interaction between N source and placement (P=92% level) was due to the large depression in leaf N (0.40% N) and stover N (0.13% N) when the UAN + ATS treatment was broadcast applied compared to ridge-top applied. The effect of placement was minimal when either UAN or UAN + AS were applied. Leaf N was below the sufficiency level for all N treatments.

Grain N concentrations were higher, probably due to the late season rainfall, and were increased over the check by some of the N treatments. The source of N had no effect on grain N. Although grain N was slightly lower with the broadcast placement and specifically the broadcast UAN + ATS treatment, these differences were not significant at the 90% probability level. Final population was not affected by any of the treatments.

Yields

Stover yields were increased significantly over the check by 4 of the 9 treatments (P=95% level) while silage yields were increased by 5 of the 9 treatments (P=90% level) (Table 2). Grain yields were variable and, thus, were not significantly improved by the N treatments. Neither N source when averaged over placement methods nor placement method when averaged over N sources affected stover, silage or grain yields. The significant (P>90% level) interaction between N source and N rate was due to the increase in stover, silage, and grain yield when UAN was broadcast compared to banded on the ridge-top; whereas, when either AS or ATS was added to the UAN, broadcast application resulted in slightly decreased yields. Because plant population was not affected and phytotoxic symptoms did not appear with the banded ridge-top placement, no explanation for this apparent advantage for broadcast UAN placement can be given.

N Uptake

Uptake of N into the grain (product of N concentration times grain yield) was not influenced significantly by any of the N treatments because of the high variability (CV=12%) (Table 2). Although uptake of N into the total plant (grain + stover) was not increased significantly over the check by any of the N treatments, a significant (P=94% level) N source x placement method interaction did exist. Broadcast application of UAN increased total N uptake over the ridge-top band application, whereas when ATS was added to UAN the broadcast application markedly reduced N uptake. Placement method did not affect N uptake when AS was added to the UAN. Again, the reasons for this are not clear at this time.

Table 1. Nitrogen concentrations in corn tissue and final plant population as affected by placement method of UAN with and without S in Goodhue Co.

N Treatment			N Concentration in			Final
No.	Material[1/]	Placement[2/]	Leaf	Stover	Grain	population
			%			ppA x 10^{-3}
1	CHECK	----	1.92	.57	1.26	24.5
2	Am. Nitrate	Bdct.	2.20	.64	1.39	22.8
3	UAN	Ridge top	2.10	.59	1.40	23.2
4	"	Between rows	2.06	.61	1.34	23.1
5	"	Bdct.	2.11	.65	1.36	25.0
6	"	Split[3/]	2.10	.57	1.35	24.6
7	UAN+AS	Ridge top	2.07	.60	1.40	24.5
8	"	Bdct.	2.19	.66	1.38	23.2
9	UAN+ATS	Ridge top	2.34	.70	1.44	24.7
10	"	Bdct.	1.94	.57	1.34	26.0
Signif. Level (%):			58	58	95	63
BLSD (.05) :					0.12	
CV (%) :			12.	14.	4.8	8.0
ORTHOGONAL COMPARISONS						
N Source						
UAN (trts 3&5)			2.10	.62	1.38	24.1
UAN+AS			2.13	.63	1.39	23.8
UAN+ATS			2.14	.63	1.40	25.4
Signif. Level (%):			5	5	11	64
Placement						
Ridge top			2.17	.63	1.41	24.1
Broadcast			2.07	.63	1.36	24.7
Signif. Level (%):			67	4	89	48
Interaction			Significance Level (%)			
Source x Placement			92	95	48	65

1/ UAN = 28-0-0; UAN + AS = 25-0-0-3 w/S as ammonium sulfate; UAN + ATS = 25-0-0-3 w/S as ammonium thiosulfate.
2/ All materials applied at 120 lb N/A.
3/ 40% on ridge top preemergence + 60% sidedressed in a band 6-8" from row at 6-leaf stage.

Nitrogen efficiency determined by subtracting the grain and total N uptake of the check plots ranged from 10 to 20% for grain N uptake and from 12 to 28% for the total plant N uptake.

Sulfur Concentrations

The addition of 14.4 lb S/A as AS did not increase the S concentrations in the leaf, stover, or grain or S uptake in the grain or in the whole plant (Table 3). Placement of the UAN + ATS in a band on the ridge-top significantly increased leaf S and grain S uptake but did not affect stover or grain S concentration or S uptake by the whole plant. Between 2 and 5% of the applied S was taken up by the plants.

Waseca County

Even though conditions were dry until late July, a good response to the N treatments was found.

Table 2. Corn yields and N uptake as influenced by placement method of UAN with and without S in Goodhue Co.

N Treatment			Ear	Yields			N Uptake	
No.	Material	Placement	moisture	Stover	Silage	Grain	Grain	Total[1/]
			%	---- T DM/A ----		bu/A	---- lb N/A ---	
1	CHECK	----	33.1	1.42	4.92	132.8	79.4	95.7
2	Am. Nitrate	Bdct.	32.2	1.71	5.49	142.4	94.1	116.2
3	UAN	Ridge top	32.6	1.57	5.16	137.8	91.1	109.6
4	"	Between rows	32.6	1.83	5.85	151.5	95.9	118.3
5	"	Bdct.	33.3	1.78	5.88	154.7	99.6	122.9
6	"	Split	32.8	1.92	5.95	153.3	98.2	120.4
7	UAN+AS	Ridge top	33.7	1.93	5.84	147.0	96.9	120.1
8	"	Bdct.	32.8	1.60	5.46	145.9	95.3	116.3
9	UAN+ATS	Ridge top	32.6	1.85	5.88	151.8	104.1	129.7
10	"	Bdct.	32.0	1.72	5.51	143.8	91.5	111.3
	Signif. Level (%):		72	95	94	69	75	88
	BLSD (.05), (.10)*:			0.38	0.73*			
	CV (%) :		2.7	12.	8.6	8.7	12.	12.
	ORTHOGONAL COMPARISONS							
	N Source							
	UAN (trts 3&5)		33.0	1.68	5.52	146.3	95.3	116.2
	UAN+AS		33.3	1.77	5.65	146.4	96.1	118.1
	UAN+ATS		32.3	1.79	5.70	147.8	97.8	120.5
	Signif. Level (%):		91	46	37	7	14	22
	Placement							
	Ridge top		33.0	1.78	5.63	145.5	97.4	119.8
	Broadcast		32.7	1.70	5.61	148.1	95.4	116.8
	Signif. Level (%):		50	65	07	50	37	45
	Interaction				Significance Level (%)			
	Source x Placement		86	94	99	96	89	94

1/ Grain + stover

Plant Height

Because visual phytotoxicity symptoms were apparent with the UAN and UAN + ATS treatments when banded on the ridge, extended leaf heights were measured on 10 random plants per plot on July 2. Plant height was increased significantly (P=95% level) by all of the treatments except UAN + ATS banded on the ridge (Table 4). When averaged over N sources, ridge-top placement significantly reduced plant height compared to broadcast placement.

Nitrogen Concentrations

Leaf and grain N concentrations were increased over the check by all of the N treatments (Table 4). Stover N was increased over the check by 5 of the 9 treatments. Leaf and grain N concentrations were highest with UAN and lowest with UAN + AS when averaged over placement method. Broadcast placement of all three N sources significantly reduced leaf, stover, and grain N concentrations compared to banding the N on the ridge-top. Nitrogen deficiency symptoms were readily evident on the broadcast, between the ridge, and split application treatments at the silking stage. These results suggest that N losses occurred, perhaps through volatilization, with the broadcast and between the row applications. The addition of S as either AS or ATS appeared to enhance the N losses from the UAN.

Table 3. Sulfur concentrations in plant tissue and S uptake as influenced by S source and placement method in Goodhue Co.

N + S Treatment			S Concentration in			S Uptake	
No.	Material[1/]	Placement	Leaf	Stover	Grain	Grain	Total[2/]
			%			lb S/A	
3	UAN	Ridge top	.149	.059	.084	5.46	7.31
5	"	Bdct.	.150	.060	.085	6.20	8.35
7	UAN+AS	Ridge top	.156	.061	.084	5.88	8.22
8	"	Bdct.	.151	.068	.085	5.87	8.03
9	UAN+ATS	Ridge top	.174	.071	.088	6.36	9.00
10	"	Bdct.	.142	.065	.086	5.88	8.13
FACTORIAL ANALYSIS							
N Source							
UAN			.150	.606	.084	5.83	7.83
UAN+AS			.153	.064	.085	5.87	8.12
UAN+ATS			.158	.068	.088	6.12	8.55
Signif. Level (%):			63	70	65	53	72
BLSD (.05) :							
Placement							
Ridge top			.160	.064	.086	5.90	8.17
Broadcast			.148	.064	.085	5.98	8.17
Signif. Level (%):			98	11	7	33	1
Interaction			Significance Level (%)				
Source x Placement			98	52	21	93	88
CV (%):			7.2	16.	5.4	8.3	11.

1/ N applied at 120 lb N/A; S applied at 14.4 lb S/A (25-0-0-3)
2/ Grain + stover

Final Population

Plant population was reduced significantly (5%) by the band application of UAN and UAN + ATS on the ridge (Table 4). Apparently, these applications were concentrated too close to the germinating seedling.

Grain Moisture

Grain moisture at harvest, an indication of plant maturity, was decreased significantly by all of the N treatments (Table 5).

Yields

Stover, silage, and grain yields were increased significantly (P=95% level) over the check by all of the N treatments (Table 5). Compared to the highest yielding AA treatment, grain yields were reduced about 10% and significantly (P=95% level) by the broadcast UAN + AS treatment and both UAN + ATS treatments. Although not as statistically clear as the N concentration data, the yield data show a slight trend toward lower yields with the surface applications of UAN regardless of placement method. The inclusion of S, especially ATS, tended to further decrease yields. These data suggest that N losses occurred, probably from volatilization or immobilization of N.

N Uptake

Both grain and total plant uptake of N were increased by all of the N treatments (Table 5). Uptake of N was significantly reduced when either AS or ATS was added to the UAN when averaged over placement methods. Band application of all three N sources significantly increased N uptake over broadcast application.

Table 4. Plant height, N concentrations in plant tissue, and final plant population as affected by placement method of UAN with and without S in Waseca Co.

N Treatment			Plant	N Concentration in			Final
No.	Material1/	Placement2/	height	Leaf	Stover	Grain	population
			cm	---------- % ----------			ppA x 10³
1	CHECK	----	89	1.69	.35	1.07	26.1
2	An. ammonia	preplant	98	2.57	.51	1.41	26.8
3	UAN	Ridge top	97	2.70	.48	1.43	24.6
4	"	Between rows	100	2.35	.40	1.32	27.0
5	"	Bdct.	105	2.36	.40	1.30	27.1
6	"	Split3/	103	2.35	.42	1.37	26.0
7	UAN+AS	Ridge top	100	2.44	.48	1.35	26.7
8	"	Bdct.	103	2.14	.39	1.19	26.8
9	UAN+ATS	Ridge top	95	2.63	.45	1.37	25.3
10	"	Bdct.	101	2.19	.37	1.21	26.6
	Signif. Level (%):		99	99	99	99	99
	BLSD (.05) :		7	.18	.06	.06	1.5
	CV (%) :		5.2	6.5	11	3.9	4.0
	ORTHOGONAL COMPARISONS						
	N Source						
	UAN (trts 3&5)		101	2.53	.44	1.36	25.8
	UAN+AS		102	2.29	.44	1.27	26.8
	UAN+ATS		98	2.41	.41	1.29	25.9
	Signif. Level (%):		67	99	75	99	78
	BLSD (.05) :			.13		.05	
	Placement						
	Ridge top		97	2.59	.47	1.38	25.5
	Broadcast		103	2.23	.39	1.23	26.8
	Signif. Level (%):		99	99	99	99	99
	Interaction				Significance Level (%)		
	Source x Placement		38	47	11	25	86

1/ UAN = 28-0-0; UAN+AS = 25-0-0-3 w/S as ammonium sulfate; UAN+ATS = 25-0-0-3 w/S as ammonium thiosulfate.

2/ All materials applied at 150 lb N/A.

3/ 40% on ridge top preemergence + 60% sidedressed in a 6-8" from row at 6-leaf stage.

Nitrogen efficiency measured by the difference method was 36 and 42% for the AA treatment for grain and total plant uptake, respectively. This was reduced to 30 and 35% by the UAN treatments, to 25 and 30% by the UAN + AS treatments, and to 24 and 28% by the UAN + ATS treatments, respectively. Ridge-top, band applications showed efficiency values of 30 and 35% while broadcast applications reduced N efficiency to 23 and 26%. Application of UAN between the rows gave efficiency values similar to broadcast applications, while the split application was similar to the band, ridge-top application.

These results further confirm that N losses must have occurred, especially with the broadcast applications containing either AS or ATS.

Sulfur Concentrations

Leaf and grain S concentrations were affected slightly and inconsistently by the 18 lb S/A N + S treatments (Table 6). However, S concentrations in all three plant parts were increased consistently by the band application of N on the ridge-top compared to the broadcast application. Sulfur uptake in the grain and the whole plant was also increased with the band application on the ridge. Sulfur uptake values showed that between 1 and 2% of the applied S was taken up by the plants.

Table 5. Grain yeilds and N uptake as influenced by placement method of UAN with and without S in Waseca Co.

N Treatment			Grain	Yields			N Uptake	
No.	Material 1/	Placement 2/	Moisture	Stover	Silage	Grain	Grain	Total 1/
			%	-------- T DM/A --------			---- lb N/A ----	
1	CHECK	----	25.7	1.45	4.05	86.2	44.0	54.1
2	An. ammonia	preplant	22.1	1.94	6.31	146.2	97.8	117.6
3	UAN	Ridge top	22.8	1.82	5.90	135.8	91.6	109.1
4	"	Between rows	22.9	1.93	6.03	137.5	86.2	101.5
5	"	Bdct.	22.3	2.04	6.31	141.5	86.9	103.3
6	"	Split	22.8	1.99	6.17	139.7	90.6	107.4
7	UAN+AS	Ridge top	22.1	2.03	6.10	139.3	88.9	108.6
8	"	Bdct.	23.3	1.92	5.90	131.7	74.0	88.8
9	UAN+ATS	Ridge top	22.8	1.96	5.83	131.0	84.7	102.1
10	"	Bdct.	23.0	1.79	5.75	131.2	75.5	88.7
	Signif. Level (%):		99	99	99	99	99	99
	BLSD (.05) :		.8	.32	.65	10.5	7.5	9.4
	CV (%) :		2.9	12.	9.1	6.8	7.9	8.2
	ORTHOGONAL COMPARISONS							
	N Source							
	UAN (trts 3&5)		22.5	1.93	6.10	138.6	89.3	106.2
	UAN+AS		22.7	1.97	6.00	135.5	81.4	98.7
	UAN+ATS		22.9	1.87	5.79	131.1	80.1	95.4
	Signif. Level (%):		62	43	61	79	99	99
	BLSD (.05) :						6.1	7.0
	Placement							
	Ridge top		22.6	1.94	5.94	135.3	88.4	106.6
	Broadcast		22.9	1.91	5.99	134.8	78.8	93.6
	Signif. Level (%):		80	21	19	13	99	99
	Interaction				Significance Level (%)			
	Source x Placement		98	90	62	71	76	87

1/ Grain + Stover

SUMMARY

Results from the study conducted at the Goodhue County site were quite inconclusive due to the high check plot yields, lack of N response, and high variability. However, the addition of S as ATS to the broadcast UAN solution quite consistently reduced N concentrations in the plant and plant yield. At the Waseca site response to the N treatments was excellent. Yields and N uptake were generally highest with the preplant anhydrous ammonia treatment. The UAN treatments usually resulted in lower N concentrations, slightly lower yields, and lower N uptake values, especially when the UAN contained S and was broadcast on the soil surface. Nitrogen was apparently being lost thru either volatilization or immobilization. Band application of UAN to the ridge top, especially with ATS, showed some early season phytotoxicity. Split application of UAN did not improve N uptake or yield over the single preemergence applications. Addition of S to the UAN did not improve corn production at either site. Based on these first-year data, the addition of S to UAN could not be recommended. Moreover, surface application of UAN showed slightly lower N efficiencies especially when broadcast applied.

Table 6. Sulfur concentrations in plant tissue and S uptake as influenced by S source and placement method in Waseca Co.

N + S Treatment			S Concentration in			S Uptake	
No.	Material[1/]	Placement	Leaf	Stover	Grain	Grain	Total[2/]
			%			lb S/A	
3	UAN	Ridge top	.175	.049	.087	5.62	7.41
5	"	Bdct.	.153	.044	.085	5.70	7.51
7	UAN+AS	Ridge top	.169	.053	.093	6.14	8.29
8	"	Bdct.	.146	.049	.089	5.52	7.38
9	UAN+ATS	Ridge top	.179	.052	.094	5.79	7.80
10	"	Bdct.	.152	.043	.084	5.25	6.79
FACTORIAL ANALYSIS							
N Source							
UAN			.164	.046	.086	5.66	7.46
UAN+AS			.157	.051	.091	5.83	7.84
UAN+ATS			.165	.047	.089	5.52	7.29
Signif. Level (%):			97	88	98	64	89
BLSD (.05) :			.007		.003		
Placement							
Ridge top			.174	.051	.091	5.85	7.83
Broadcast			.150	.045	.086	5.49	7.23
Signif. Level (%):			99	99	99	95	99
Interaction							
Source x Placement			21	48	93	79	93
CV (%) :			4.3	10.	3.7	8.3	7.5

1/ N applied at 150 lb N/A; S applied at 18 16 S/A (25-0-0-3).

2/ Grain + Stover

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NITROGEN LOSS TO TILE LINES AS AFFECTED BY TILLAGE

Waseca, 1985

G. W. Randall and P. L. Kelly

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

EXPERIMENTAL PROCEDURES

A study was initiated in 1975 on a Webster clay loam at Waseca to monitor the movement of N into a tile line installed in each of 12 plots measuring 45' x 50'. Each plot is enclosed with plastic sheeting to a 6' depth. Annual N rates of 0, 100, 200, and 300 lb N/A were applied from 1975-1979. No N was applied for the 1980 and 1981 crops. Residual N from N applied over the 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, eight plots with the most uniform tile flow rates over the 1975-81 period were selected. Two tillage treatments (fall moldboard plow and no tillage) were replicated four times and randomized over the previous plot histories. Corn was grown on these plots in 1982 through 1984. The stalks were chopped in October, 1984 and moldboard plots plowed.

On May 7, 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 7 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) applied May 7. Weed and insect control was excellent.

The leaf opposite and below the ear was taken from 10 randomly selected plants per plot at silking (Moldboard plow = July 24, No tillage = July 29) 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 late March 1985 and continued to flow intermittently until mid-May. Conditions were extremely dry in June and July and no tile flow was recorded during this period. Tile lines commenced flowing again in late September and flowed throughout October. When tile lines were flowing, flow rates were measured daily and samples taken on a Monday, Friday, Wednesday two-week rotation for NO_3-N analysis. All analyses were done by the Research Analytical Lab.

Soil NO_3-N in the 0-8' profile was determined from two cores/plot taken in 1-foot increments on April 29 and November 1, 1985.

RESULTS

Grain yield, N removed in the grain, and N uptake in the silage were significantly higher (P=95% level) with moldboard plow tillage compared to no tillage (Table 1). Silage yields were significantly improved with moldboard plowing (P=90% level). Leaf and grain N and final population were not influenced by the tillage system.

Precipitation for the March and April period was 4.2" above normal while rainfall was 4.0" above normal for the August and September period. Thus, most of the tile flow shown in Table 2 occurred in April and October. Total tile flow, flow-weighted NO_3-N concentration, and NO_3-N lost thru the tile lines were not markedly different between the two tillage systems. Nitrate-N concentrations averaged about 12 mg/L in comparison to 11 mg/L in 1984.

Table 1. Influence of tillage system on corn production and N utilization at Waseca in 1985.

Tillage system	Final population	Leaf N	Silage Yield	Silage N uptake	Grain Yield	Grain N	Grain N removal
	$x10^{-3}$	%	T DM/A	lb N/A	bu/A	%	lb N/A
Mb. Plow	27.1	2.35	6.89	133.4	160.3	1.37	103.6
No Tillage	27.3	2.26	6.29	124.5	145.1	1.34	92.4
Signif. Level (%):1/	33	79	90	98	99	40	98
CV (%) :	2.2	3.5	5.5	2.2	2.5	4.0	3.3

1/ Probabililty level of significance.

Table 2. Influence of tillage system on tile flow, NO_3-N concentration and NO_3-N loss in 1985.

Tillage system	Tile flow	Nitrate-N Concentration1/	Nitrate-N Loss
	acre-inches	mg/L	
Mb. Plow	5.63	12.1	15.4
No Tillage	6.82	11.6	17.9

1/ Flow-weighted

Residual NO_3-N remaining in the 0-8' soil profile were not different between the two tillage systems when measured prior to N application (Table 3). After harvest slightly more residual NO_3^- remained in the no tillage system. The NO_3-N concentrations were surprisingly uniform throughout the profile of both tillage systems. No accumulation zone was apparent except for the slight increase in the surface 0-2' with no tillage.

Table 3. Influence of tillage systems on residual NO_3-N in the soil profile in 1985.

Profile depth	April Mb. Plow	April No Tillage	November Mb. Plow	November No Tillage
feet	NO_3-N (lb/A)			
0-1	19.2	14.9	12.5	23.6
1-2	15.3	10.7	12.8	19.7
2-3	14.0	10.1	14.0	15.7
3-4	14.6	14.4	13.3	13.3
4-5	13.8	14.3	13.3	18.2
5-6	10.0	13.4	12.8	14.2
6-7	9.0	11.1	10.8	14.8
7-8	10.0	9.9	9.9	13.2
Total (lb NO_3-N/A 0-8')	105.9	98.8	99.4	132.7

FOUR-YEAR SUMMARY

The cumulative totals for the 4-year period (1982-1985) are shown in Table 4. Corn yields over this period have averaged 8 bu/A better with moldboard plow tillage, although the difference between the two systems has widened each year. Approximately 10% more N has been removed in the grain with moldboard plow tillage. This has been due to both higher yields and slightly higher grain N concentrations with the moldboard tillage system some years. Even so, very little difference in applied N removed in the grain exists between the two treatments (48% vs 44% for plow vs no tillage, respectively). Total tile flow has been almost identical between the two systems. Even though about 10% more NO_3-N was lost through the tile lines with no tillage, this small difference is considered to be insignificant when considering tile flow variability among the eight plots over this 4-year period.

Table 4. Cumulative effects of the two tillage systems over the 4-year period.

Parameter	Tillage System: Mb. plow	Tillage System: No tillage
Fert. N applied (lb/A)	720	720
Corn grain removed (bu/A)	530	497
N removed in grain (lb/A)	346	315
Percent of applied N removed in grain (%)	48	44
Tile flow (acre inches)	41.1	43.7
Nitrate-N lost in tile (lb/A)	88.4	97.5
Percent of applied N lost via tile lines (%)	12	14

STARTER FERTILIZER PLACEMENT EFFECTS ON CORN PRODUCTION

Waseca, 1985

G. W. Randall and P. L. Kelly

Starter fertilizers will increase in popularity as farmers attempt to maximize return from their fertilizer dollar and as reduced tillage becomes more popular. However, with less spring secondary tillage, farmers somtimes encounter problems with the conventional disk opener systems when moist soil is dislodged by them and then sticks to the depth bands on the planter. The result can be uneven seeding depth. To correct this problem, farmers would like to remove the disk opener fertilizer attachment and instead place the starter fertilizer directly with the seed rather than in the conventional 2 x 2" placement. The purpose of this study was to evaluate seed placement versus 2 x 2" placement of two liquid fertilizers on the early growth, final stand, and yield of corn.

Experimental Procedures

A Webster clay loam soil planted to soybeans in 1984, chisel plowed in the fall, and field cultivated in the spring was the experimental site. The soil tests were: pH = 7.0, OM = High, Bray P_1 = 15 lb/A (M), and exchangeable K = 280 lb/A (H).

A randomized, complete block design with four replications was used. Factorial treatments consisting of two liquid starter fertilizers (10-34-0 and 7-21-7), three rates (5, 10, and 15 gal/A), and two placement methods (directly with the seed and 2" to the side and below) plus a no starter fertilizer check were applied.

Corn (Pioneer 3732) was planted in 30" rows with a JD Max-Emerge planter at 27,700 plants per acre on May 3. The liquid materials were applied either directly on the seed by running the delivery tube between the double disk openers on the planter or in the 2 x 2" position with the starter fertilizer disk opener. No insecticide was used. Chemical weed control consisted of 3½ qt. Lasso and 3½ qt. Bladex/A applied preemergence.

Table 1. Daily precipitation and average soil temperatures (2" depth) in the 2-week period following planting.

Days after planting	Avg. Soil temperature (2")	Precipitation
	°F	inches
1	69	0
2	60	.20
3	66	0
4	69	0
5	71	0
6	76	0
7	75	.06
8	68	.07
9	58	0
10	64	.26
11	60	.07
12	56	.50
13	52	.05
14	59	0

Plant counts to obtain emergence rate and final stand were then taken daily from two rows each 55' long for 12 days beginning on the 10th day after planting. Grain yield was determined by harvesting each plot with a modified JD 3300 plot combine.

Results and Discussion

Growing conditions following planting were excellent for corn germination and emergence. Soil temperature at the 2" depth averaged well above 50°F (Table 1). Soil moisture in the seed zone was slightly dry at planting and remained on the dry side for 11 days. On the 12th day 0.50" rain thoroughly wet the seed zone.

The salt rate ($N+K_2O$) of fertilizers has been shown to be important when applying fertilizer with the seed. Ammonia toxicity and/or salt burn can affect the germination of seedlings. A rule of thumb in Minnesota based on older research is not to apply more than 15 lb of $N+K_2O$/A. The $N+K_2O$ application rates with the various treatments are shown in Table 2. Salt levels are higher for 7-21-7 than for 10-34-0 because of the K component. Fifteen gallons of either material clearly exceeded the 15 lb/A threshold.

Table 2. Salt rate as influenced by starter fertilizer material and rate of application.

	Liquid fertilizer	
Application rate	10-34-0	7-21-7
gal/A	--- lb $N+K_2O$/A ---	
5	6	7.5
10	12	15.0
15	18	22.5

Emergence rate was affected significantly by the seed-placed fertilizers (Table 3). Application of 15 gal/A of both fertilizer materials with the seed resulted in less than 50% of the plants emerged on the 10th day following planting compared to about 80% with the 2 x 2" placement. At the high application rate 90% emergence was delayed by 5 to 6 days with seed-placement. Emergence was delayed slightly more with the 7-21-7 material because of the higher salt rate.

Table 3. Influence of liquid starter fertilizer material, application rate, and placement on emergence rate of corn.

Treatment			Days after planting									
Material	Rate	Placement	10	11	12	13	14	15	16	17	19	21
	gal/A		% of final stand									
None	0	CHECK	80	87	91	94	95	96	96	97	97	100
10-34-0	5	Seed	86	84	94	97	97	98	98	99	100	100
"	"	2 x 2	89	91	93	95	95	96	97	99	99	100
"	10	Seed	75	86	91	94	95	96	97	98	99	100
"	"	2 x 2	87	90	94	95	94	96	97	97	100	100
"	15	Seed	48	61	73	79	81	84	87	91	96	100
"	"	2 x 2	85	87	92	95	96	96	97	98	99	100
7-21-7	5	Seed	78	82	87	93	93	95	95	96	98	100
"	"	2 x 2	82	86	93	93	98	95	97	97	100	100
"	10	Seed	63	70	78	86	88	91	93	95	97	100
"	"	2 x 2	73	76	87	92	93	93	94	95	98	100
"	15	Seed	38	54	65	75	77	81	86	88	94	100
"	"	2 x 2	71	76	84	88	88	90	94	95	96	100

Final population was not effected by any of the treatments except with the seed-placed, high rate of both materials which reduced stand by almost 10% (Table 4). Factorial analyses (Table 5) showed no difference between 10-34-0 and 7-21-7 when seed-placed at the 15 gal/A rate. Application of 10 gal/A, although close to the 15 lb $N+K_2O$/A threshold, did not influence final population.

Seeds were excavated from the gaps where plants were missing. In almost all cases the seed had started to germinate as evidenced by the the emerged radicle (root). This radicle was usually from 1/4 to 3/4" long and was dark brown, indicating that it had been killed by salt burn and/or ammonia toxicity.

Grain moisture was reduced slightly by selected treatments (Table 4) and by 10-34-0 when averaged over rate and placement.

Grain yields were quite variable and thus were not effected statistically by the treatments (Table 4). When averaged over fertilizer materials and placement methods, higher yields were found with the 10 and 15 gal/A treatments compared to the 5 gal/A. This would be expected on this medium P testing soil. The delayed emergence and reduced stand did not effect the yield or moisture of the grain at harvest.

Table 4. Influence of liquid starter fertilizer material, application rate and placement on plant population, grain moisture, and corn grain yield.

Treatment			Final	Corn grain	
Material	Rate	Placement	population	Moisture	Yield
	gal/A		ppA x 10^{-3}	%	bu/A
None	0	Check	26.1	24.3	130.8
10-34-0	5	Seed	26.2	25.2	128.3
"	"	2 x 2	26.5	25.2	130.6
"	10	Seed	26.3	25.4	140.7
"	"	2 x 2	27.2	24.8	141.2
"	15	Seed	24.1	25.1	149.1
"	"	2 x 2	26.5	23.2	152.1
7-21-7	5	Seed	26.8	25.5	135.3
"	"	2 x 2	25.5	25.5	143.6
"	10	Seed	25.6	25.1	145.5
"	"	2 x 2	27.4	25.6	146.0
"	15	Seed	24.7	26.1	140.9
"	"	2 x 2	25.6	25.6	141.3
Signif. Level (%):[1/]			98	95	48
BLSD (.05):			2.1	1.9	--
CV (%):			4.7	4.0	10.7

[1/] Probability level of significance.

Conclusion

In this 1-yr study application of 10-34-0 or 7-21-7 at 15 gal/A with the seed resulted in delayed emergence and reduced stand but did not effect yield. To be on the safe side, however, we cannot recommend rates greater than 10 gal/A with either of these materials when applied with the seed. Rates should be reduced further if soil conditions are very dry at planting and/or soils are lower in organic matter and coarse to medium textured.

Table 5. Factorial analyses of the effect of liquid starter fertilizer material, rate, and placement on corn production parameters.

Factors		Final population	Corn grain Moisture	Corn grain Yield
MAIN FACTORS		ppA x 10^{-3}	%	bu/A
Material				
10-34-0		26.1	24.8	140.3
7-21-7		26.0	25.6	142.1
Signif. level (%):		37	98	31
Rate (gal/A)				
5		26.3	25.4	134.4
10		26.6	25.2	143.3
15		25.2	25.0	145.8
Signif. level (%):		99	40	90
BLSD (.05):		0.9	--	--
Placement				
Seed		25.6	25.4	139.9
2 x 2		26.4	25.0	142.4
Signif. level (%):		97	87	43
INTERACTIONS				
Material x Rate				
10-34-0	5	26.4	25.2	129.4
"	10	26.7	25.1	140.9
"	15	25.3	24.2	150.6
7-21-7	5	26.2	25.5	139.4
"	10	26.5	25.3	145.7
"	15	25.2	25.8	141.1
Signif. level (%):		1	90	82
Material x Placement				
10-34-0	Seed	25.6	25.3	139.3
"	2 x 2	26.7	24.4	141.3
7-21-7	Seed	25.7	25.6	140.5
"	2 x 2	26.2	25.5	143.6
Signif. level (%):		66	87	10
Rate x Placement				
5	Seed	26.5	25.4	131.8
"	2 x 2	26.0	25.4	137.1
10	Seed	26.0	25.3	143.1
"	2 x 2	27.3	25.2	143.5
15	Seed	24.4	25.6	145.0
"	2 x 2	26.0	24.4	146.7
Signif. level (%):		96	80	11
		Significance level (%)		
Material x Rate x Placement		72	44	8

STARTER FERTILIZER N, P, AND S FOR RIDGE-PLANTED CORN

Waseca, 1985

G. W. Randall

Many soils test high in phosphorus (P) in Southern Minnesota where corn is intensively grown. However, an early growth response to starter fertilizer containing NPK or just NP is frequently observed. Is that response due to the P as is commonly thought or is it due to the closely placed N? The purpose of this study was to determine the effect of N in starter fertilizer applied to corn grown with ridge tillage on a high P testing soil. An additional objective was to evaluate the addition of P and S to the high N analysis starter fertilizer.

Experimental Procedures

The site selected at the Southern Experiment Station was a tile drained Nicollet clay loam which had been ridge-planted to corn in 1984. Ridges were rebuilt just prior to layby. Following harvest all stalks were chopped. Soil test results from a spring 1985 sample indicated pH = 6.5, OM = High, Bray P_1 = 64 lb/A (VH), exchangeable K = 320 lb/A (VH), and SO_4-S = 4 ppm (L). Six treatments were applied using a randomized, complete-block design with six replications. Each plot measured 4 rows wide (10') by 55' long. Nitrogen was applied to all plots as anhydrous ammonia at a rate of 135 lb N/A on April 30.

Five liquid starter fertilizer treatments were applied 2" to the side and 2" below the seed using a JD Max-Emerge planter equipped with B & H ridge cleaning units and Acra-Plant Nutri-Till liquid fertilizer attachments (Table 1). No starter fertilizer was used in the sixth treatment. Corn (Pioneer 3732) was planted in 30" rows at 27700 plants per acre on May 3. Furadan was applied at 1 lb a.i./A to control corn rootworms. A Lasso (3½ qt./A) plus Bladex (3½ qt./A) tank-mix combination was applied preemergence to all plots to control weeds. Rootworm and weed control were excellent. Surface residue coverage after planting averaged 32 percent.

Early plant growth measurements were taken on June 11 at the 6-leaf stage by cutting 10 random plants (5 each from rows 1 and 4) and oven dried. After weighing and grinding, the plant tissue was chemically analyzed by the U of M Research Analytical Laboratory.

Final population was taken on August 19 by counting the plants from 25' of row in each of the center two rows. Grain yields were determined on October 16 by harvesting the two center rows with a modified JD 3300 plot combine.

Table 1. Treatment identification in starter fertilizer material study.

Treatment code	Fertilizer analysis	Application rate	Nutrients applied
		gal/A	lb N + P_2O_5 + K_2O + S/A
CHECK	0	0	0
APP	10-34-0	12.5	15 + 51 + 0 + 0
UAN	28-0-0	5.0	15 + 0 + 0 + 0
N+P	25-5-0-0	5.6	15 + 3 + 0 + 0
N+P+S	20-5-0-3	6.5	15 + 4 + 0 + 2.2
N+S	20-0-0-4	6.5	15 + 0 + 0 + 3.6

Results and Discussion

Temperatures during May were quite warm with growing degree days for the month averaging 27% above normal. Consequently, early plant growth was rapid on this very high testing soil. Visual differences in early growth were not visible.

Dry matter measurements taken on June 11 showed a slight (approx. 15%) growth advantage over the check with 4 of the 5 starter fertilizer treatments (Table 2). No explanation can be given at this time for the lack of early growth response with the APP treatment. With the exception of Mg, none of the nutrient concentrations were affected by the starter fertilizer treatments (Table 2).

Table 2. Early plant growth and nutrient concentrations as influenced by starter fertilizer material.

		Nutrient[1/]										
Treatment	EPG	N	P	K	S	Ca	Mg	Fe	Mn	Zn	Cu	B
	g/plant	%						ppm				
CHECK	4.1	3.70	.43	3.71	.236	.55	.47	281	51	42	9.3	8.5
APP	4.2	3.66	.42	3.49	.232	.57	.50	297	53	42	9.4	8.9
UAN	4.8	3.66	.41	3.43	.233	.56	.54	284	57	43	9.3	9.1
N+P	4.8	3.77	.42	3.50	.228	.54	.51	264	53	43	9.2	8.7
N+P+S	4.7	3.62	.41	3.51	.236	.57	.53	278	53	43	9.2	8.6
N+S	4.8	3.71	.41	3.65	.235	.55	.51	274	56	45	9.4	8.8
Signif. Level(%):	99	31	89	67	37	82	99	79	82	74	1	74
BLSD(.05):	0.4						.04					
CV(%):	7.0	4.4	3.6	6.8	4.0	4.2	5.9	7.8	7.5	5.0	5.7	4.5

[1/] Whole plant at 6-leaf stage.

Nutrient uptake at the 6-leaf stage (product of dry matter yield times nutrient concentration) was generally increased over the control by four of the starter treatments (Table 3). This increased uptake was due directly to the increase in early DM accumulation.

Table 3. Nutrient uptake by the small plants as influenced by starter fertilizer material.

	Nutrient uptake[1/]										
Treatment	N	P	K	S	Ca	Mg	Fe	Mn	Zn	Cu	B
	mg/plant						mg/10 plants				
CHECK	152.	17.8	153.	9.7	22.6	19.2	11.5	2.1	1.7	.38	.35
APP	154.	17.8	146.	9.7	24.1	20.9	12.5	2.2	1.8	.40	.37
UAN	177.	20.0	166.	11.3	26.9	26.0	13.7	2.7	2.1	.45	.44
N+P	182.	20.2	171.	11.0	26.1	24.5	12.8	2.6	2.1	.44	.42
N+P+S	171.	19.3	165.	11.1	26.9	25.0	13.2	2.5	2.0	.43	.41
N+S	178.	19.7	175.	11.2	26.1	24.3	13.1	2.7	2.2	.45	.42
Signif. Level(%):	99	99	87	99	99	99	71	99	99	99	99
BLSD(.05):	16.	1.8		0.9	2.0	1.9		0.4	0.2	.04	.04
CV(%):	7.9	7.3	12.	7.3	6.6	7.3	13.	12.	9.4	8.0	8.4

[1/]Whole plant at 6-leaf stage.

Corn grain yield, grain moisture at harvest, and final population were not affected by any of the starter fertilizer treatments (Table 4).

Table 4. Corn yield, moisture, and population as affected by starter fertilizer material.

Treatment	Final population	Corn grain Moisture	Corn grain Yield
	ppA x 10^{-3}	%	bu/A
CHECK	26.6	29.3	157.1
APP	27.1	27.8	155.8
UAN	27.4	29.6	157.8
N+P	26.5	29.8	155.0
N+P+S	27.7	29.4	163.2
N+S	28.2	30.2	152.2
Signif. Level(%):	86	78	60
CV(%):	4.2	2.2	5.6

Summary

Data obtained from this high testing site with warm spring conditions showed a slight early growth response with some of the treatments, no effect on small plant nutrient concentrations, and no effect on grain yield. The individual effects of the N, P, and S components in the starter materials was inconclusive. Under these conditions, starter fertilizer could not be recommended to increase the economic return to farmers growing corn in a ridge plant system.

Acknowledgement

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LONG-TERM CARRYOVER FROM HIGH RATES OF MANURE

Waseca, 1985

G. W. Randall and R. H. Anderson

Conditions sometime exist in livestock operations where acreage, time and/or labor may not be sufficient to permit the application of manure to land just prior to planting or at conventional rates. In addition, the monetary value of the nutrients contained in the manure in relation to prices for inorganic fertilizers sometimes is relatively low. As a result of these factors, heavy rates of manure have been applied or disposed of in localized areas; often close to the livestock facility.

With these conditions in mind an experiment was established to determine the maximum quantity of manure that can be applied and incorporated in a limited non-crop area. Primary objectives were to investigate: (a) the capacity of land to serve as a disposal medium for excessive rates of manure, (b) the accumulation and movement of nutrients in the soil profile and (c) the response of future crops to these high rates.

Experimental Procedures

During 1971, 1972 and 1973, beginning in mid-May and ending in mid-September, dairy cattle manure taken directly from the barn was applied to the surface of a Webster clay loam soil. Manure was applied to the same 0.5-acre area in both 1971 and 1972. In 1973, this area was split and manure was applied to one of the 0.25-acre areas. The manure was allowed to dry for 1 to 7 days before incorporating by disking, field cultivating or periodic plowing by either moldboard or chisel plow. Dry matter determined at 105 C and nutruent application rates were calculated by weighing each load of manure and by gathering random manure samples throughout the season for chemical analysis. Total N, organic N, inorganic N, total P and total K applied in the manure treatments are shown in Table 1.

To evaluate the carryover from the manure treatments a 0.25-acre section has received an annual application of N (approximately 150 lb N/A) as anhydrous ammonia each year. Supplemental P and K or starter fertilizers have not been used on the whole experimental site due to very high soil test levels.

Corn has been planted annually beginning in 1974. Excellent weed control has been obtained with preemergence herbicides. Corn root worms have been controlled with a rotation of Furadan and Counter. Soil samples have been taken in 1-foot increments to a depth of 10' each spring. Leaf nutrient concentrations at silking, fodder N and grain N have been determined annually. Corn silage and grain yields have been obtained by hand harvesting four replicated sections within each of the treatments each fall.

Results

The manure application rates and amount of nutrients applied in the manure are shown in Table 1. These extremely high manure rates resulted in approximately 10, 3 and 5 tons of N, P, and K/A, respectively, applied over the 3-year period with slightly less over the 2-year application period. Approximately 75% of the N was in the organic form with the remainder as NH_4-N.

Soil and plant samples taken annually (data not shown) and corn yields show that there has been a long-term effect of these manure rates on corn production (Table 2). Yield differences among the treatments have not been significant (P = 90% level) in 6 of the 10 years. Significant yield advantages were obtained with at least one of the manure treatments in 1976 and 1978. Yields in 1979 showed an advantage for the fertilizer N and high rate of manure treatments. Although significant yield differences were found in 1982, no consistent advantage was seen for either manure or fertilizer.

Some of the data shown in Table 3 indicate that the residual effect of the manure is waning in the 12th year of the study. Leaf and grain N concentrations were significantly lower for both of the manure treatments compared to the annual fertilizer N treatment. However, silage and grain yields along with N uptake did not show consistent advantages for the fertilizer treatment over the manure treatments.

Table 1. Nutrient amounts applied with the manure treatments in 1971-73.

	Period	
	1971-72	1971-73
Manure rate (T/A, dry basis)	200[1/]	345[2/]
Nutrients (lb/A)		
Total N	11800	20150
Org. N	8980	15320
NH_4-N	2820	4820
NO_3-N	3	5
P	3220	5840
K	6210	10780

1/ 1040 T/A on a wet basis.
2/ 1785 T/A on a wet basis.

Table 2. Corn grain yields from 1974-1984 as influenced by previous manure application rates at Waseca.

	Treatment				
	Manure		Fertilizer	Signif.	BLSD
Year	345 T/A	200 T/A	150 lb N/A	level	.05 (.10)
	bu/A			%	
1974	117.1	119.9	117.0	NS	
1975	99.2	93.2	105.3	NS	
1976	98.7	88.0	86.4	99	7.5
1977	148.0	158.0	161.8	84	
1978	152.9	148.3	138.0	96	11.7
1979	179.6	161.4	183.5	99	11.8
1980	103.1	111.0	111.1	33	
1981	183.3	177.3	177.3	54	
1982	148.3	165.2	158.9	93	(12.4)
1983	85.4	77.6	93.2	76	
1984	114.6	112.8	96.3	98	13.3

Reasons for these inconclusive data can probably be attributed to the weather. Conditions from May thru most of July were extremely dry. At the end of July when the leaf samples were taken, corn growing on the two manure treatments looked extremely N deficient while on the fertilizer N treatment corn was taller and was not N deficient. After rain started on July 25 and continued above normal throughout August, the corn on the manure plots improved tremendously. Growth was improved and N deficiency symptoms were not nearly as prevalent. Apparently, substantial amounts of N were released by mineralization from the manure treatments after the soils were sufficiently wetted. Consequently final yields and N uptake were not significantly different (P = 95% level) from the fertilized treatment.

Table 3. Influence of manure and fertilizer application on corn production and N utilization at Waseca in 1985.

	Final	Leaf	Fodder	Silage		Grain			Ear
Treatment	popl'n	N	N	Yield	N Uptake	Yield	N	N removal	Moisture
	ppAx10^{-3}	%	%	T DM/A	lb N/A	bu/A	%	lb N/A	%
Manure-(345 T/A)	27.1	2.11	.68	6.87	138.4	148.1	1.42	99.3	38.9
" -(200 T/A)	28.1	2.10	.54	7.45	145.5	168.3	1.42	113.6	37.2
Fert. N (150 lb/A)	26.6	2.68	.71	6.80	149.0	150.2	1.54	109.6	38.2
Signif. Level (%):	94	99	99	90	66	93	97	91	90
BLSD (.05),(.10)*:	1.1*	.13	.10	.57*		15.9*	.10	11.3*	1.3*
CV (%) :	2.7	3.5	8.9	5.4	6.6	6.9	3.9	7.0	2.3

Nitrate-N concentrations taken in early June within the 0-10' soil profile show substantially more NO_3-N in the top 1-foot with the fertilizer N treatment (Table 4). Much of this could have come from the nitrified anhydrous ammonia that was applied on April 26. At depths below 1' there was slightly but consistently more NO_3-N with the fertilizer N treatment. Consequently, total NO_3-N accumulation in the top 10' was almost twice as high with the fertilizer treatment as with the manure treatments.

Table 4. Influence of past manure treatments and annual N applications of NO_3-N in the 0-10' soil profile at Waseca in June, 1985.

Profile depth	Treatment		
	345 T/A	200 T/A	150 lb N/A
feet	ppm		
0-1	14.4	12.5	40.9
1-2	7.0	8.3	8.3
2-3	4.7	5.6	7.7
3-4	4.4	5.0	6.9
4-5	4.5	5.5	8.2
5-6	4.1	5.5	7.5
6-7	2.5	5.2	9.4
7-8	3.1	5.1	7.5
8-9	2.9	5.8	7.9
9-10	2.6	6.2	7.4
lb NO_3-N in top			
0-5' =	140	148	288
5-10' =	76	112	159
0-10' =	216	260	447

Summary

High rates of manure resulted in large quantities of nutrients applied to a Webster clay loam soil in 1971-73. Carryover from these manure treatments without additional fertilizer applications sustained corn production from 1974-1984. Nitrogen concentrations in the corn and soil NO_3-N levels in 1985 indicated that the carryover effect from the previous manure treatments has begun to wane. Corn yields from the manure treatments, however, were not consistently and significantly different (P = 95% level) from the fertilized treatment. Even though NO_3-N levels within the 10-foot profile were 50% lower with the manure treatments, sufficient N was apparently released from the soil organic matter thru mineralization to sustain corn production in 1985. This was true even though severe N deficiency symptoms were present at the silking stage. Apparently mineralization and subsequent N uptake were enhanced by the above normal August and September rainfall.

SOIL TEST COMPARISON STUDY

Waseca, 1985

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 and soybean production.

PROCEDURES

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

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

After the 1980 crop, soil samples (5 cores/plot times 6 replications yielding 30 cores per treatment) were taken yearly from each treatment and sent to the respective laboratory. This allowed us to follow the buildup or decline of nutrients in the soil as affected by the recommendations of a particular laboratory over this 6-year period.

Soybeans were planted in this study in 1982 after nine years of continuous corn at the very high testing site and after seven years at the medium-high testing site.

Fertilizer amounts based on the analyses and recommendations from the summer 1984 samples were applied October 24 to the appropriate plots and chisel plowed in. Nitrogen as urea was spread the following spring (April 18) and field cultivated in. These fertilizer recommendations were based on a yield goal of 160 bu/A corn following soybeans. Corn (Pioneer 3732) was planted at 27,700 ppA in 30" rows on April 30 with neither starter fertilizer or insecticide. Chemical weed control consisted of 3½ qt. Lasso and 3½ qt. Bladex/A applied preemergence to all plots.

On July 22 the leaf opposite and below the ear at 50% silking was randomly sampled from 10 plants and was submitted for analyses. Final populations were determined from 50' of row. Grain yield and moisture were determined on corn harvested from the center two rows of each plot with a modified JD 3300 plot combine. Grain yields were converted to 15.5% moisture.

In August, 1985, 0-7" soil samples were taken from each treatment at 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 1986 growing season.

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 sometimes similar, the interpretations (whether the soil tests high, low, medium, deficient, etc.) varied substantially. As a result P and K recommendations among the laboratories were substantially different. Various micronutrients and sulfur were recommended by three of the four private labs. Lime was recommended by all four private labs.

Table 1. Soil test results and the recommended fertilizer programs on the very high testing site at Waseca in 1985.

	Laboratory				
Test[1/]	A&L	Harris	MVTL	Cropmate	U of Mn.
	Soil test results				
pH	6.1	6.1	6.1	5.6	6.1
pH buffer	6.7	6.5	6.6	6.5	---
Phosphorus	27 H	33 D	22 VH	33 M	18 H
Potassium	174 H	221 L	130 H	218 H	141 H
Organic Matter (%)	3.9 H	3.6 A	3.8 M	4.1	M
Calcium	1660 M	3350 A	3550	3735 M	---
Magnesium	449 VH	468 A	515	565 M	476 A
Sulfur	6 L	4 L	11 L	15 H	4 LM
Iron	121 VH	87.2 E	11.8 S	5.6 H	---
Manganese	24 H	21.6 E	13.7 S	2.1 H	---
Zinc	2.1 M	1.5 E	1.5 VH	2.7 H	.9 M
Copper	1.3 H	.9 A	1.0 S	---	.8 A
Boron	1.3 H	1.0 A	1.0 L	---	---
ENR (lb/A)	87	---	---	105 H	---
C.E.C. (meq/100g)	15.0	27.3	26.3	31.1	---
Nutrient	Recommended fertilizer program[2/]				
Nitrogen	190	175	167	237	160
Phosphorus (P_2O_5)	50	65	60	91	50[6/]
Potassium (K_2O)	125	105[3/]	65[4/]	112	50[6/]
Sulfur	16	15	---	---	---
Iron	---	---	---	.12[5/]	---
Manganese	---	---	---	.12[5/]	---
Zinc	2.0	---	---	.62[5/]	---
Copper	---	---	---	---	---
Boron	---	---	---	---	---
Lime (T/A)	1.5	3.0	1.0	2.9	---

1/ All soil test results are stated in ppm unless otherwise noted.
2/ All values are pounds of nutrient recommended per acre for a corn yield goal of 160 bu/A.
3/ Value includes maintenance recommendation, plus 50% of the build up recommendation was to be applied over a two-year period.
4/ Value includes standard recommendation plus 50% of the maintenance recommendation to be applied over a 2-year period.
5/ As 5 qt/A of a material weighing 9.9 lb/gal and containing 5% Zn, 1% Fe, and 1% Mn.
6/ Rate for broadcast application.

Grain yields were increased significantly over the unfertilized check by all five fertilizer treatments (Table 2). However, the yield with the Harris recommendation was significantly lower (P = 95% level) than with the MVTL or Cropmate recommendations. The reason for this is unknown. Grain moisture and final population were not affected by the fertilizer treatments.

Fertilizer recommendations from all five laboratories influenced all leaf nutrient concentrations except Ca over the unfertilized check and resulted in sufficient nutrient levels for optimum yields (Table 3). Leaf N and Fe concentrations did not vary among the labs. Slight differences in leaf P, Cu and B concentrations did exist among the laboratories. The higher 1985 K recommendations and soil test K levels with the long-term A&L, Harris, and Cropmate recommendations resulted in significantly higher leaf K and lower leaf Mg concentrations. The small amount of micronutrients recommended by Cropmate appeared to increase leaf Mn but had no effect on leaf Fe or Zn. Leaf Zn was increased by the A&L recommendation of two pounds Zn/A.

Table 2. Effect of fertilizer recommendations on corn final population, grain yield and moisture on the very high testing site in 1985.

Lab	Fertilizer Recommendations	Final Population	Grain Yield	Grain H_2O
	lb/A[1/]	$x10^3$	bu/A	%
A&L	190N + 50P + 125K + 16S + 2 Zn	26.2	158.0	29.5
Harris	175N + 65P + 105K + 15S	26.9	153.7	29.4
MVTL	167N + 60P + 65K	26.6	166.0	29.1
Cropmate	237N + 91P + 112K + .12 Fe + .12 Mn + .62 Zn	26.4	165.1	29.1
U of Mn.	160N + 50P + 50K	26.8	162.5	29.2
Check	Unfertilized	26.6	123.6	28.8
	Significance Level (%):	13	99	28
	BLSD (.05) :	--	10.7	--
	CV (%) :	4.1	6.3	2.4

1/ P and K expressed on oxide basis.

Table 3. Effect of fertilizer recommendations on corn leaf nutrient concentrations on the very high testing site in 1985.

Lab	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%					ppm				
A&L	2.50	.25	2.00	.51	.42	132	48	41	6.8	11.5
Harris	2.47	.26	2.15	.50	.40	136	46	36	6.5	11.0
MVTL	2.45	.24	1.81	.51	.46	137	43	37	6.6	10.2
Cropmate	2.50	.26	2.07	.50	.42	134	53	34	6.2	10.3
U of Mn.	2.48	.24	1.88	.50	.46	137	44	30	7.0	10.2
Check	1.76	.18	1.70	.54	.46	126	32	24	5.3	9.4
Signif.(%):	99	99	99	93	99	95	99	99	99	99
BLSD (.05):	.11	.01	.12	-	.03	9	5	2	.6	.9
CV (%) :	4.4	3.8	5.8	4.8	5.8	4.8	11.	5.0	7.8	7.0

Nutrient

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 three of the four private labs. Only one of the four private labs recommended liming the soil.

The treatments that received fertilizer yielded significantly more than the unfertilized 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.

Fertilizer recommendations from all five laboratories influenced all leaf nutrient concentrations over the unfertilized check and resulted in sufficient levels to optimize yields (Table 6). No difference was found in the leaf P and B concentrations among the laboratory treatments. Slight differences existed among the labs for the leaf N, Ca, Fe, Mn and Cu concentrations. Even though an extra 90 lb N/A was applied with the Cropmate recommendation, leaf N was not increased over that with the MVTL recommendation. The higher K recommendations in 1985 from the A&L, Harris and Cropmate labs along with the long-term high K recommendation from Harris resulted in substantially higher soil test K and greater amounts of leaf K than with the MVTL or U of Minnesota recommendations. The micronutrients recommended by Cropmate did not increase leaf Fe or Mn significantly but appeared to give a slightly higher leaf Zn concentration. Leaf Zn was also increased by the A&L recommendation.

Table 4. Soil test results and the recommended fertilizer programs on the medium-high testing site in 1985.

Test[1/]	Laboratory				
	A&L	Harris	MVTL	Cropmate	U of Mn.
	Soil test results				
pH	6.6	7.0	6.5	6.1	6.3
pH buffer	6.8	---	6.9	6.8	---
Phosphorus	23 H	24 D	15 M	13 L	14 MH
Potassium	198 H	240 L	135 H	221 H	147 H
Organic Matter (%)	4.7 H	4.6 A	4.9 H	4.8	M
Calcium	2650 M	6551 A	4950	5940 H	---
Magnesium	616 VH	543 A	570	661 M	582 A
Sulfur	6 L	4 L	10 H	16 H	4 LM
Iron	55 VH	42.9 E	11.8 S	5.6 H	---
Manganese	21 H	17.7 E	12.6 S	2.1 H	---
Zinc	2.4 M	1.5 E	1.1 H	1.6 M	1.2 H
Copper	1.5 H	1.2 A	1.4 S	---	1.1 A
Boron	1.8 H	1.4 A	1.2 S	---	---
ENR (lb/A)	96	---	---	120 H	---
C.E.C. (meq/100g)	20.1	38.0	30.8	38.6	---
Nutrient	Recommended fertillizer program [2/]				
Nitrogen	180	170	147	237	160[6/]
Phosphorus (P_2O_5)	50	120	88	105	70[6/]
Potassium (K_2O)	105	132[3/]	58[4/]	112	50[6/]
Sulfur	16	15	---	---	---
Iron	---	---	---	.12[5/]	---
Manganese	---	---	---	.12[5/]	---
Zinc	2.0	---	---	.62[5/]	---
Copper	---	---	---	---	---
Boron	---	---	---	---	---
Lime (T/A)	1.0	---	---	---	---

1/ All soil test results are stated in ppm unless otherwise noted.
2/ All values are pounds of nutrient recommended per acre for a corn yield goal of 160 bu/A.
3/ Value includes maintenance recommendation, plus 50% of the build up recommendation was to be applied over a two-year period.
4/ Value includes standard recommendation plus 50% of the maintenance recommendation to be applied over a 2-year period.
5/ As 5 qt/A of a material weighing 9.9 lb/gal and containing 5% Zn, 1% Fe, and 1% Mn.
6/ Rate for broadcast application.

Table 5. Effect of fertilizer recommendations on corn final population, grain yield and moisture on the medium-high testing site in 1985.

Lab	Fertilizer Recommendations	Final Population	Grain Yield	Grain H_2O
	lb/A[1/]	x10[3]	bu/A	%
A&L	180N + 50P + 105K + 16S + 2 Zn	26.3	169.8	26.4
Harris	170N + 120P + 132K + 15S	26.4	177.3	26.0
MVTL	147N + 88P + 58K	27.3	171.8	25.4
Cropmate	237N + 105P + 112K + .12 Fe + .12 Mn + .62 Zn	26.5	175.7	26.0
U of Mn.	160N + 70P + 50K	26.7	169.9	25.6
Check	Unfertilized	26.1	95.3	27.6
	Significance Level (%):	55	99	99
	BLSD (.05) :	--	10.1	.9
	CV (%) :	4.2	5.9	3.0

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 1985.

Lab	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%					ppm				
A&L	2.63	.24	1.38	.56	.52	111	45	33	4.4	9.1
Harris	2.67	.25	1.72	.53	.43	113	50	26	4.6	8.8
MVTL	2.71	.24	1.29	.55	.54	116	48	28	4.7	8.7
Cropmate	2.70	.25	1.46	.54	.51	115	52	32	4.2	9.0
U of Mn.	2.73	.24	1.23	.56	.57	122	49	28	4.7	8.6
Check	1.66	.16	.87	.59	.58	94	34	23	3.6	7.5
Signif.(%):	99	99	99	99	99	99	99	99	99	98
BLSD (.05):	.09	.02	.15	.03	.05	10	4	4	.4	1.1
CV (%) :	3.4	8.4	10.	4.1	7.8	8.1	8.6	12.	8.5	9.5

SUMMARY - 1985

Substantial differences again existed among the laboratories fertilizer recommendations at both sites. Excessive N was recommended by the Cropmate laboratory even though corn followed soybeans at both sites. High amounts of P were recommended by the Harris and Cropmate labs at the medium-high testing site and by Cropmate at the very high testing site. High amounts of K were recommended by the A&L, Harris and Cropmate Labs at both sites. Micronutrients and sulfur were recommended by three of the four private labs for both sites. The fertilizer recommendations influenced nutrient concentrations in the corn earleaf compared to the unfertilized check. However, only slight differences in leaf nutrient concentrations were found among the laboratories. The exception was leaf K and Zn.

Differences in grain yield, grain moisture, and final population were not observed among the five laboratories' recommendations at the medium-high site while only a slight yield difference was found at the very high site. Yields were excellent at both sites.

Fertilization resulted in only two (MVTL and U of Mn) of the five labs showing any profit on the very high testing site (Table 7). Fertilizer costs ranged from $54/A with the U of Mn recommendation to $96/A with the Cropmate recommendation. On the medium-high testing site a positive return was gained from fertilizer recommended by all laboratories. Greatest returns were again found with the MVTL and U of Mn recommendations while the least return was found with the Cropmate recommendation, which was also the most expensive recommendation. Fertilizer costs ranged from $58/A with the U of Mn recommendation to $99/A with Cropmate's recommendation.

Table 7. Effect of fertilizer recommendations on yield, value, fertilizer, cost and economic return on both the very high and medium-high testing sites at Waseca in 1985.

	Very High Testing Site				Medium-High Testing Site			
Lab	Yield	Value @2.07/bu	Fert. cost[1/]	Return[2/]	Yield	Value @2.07/bu	Fert. cost[1/]	Return[2/]
	bu/A	$/A			bu/A	$/A		
A&L	158.0	327	72	- 1	169.8	351	68	+86
Harris	153.7	318	69	- 7	177.3	367	82	+88
MVTL	166.0	344	59	+29	171.8	356	60	+99
Cropmate	165.0	341	96	-11	175.7	364	99	+68
U of M	162.5	336	54	+26	169.8	351	58	+96
Check	123.6	256	--	--	95.3	197	--	--

1/ Using May, 1985 prices for each nutrient expressed as dollars/lb as follows: N, .24; P_2O_5, .21; K_2O, .10; S, .21; Zn, .40.

2/ Return yield value @2.07/bu - (fertilizer cost & value of check trt).

Conclusions from the 1985 study can be summarized as follows:

1. Although soil test P and K values were sometimes similar, interpretation ranged from deficient to very high and suggests that some laboratories calibration curves do not fit these soils.

2. Excessive and economically unprofitable rates of N were recommended by Cropmate while little difference existed among the other laboratories.

3. Application of high rates of P and K to soils already testing high to very high did not improve yields and, thus, was not profitable.

4. No yield response was obtained with the addition of S or micronutrients recommended by three of the four private laboratories.

5. Highest economic return was obtained with the fertilizer recommendations provided by MVTL and the U of Mn for both of the sites.

Table 8. Effect of fertilizer recommendations on total crop value, total fertilizer cost and the resulting economics on both very high and medium-high testing sites at Waseca from 1980-85.

	Very High Testing Site			Medium-High Testing Site		
	6-Yr Total			6-Yr Total		
Lab	Crop value[1/]	Fert. cost	Return[2/]	Crop value[1/]	Fert. cost	Return[2/]
	$/A					
A&L	1926	337	-101	2154	371	+180
Harris	1946	352	- 96	2159	435	+121
MVTL	2009	248	+ 71	2159	283	+273
Cropmate	1999	407	- 98	2159	432	+124
U of M	1962	206	+ 66	2165	255	+307
Check	1690	0	---	1603	0	---

1/ 3.00, 2.40, 3.00 and 2.07/bu used for corn in 1980, 1981, 1983 and 1985 respectively and 5.50/bu and 6.00/bu used for soybeans in 1982 and 1984, respectively, for a six-year total crop value.

2/ Return over 6-year period = crop value - (fertilizer cost & value of check treatment).

SIX-YEAR SUMMARY

Economic returns to the fertilizer recommended at the very high testing site ranged from sizable losses to modest gains (Table 8). Net return over the 1980-85 period was highest with the MVTL ($71/A) and U of Mn ($66/A) recommendations. Negative returns ranging from -$96/A to -$101/A were found with the higher cost recommendations provided by A&L, Harris and Cropmate. Part of the low overall return on this site was due to fertilizer recommendations for a yield goal of 180 bu/A of corn in 1980 while the yields obtained barely exceeded 100 bu/A due to drought stress conditions.

On the medium-high testing site yield responses paid for the fertilizer recommendations made by all five laboratories (Table 8). However, net return was highest with the lowest cost fertilizer recommendations. The higher cost recommendations given by A&L, Harris, and Cropmate resulted in lowest economic return. It is interesting to note the very narrow range in crop value among the five laboratories over this 6-year period (a low of $2154/A to a high of $2165/A).

Soil samples from the 0-7" layer were taken in August 1985 from all plots, composited according to the respective laboratory, and sent to the U of Mn lab. The purpose of this was to determine the effect of the various amounts of fertilizer on the soil test levels after the six years of application. Soil test values shown in Table 9 indicate substantial differences in soil pH, P, K and Zn between the unfertilized check and the fertilized treatments. Soil pH was lowered by as much as 0.7 pH unit with the N applications. Soil test P and K were maintained in the high to very high ranges with all fertilizer recommendations. In addition, the magnitude of the soil P & K values was closely related to the amount of P and K applied. Slightly higher soil SO_4-S and Zn levels were found with the laboratories that recommended these nutrients.

Figure 1 shows the relationship between the amount of P_2O_5 applied with each of the laboratories and the soil test P level. At the medium-high soil test P increased linearly at a rate of 1 lb P/A for each 19 lb P_2O_5 applied/A. Soil test P declined very little over the 6-yr period at this site when no fertilizer P was added. At the very high testing site soil test P dropped from 56 to 32 lb P/A or on the average 4 lb P/year when no fertilizer P was applied. Addition of P with the five long-term laboratory recommendations resulted in a gain of 1 lb soil test P for every 9 lb P_2O_5 applied. In addition, fertilizer P recommended by Harris and Cropmate raised the soil test considerably over the initial very high tests found in 1980.

In summary, maintenance and buildup fertilization philosophies, which continue to recommend fertilizer P and K and sometimes S and micronutrients regardless of soil test level, clearly result in high fertilizer costs and poor economic return to the farmer. Soil testing should be used to determine what and how much fertilizer should be applied so as to maximize the farmers' profits.

Table 9. Soil test results after 6 years of fertilizer with the five laboratories recommendations.

Laboratory	Soil pH	Bray Ext. P	Exch. K	Ext. SO_4-S	Zn
		----- lb/A	------	------ ppm	------
		Very high testing site[1/]			
A&L	5.7	59	384	10	3.0
Harris	5.6	71	400	10	2.0
MVTL	5.9	59	320	5	2.1
Cropmate	5.8	76	356	6	1.8
U of Mn.	5.9	50	340	7	1.1
Check (No fert.)	6.3	32	275	6	1.2
		Medium high testing site[2/]			
A&L	6.5	39	334	7	3.1
Harris	6.6	44	342	7	2.3
MVTL	6.5	39	308	5	1.5
Cropmate	6.6	44	332	3	2.0
U of Mn.	6.8	35	290	4	1.3
Check (No fert.)	6.9	15	282	6	1.4

1/ Initial tests in 1980 were pH = 5.4, P = 56, K = 318.
2/ Initial tests in 1980 were pH = 6.4, P = 18, K = 294.

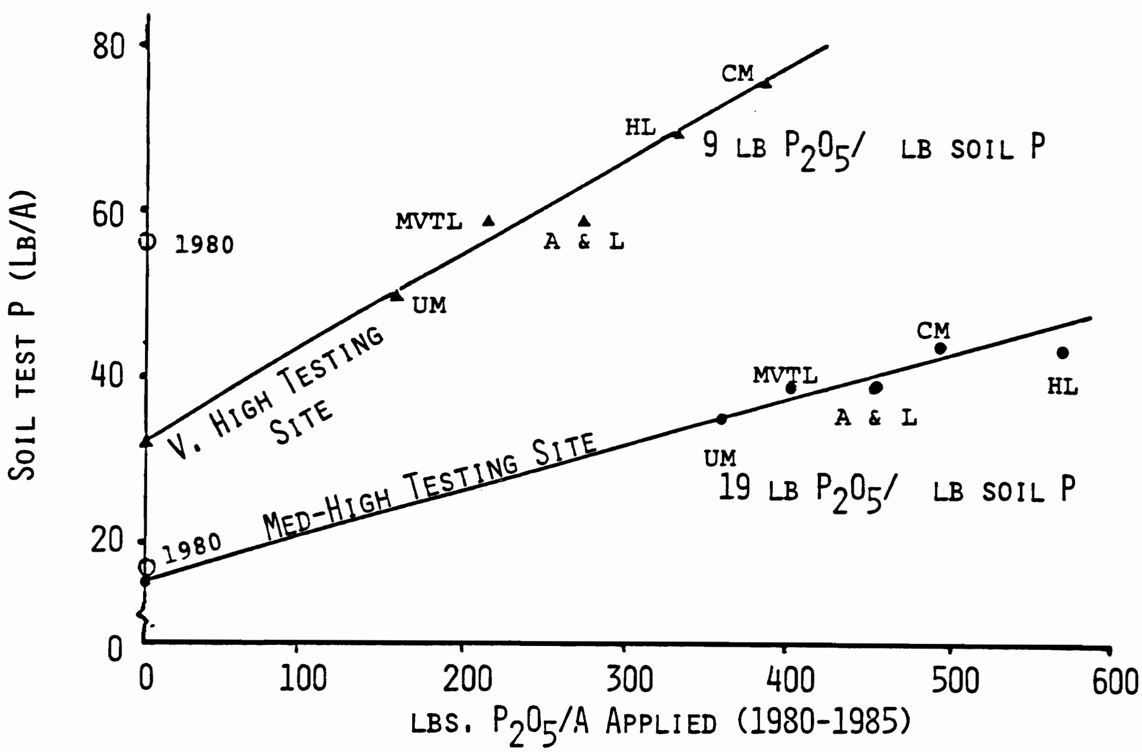

Fig. 1. Relationship between amount of P applied and soil test P.

CONSERVATION TILLAGE FOR CORN AND SOYBEAN PRODUCTION

Waseca, 1985

G. W. Randall and J. B. Swan

With increasing emphasis on controlling erosion and minimizing energy requirements (time, labor, and fuel), tillage practices have changed markedly over the last decade. Many of tillage practices have come to be known as "conservation tillage". To fit this definition, a tillage practice must leave 30% of the soil surface covered with residue after planting.

EXPERIMENTAL PROCEDURES

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

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

Ridges for the ridge plant treatment in 1985 were built in June, 1984. After the 1984 corn harvest stalks were chopped and the moldboard and chisel plow treatments were performed. On May 9 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 1986 corn were prepared in July.

Soybeans (Hardin) were planted in 30" rows at a rate of 200,000 plants/A on May 18. All treatments except no-till were planted with a John Deere 7100 planter equipped with 2" fluted coulters. B&H ridge cleaners were attached to the planter for the ridge-plant treatment. Because of high surface soil density with no tillage, seeding depth was not adequate with this planter. Thus, a JD 7000 planter was used to get better seeding depth on this tillage treatment. Ten gallons/A of 7-21-7 was used as the starter treatment.

Broadcast P and K were not applied for the 1985 soybean crop because of very high soil tests. Soil tests on this site in 1984 averaged: pH=6.7, Bray $_1$ extractable P=60 lb/A and exchangeable K=424 lb/A. Chemical weed control consisted of 3 lb Amiben and 3½ lb Lasso/A applied preemergence. Due to the heavy early-season weed pressure, tillage treatments that did not receive spring secondary tillage (ridge plant and no tillage) were treated with a "burndown" treatment of 1 qt Roundup/A on May 21. 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 4 from sprayed and unsprayed areas. On July 15, one-half of each replicate was treated with a postemergence application of Poast at a rate of ¼ lb/A with 1 qt of oil concentrate for grass control. Treatments 2, 3, 4, and 5 were cultivated on June 17.

Surface residue coverage was measured by the line-transect method on April 15 prior to spring tillage and on May 22 after planting. Soybean leaf samples were taken on July 26 (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 May 3 prior to disturbance of the ridge, 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 and at an angle into to the

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Table 1. Influence of tillage methods, starter fertilizer and Poast herbicide on soybean production at Waseca in 1985.

Tillage	Starter[1/] fertilizer	Poast[2/] herbicide	Population	Seed Moisture	Yield
			ppA x 10^{-3}	%	bu/A
No tillage	S	P		14.8	40.8
"	S	NP	126	14.6	40.8
"	NS	P		14.9	39.4
"	NS	NP	100	14.6	41.0
Fall plow, f. cult.	S	P		14.7	51.7
" "	S	NP	202	14.7	53.0
" "	NS	P		14.6	50.3
" "	NS	NP	196	14.7	50.6
Fall chisel, d., f. cult.	S	P		14.6	48.8
" "	S	NP	189	14.6	50.8
" "	NS	P		14.6	47.0
" "	NS	NP	201	14.4	46.6
Ridge Plant	S	P		15.1	46.4
"	S	NP	196	14.9	48.8
"	NS	P		15.0	49.1
"	NS	NP	195	15.0	48.6
Spring disk (2x)	S	P		14.8	49.2
"	S	NP	174	14.6	47.6
"	NS	P		14.7	48.3
"	NS	NP	183	14.6	46.8
Individual Factors					
Tillage					
No tillage			113	14.7	40.5
Fall plow			199	14.7	51.4
Fall chisel			195	14.5	48.3
Ridge plant			196	15.0	48.2
Spring disk (2x)			179	14.7	48.0
Significance Level (%):[3/]			99	97	99
BLSD (.05) :			23	.3	3.0
Starter Fertilizer					
Starter			177	14.7	47.8
No starter			175	14.7	46.8
Significance Level (%):[3/]			24	37	88
Poast Herbicide					
Poast				14.8	47.1
No Poast				14.7	47.5
Significance Level (%):[3/]				91	43
Interactions				Significance Levels(%)[3/]	
Tillage x SF			59	05	66
Tillage x Poast				26	30
SF x Poast				04	52
Tillage x SF x Poast				13	20
CV(%)			11.6	1.7	6.2

1/ S = starter fertilizer used: NS = no starter fertilizer used.

2/ P = Poast herbicide used: NP = no Poast herbicide used.

3/ Probability level of significant difference between means.

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.

RESULTS

Significant differences in population, seed moisture at harvest, and soybean yields were found among the tillage treatments (Table 1). Due to the density of the surface soil and the dry conditions following planting, plant population with the no tillage (NT) treatment was significantly lower than with the other tillage treatments. Even though a heavier planter was used, seeding depth was rather shallow and germination was poor. Starter fertilizer had no effect on plant population, seed moisture, and seed yield.

Seed moisture at harvest was slightly higher with the ridge-plant (RP) treatment and lowest with the fall chisel (CP) system. These differences were slight and are statistically significant only because of the low variability (CV=1.7). The Poast treatments had no effect on seed moisture.

Yields were significantly higher for the moldboard plow (MP) treatment compared to the CP, RP, and spring disk (SD) treatments. Identical yields were found with the CP, RP, and SD tillage systems. Yields with NT were approximately 20% lower than the other tillage systems. Because there was no effect of the Poast treatments on yield and no interactions with tillage, the impact of weed competition was judged to be minimal this year. Thus, the primary reason for the reduced yields with NT appears to be largely due to lower plant population and slightly slower emergence.

Percent surface residue cover measured before spring tillage showed highest amounts with the NT (96%) and SD (92%) systems. The RP system also had a high level of coverage (76%) and an intermediate level with CP (41%). Almost no residue was left on the surface with the moldboard plow (8%). After planting, residue coverage decreased substantially with the RP and SD systems. Only the NT, CP, and RP systems met the strict conservation tillage definition of 30% residue coverage.

Table 2. Influence of tillage methods for soybeans after corn on surface residue before spring tillage and after planting at Waseca in 1985.

	Surface Residue	
Treatment	Before spr. tillage	After planting
	%	%
No tillage	96	93
Fall plow	8	5
Fall chisel	41	30
Ridge plant	76	38
Spring disk (2x)	92	23
Significance Level (%):	99	99
BLSD (.05) :	6	13
CV (%) :	6.6	24.

The rate of seedling emergence was determined by counting the number of plants whose cotyledons had emerged in 40' of row/plot/day from the 7th through the 18th day following planting. Emergence as a percent of final stand, shown in Table 3, indicates rapid and uniform emergence among the MP, CP, RP, and SD tillage systems. Emergence was delayed approximately 4 days with NT. Ninety percent emergence was reached 9 days after planting with MP & CP systems, 10 days after planting with the RP system, 11 days with the SD system, and 13 days with the NT system.

Leaf samples taken at the R1 stage show no effect of tillage on any of the nutrient concentrations (P=90% level) except for Mg and Fe (Table 4). For some unexplainable reason Mg was slightly higher with the two most reduced systems (NT and RP). The slightly higher Fe concentrations with MP tillage may have been due to soil contamination associated with rain splashing soil onto the plants. Starter fertilizer significantly increased the leaf P, K, Ca, and Mn concentrations. For the most part these differences were very small. There was no interaction between starter fertilizer and tillage system on the nutrient concentrations.

Weed counts (broadleaf and grass) were taken between the 4th and 5th rows from 4 randomly placed 10 ft^2 sections/plot 17 days after preemergence herbicide application (Table 5). Weed pressure from broadleaf weeds was not great, as broadleaf weed counts were low from both herbicide treated and untreated areas. Grasses were controlled extremely well in the MP and RP systems and to a lesser degree with CP tillage. Considering the extremely high population of grasses with NT when no herbicide was used, weed counts were reduced by 94% with the Lasso & Amiben combination and the Roundup burndown program. Grass weed control was least adequate with the SD tillage system.

Table 3. Influence of tillage methods on the emergence progress of soybeans following corn at Waseca in 1985.

Treatment	7	8	9	10	11	12	13	16	18
	Days Post Planting — % emerged								
No tillage	0	22	48	52	70	84	91	99	100
Fall plow	1	84	93	94	98	99	99	100	100
Fall chisel	1	80	90	92	97	98	99	100	100
Ridge plant	2	76	88	91	97	99	100	100	100
Spring disk (2x)	0	75	85	87	93	96	100	100	100

Table 4. Influence of tillage methods and starter fertilizer for soybeans on leaf nutrient concentration at the R1 stage at Waseca in 1985.

Treatment: Tillage	Starter fert.	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
		%				ppm				
No tillage	S	.38	2.01	1.08	.40	70	37	38	9.2	42
"	NS	.36	1.88	1.05	.40	68	35	38	9.5	41
Fall plow	S	.35	2.02	1.09	.35	78	35	38	8.2	41
"	NS	.31	1.89	1.11	.36	74	34	36	8.4	39
Fall chisel	S	.32	1.94	1.17	.38	70	40	37	8.4	42
"	NS	.30	1.80	1.11	.37	73	37	37	8.7	40
Ridge plant	S	.35	1.92	1.17	.41	75	37	38	8.9	42
" "	NS	.35	1.87	1.11	.40	71	35	38	9.2	42
Spring disk (2x)	S	.34	1.91	1.11	.39	73	39	39	8.8	42
" "	NS	.31	1.84	1.09	.37	71	38	38	8.7	41
Individual Factors										
Tillage										
No tillage		.37	1.95	1.07	.40	69	36	38	9.4	42
Fall plow		.33	1.96	1.10	.36	76	35	37	8.3	40
Fall chisel		.31	1.87	1.14	.38	72	38	37	8.5	41
Ridge plant		.35	1.90	1.14	.41	73	36	38	9.1	42
Spring disk (2x)		.33	1.88	1.10	.38	72	39	38	8.8	41
Significance Level (%):		71	77	62	99	92	59	33	80	53
BLSD (.05)(.10)* :					.02	4.2*				
Starter fertilizer										
Starter		.35	1.96	1.12	.39	73	38	38	8.7	42
No starter		.33	1.86	1.09	.38	71	36	37	8.9	41
Significance Level (%):		99	99	96	53	82	98	86	96	99
Interactions										
Tillage x SF										
Significance Level (%):		48	27	56	42	73	23	62	32	99
CV (%) :		6.6	3.7	3.9	4.4	4.9	5.6	4.4	3.6	1.9

Postemergence application of Poast herbicide 58 days after planting provided additional weed control but, because of the lower weed pressure across all tillage systems, did not affect soybean yields (Table 1).

Table 5. Weed populations on June 4 as affected by tillage and herbicide for soybeans following corn at Waseca in 1985.

Treatment	Herbicide[1]		No Herbicide	
	Grasses	Broadleaves	Grasses	Broadleaves
	plants/10 sq. ft.[2]			
No tillage	46	1	816	2
Fall plow	7	2	7	1
Fall chisel	16	1	33	1
Ridge plant	1	1	12	3
Spring disk (2x)	85	1	88	2

1/ 3 lb Amiben and 3½ lb Lasso/A preemergence. No tillage and ridge-plant trts received 1 qt/acre Roundup preemergence.

2/ Average over 4 replications.

Soil samples taken from three different positions from the row in the RP system prior to planting showed slightly more acidic conditions in the ridge than in the valley area (Table 6). Soil test P in the top 4" was considerably higher when the samples were taken at an angle under the row starting from 6" to the side of the row. Perhaps some old starter fertilizer bonds were hit when obtaining these samples. Soil P was consistently higher at each depth with the ridge samples compared to the 15" (valley) sample. Phosphorus accumulated at very high levels in the top 4" of the ridge samples and in the top 2" of the valley sample. Soil test K accumulated at very high levels in the top 2" regardless of sampling position. At lower depths soil K was slightly higher when samples were taken in the ridge area. In summary, it appears that after 11 years of ridge tillage, soil test P and K are very high throughout the ridged area and that soil sampling position in this area is not important.

Table 6. Soil test pH, P and K after soybean planting and before ridging after 11 years continuous ridge planting at Waseca.

Profile depth	Position of ridge sample[1]		
	In row	6" to side of row	15" between row
inches	Soil pH		
0-2	6.3	6.4	6.6
2-4	6.4	6.4	6.8
4-6	6.6	6.8	6.9
6-9	6.8	6.9	7.0
	Soil P (lb/A)		
0-2	93	151	76
2-4	69	126	36
4-6	32	33	22
6-9	22	28	16
	Soil K (lb/A)		
0-2	665	660	665
2-4	530	515	425
4-6	395	360	345
6-9	335	300	280

1/ Average over 4 replications; 8 cores composited/replication.

SUMMARY - 1985

This was the second crop of soybeans grown in this long-term study with continuous corn from 1975 through 1982, soybeans in 1983, and corn in 1984. Surface residues prior to planting were greater than 70% with NT, RP, and SD tillage and remained at 30% or greater after planting with NT, CP, and RP tillage. Plant emergence was approximately 4 days slower with NT compared to the other tillage systems. Weed pressure was reduced considerably with the Lasso + Amiben preemergence application and the Roundup burndown treatment. Lowest weed pressure was noted with the RP and MP tillage systems. Highest weed counts were with the NT and SD systems. Leaf nutrient concentrations were generally unaffected by the tillage and starter fertilizer treatments. Yields averaged about 3 bu/A higher with MP tillage compared to the CP, RP, and SD systems. Yields were reduced about 20% with NT. This decrease was most likely due to the significantly lower plant population, resulting from the dense surface soil and shallow planting depth. Soil samples taken both in the top and into the side of the ridge showed very high levels of P and K and indicated that the entry position of the soil tube into the ridge when taking samples makes little difference. The accumulation of P and K appeared to be fairly uniform at each depth within the ridge and higher than from samples taken mid-way between the ridges.

ELEVEN-YEAR YIELD SUMMARY

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

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

Yields with no tillage continue to be significantly below the other tillage systems since converting to a corn/soybean sequence (Table 7). Both corn and soybean yields in this sequence averaged about 6% higher with the moldboard plow system compared to the chisel plow, ridge plant, or spring disk systems with virtually no difference among the latter three systems.

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

Treatment		Cont. Corn Yield		Soybeans	Corn
Tillage	Starter	1975-82	1979-82	1983 & 85	1984
		bu/A			
No tillage	Yes	129.2	140.6	36.6	137.2
"	No		136.0	35.4	125.4
Fall plow	Yes	154.5	170.9	48.4	155.0
"	No		170.8	47.8	161.6
Fall chisel	Yes	144.4	161.8	46.1	148.6
"	No		155.5	43.8	144.7
Ridge plant	Yes	149.2	161.5	45.8	148.2
"	No		156.4	45.0	137.2
Till plant (flat)[1/]	Yes	144.9	154.8	45.3	156.2
"	No		157.4	45.6	154.2

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

PRELIMINARY EVALUATION OF THE EFFECT OF SUBSOIL K LEVEL ON RESPONSE OF CORN TO K FERTILIZATION

G. Rehm, B. Anderson, G. Cremers, and M. O'Leary

Background:

Except for nitrogen, fertilizer recommendations are based on the analysis of soil samples collected from the plow layer, usually the top 6 to 8 inches of soil. Very little attention has been devoted to the effect of subsoil levels of major nutrients on fertilizer requirements for those nutrients. Past glacial activity in Stearns County provides a unique opportunity to study the effect of potassium (K) concentration in the subsoil on the response of corn to K fertilization.

The red glacial till in the county has a K concentration that is classified as low or very low. The gray glacial till has a K concentration that is classified as being in the medium to medium high range.

Experimental Procedure:

Four sites were selected for this study in Stearns County in 1985. The parent material at two sites was red till while the parent material at the other two was gray till. Relevant soil properties for the sites are listed in Table 1.

Three rates of K (50, 100, 150 lb./acre) supplied as 0-0-60 were combined with a control treatment in a randomized block design with four replications at each site. All treatments received 100 lb. 18-46-0 and 200 lb. gypsum per acre to supply P_2O_5 and S. Urea was used to supply 30 lb. N per acre before planting. All of these materials were broadcast and incorporated before planting. A second application of urea was made at the 8-leaf stage to supply 70 lb. N per acre. Ear leaf samples were collected at silking. Yields and grain moisture values were recorded in mid-October.

Results and Discussion:

The effect of rate of applied K on grain yield, grain moisture at harvest and concentration of K in the ear leaf tissue at silking in summarized in Table 2. Data were collected from 3 of the 4 original sites. Erratic stand at the 4th site prevented collection of meaningful data.

Neither rate of applied K nor level of subsoil K had a significant effect on grain yield in 1985. Except for the Dobis location, neither variable had any effect on the grain moisture at harvest. Grain moisture did vary with location, but this was due to variability in hybrid and planting date used at each location. The cooperating farmers were responsible for planting (without starter fertilizer) and cultivation of the plots.

The concentration of K in the ear leaf tissue was not influenced rate of applied K. The average K concentration did increase at the Dobis location as rate of fertilizer K was increased. These increases, however, were not highly significant.

The results of this study raised more questions than were answered. Considering the combination of levels of K in the plow layer as well as the subsoil, a yield response to fertilizer K was not expectd at the Pratt and Elfering locations (Table 1). The K content of the soil at the Dobis location, however, was low. Yet there was no response to added K. Based on the current standards used, there is no apparent explanation for this lack of response. Perhaps there is a real need to evaluate the usefulness of the current soil test procedure used to extract K from sandy soils.

Table 1. Relevant soil properties of the experimental sites in Stearns County, 1985.

Name	Property	Depth (in) 0-6	6-12	12-24	24-36
Dobis	pH	6.4	6.4	6.1	5.4
Dobis	Bray & Kurtz #1 P,lb/acre	50	37	40	58
Dobis	Extractable K, lb/acre	51	42	52	97
Pratt	pH	5.8	6.1	6.2	7.2
Pratt	Bray & Kurtz #1 P,lb/acre	95	38	28	15
Pratt	Extractable K, lb/acre	200	247	221	208
Elfering*	pH	6.8	7.0	6.9	7.0
Elfering	Bray & Kurtz #1 P,lb/acre	72	30	27	17
Elfering	Extractable K, lb/acre	300	144	138	110

*History of heavy manure use at this location. No manure used at other locations.

Table 2. Effect of rate of applied K on grain yield, grain moisture at harvest and concentration of K in ear leaf at silking.

K Applied	Dobis Yield	Dobis Grain Moisture	Dobis Ear Leaf K	Pratt Yield	Pratt Grain Moisture	Pratt Ear Leaf K	Elfering Yield	Elfering Grain Moisture	Elfering Ear Leaf K
lb/acre	bu/acre	-------%	------	bu/acre	-------%	------	bu/acre	-------%	-----
0	123.6	29.1	1.58	118.9	35.2	2.02	124.4	27.2	2.46
50	109.6	30.0	1.71	131.2	34.9	1.95	124.6	25.7	2.58
100	116.3	30.9	1.87	124.9	34.8	2.06	121.5	28.6	2.54
150	116.5	30.8	1.82	138.3	34.5	2.06	127.4	28.5	2.55
PR>F(%)	63	99	79	80	10	24	30	66	45
BLSD(.05)	---	0.9	---	---	---	---	---	---	---
C.V.(%)	9.1	1.8	10.8	9.4	4.0	8.7	5.6	4.4	4.8

HIGH PHOSPHORUS AND POTASSIUM RATES IN A CORN-SOYBEAN ROTATION

1985

G. W. Randall, S. D. Evans, and W. W. Nelson

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.

	Application Year (Fall)	
Trt. No.	1973,'76,'79,'82	1974,'75,'77,'78,'80,'81,'83,'84
	------------------ 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 from 1980 through 1984.

6/ 100 + 0 was applied at all locations from 1980 through 1984.

The P and K materials were broadcast on soybean residue and chiseled in at all locations in the fall of 1984. 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 for corn at each of the stations are presented in Table 2. Management practices providing for optimum yields were employed at each location.

At Lamberton each of the plots was split with the east half planted to soybeans and the west half to corn. Soybeans (Corsey 79) were planted in 30" rows at a rate of 9 seeds/foot on May 7. Weeds were controlled with a ppi application of Treflan. Plant tissue samples were not taken. Soybeans were harvested October 21.

Planting in 1983 went smoothly due to the warm and dry conditions in late April and during May. Although some moisture stress occurred at Waseca during July, conditions were generally very good for exceptional yields at all three locations. Weed and insect control were excellent at all locations.

Table 2. Experimental procedures for the high P and K rate study on continuous corn at the three branch stations in 1985.

	Branch Station		
Variable	Lamberton	Morris	Waseca
Planting date	5/7	5/1	5/1
Row spacing	30"	30"	30"
Planting rate	26,000	27,800	31,000
Hybrid	Pioneer 3732	Pioneer 3901	Pioneer 3732
Nitrogen rate	150#	140#	160#
Herbicide	3# Lasso + 2# Bladex/A ppi	3# Lasso + 2.2# Bladex/A preemerge	3½# Lasso + 3½# Bladex/A preemerge
Insecticide	Counter 1 lb/A	Counter 1.8 lb/A	None
Harvest date	10/2	10/14	10/16

RESULTS AND DISCUSSION

Soil samples taken at the end of the 1985 growing season indicate significant differences in Bray P_1 extractable P and exchangeable K at all locations (Table 3). There appeared to be a good linear response between extractable Bray P_1 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 all locations were quite similar to those obtained in 1984. Soil test K values were approximately 25% lower than in 1984 at Lamberton, 15% higher at Morris and remained the same at Waseca. Soil P values obtained with Olsen's $NaHCO_3$ test on the calcareous soil at Morris were slightly but consistently lower than the values from the Bray P_1 test (1:10 ratio).

Table 3. Soil test values as influenced by 12 years' application of P and K treatments at Lamberton, Morris, and Waseca.1/

Treatment		pH			P				K		
No.	Description	La	Mo	Wa	L_{10}	M_{10}	M_{OL}	W_{10}	La	Mo	Wa
	lb P_2O_5+K_2O/A2/				----------	----------	----------	lb/A	----------	----------	----------
1	0 + 0	5.7	7.8	6.5	51	9	6	17	242	396	239
2	0 + 100	5.7	7.8	6.7	39	9	6	12	368	557	281
3	50 + 100	6.1	7.7	6.5	73	43	37	44	337	489	275
4	100 + 100	5.6	7.7	6.6	106	85	79	79	308	499	288
5	0 + 100	5.8	7.7	6.7	68	26	22	37	328	500	301
6	100 + 0	5.6	7.6	6.7	104	86	77	75	237	373	249
7	100 + 50	5.7	7.7	6.7	106	81	72	72	302	454	257
8	100 + 0	5.8	7.6	6.4	90	96	86	81	267	426	246
9	0 + 100	5.9	7.7	6.7	44	21	14	18	305	448	272
10	100 + 0	5.7	7.8	6.6	74	37	33	61	258	405	248
Signif. Level (%):		45	94	74	99	99	99	99	99	99	90
BLSD (.05),(.10)*:			.2		22	18	14	12	34	45	46*
CV (%) :		5.2	1.2	2.7	21.	26.	24.	16.	8.5	7.	9.6

1/ Samples were taken in September before the 1985 treatments were applied.
2/ Rates applied in fall of 1984 for 1985 crop.

Soil test K was influenced (P = 90% level) by the K applications at all locations in 1985 (Table 3). The response to annual K applications was not as pronounced as with P. Highest soil test K values were associated with the annual application of 100 lb K_2O/A. Soil pH was not related to the P and K treatments.

Soil samples were taken from both the corn and soybean areas in 1985 (Table 4). Consistent differences in soil pH, extractable P or exchangeable K were not found between the corn and soybean crops regardless of past fertilizer treatment.

Table 4. Soil test values as influenced by the crop grown at Lamberton.[1/]

Treatment[2/]	Corn pH	Corn P	Corn K	Soybeans pH	Soybeans P	Soybeans K
lb P_2O_5+K_2O/A		-- lb/A --			-- lb/A --	
0 + 0	5.7	51	242	5.8	58	228
100 + 100	5.6	106	308	5.7	102	315

[1/] Samples taken in September before the 1985 treatments were applied.
[2/] Twelve-year annual application rate.

To determine the depth of accumulation of P and K from the long-term fertilizer additions, soil samples were taken in 6-inch increments to a depth of 36 inches from both the continuous check and annual 100-lb P_2O_5 and K_2O rates (Table 5). Soil pH was unaffected at both locations by the treatments. Fertilizer P accumulated almost entirely in the top 12 inches at both locations. Potassium also accumulated in the top 12 inches at Lamberton. At Waseca there was some indication of accumulation of soil K to a depth of 30" with the annual 100 + 100 treatment.

Table 5. Influence of 12 years' fertilizer P and K additions on the accumulation of P and K in the soil profile at Lamberton and Waseca.

Depth.	Soil pH, Trt.[1/]: 0 + 0	Soil pH, 100 + 100	Soil P, 0 + 0	Soil P, 100 + 100	Soil K, 0 + 0	Soil K, 100 + 100
inches			----------	lb/A	----------	
			Lamberton			
0-6	6.1	5.8	40	95	280	418
6-12	5.9	5.9	33	80	258	363
12-18	6.6	6.6	4	8	194	207
18-24	7.2	7.2	2	2	154	162
24-30	7.8	7.8	2	2	122	132
30-36	8.0	8.0	2	2	124	134
			Waseca			
0-6	6.7	6.8	13	82	215	298
6-12	6.7	6.8	7	47	219	281
12-18	6.8	7.2	3	7	223	308
18-24	7.1	7.5	3	4	218	315
24-30	7.4	7.7	3	3	210	290
30-36	7.5	7.7	3	3	212	228

[1/] Twelve-year annual application rate of pounds P_2O_5 and K_2O/A.

Approximately 5 to 6 weeks after planting, ten plants were selected randomly from each plot, measured, harvested, dried and weighted to determine early plant growth. Early weight and height of the corn were increased significantly by the treatments at all three locations (Table 6). Both early plant weight and height were lowest with the check treatment (no. 1). 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 (trt. no. 2). At Waseca, plant weight and height were increased by 25 and 10%, respectively, with the 100-lb K_2O treatment over the 0-lb K_2O rate. Responses to K were not found at the other two locations.

Table 6. Early plant growth as influenced by high P and K rates at the three experimental sites in 1985.

Treatment		Weight			Height (Extended)		
No.	Description	La	Mo	Wa	La	Mo	Wa
	lb P_2O_5+K_2O/A	-- g/dry plant --			------ cm -----		
1	0 + 0	2.7	2.6	3.9	36	48	52
2	0 + 100	3.0	3.1	4.8	38	50	59
3	50 + 100	3.0	4.2	5.7	40	59	63
4	100 + 100	3.8	4.5	6.4	43	61	67
5	0 + 100	2.8	4.1	5.2	38	57	62
6	100 + 0	3.5	4.4	5.1	40	58	61
7	100 + 50	3.2	4.5	5.6	42	60	64
8	100 + 0	3.7	4.9	5.6	42	63	62
9	0 + 100	2.7	3.5	4.6	36	55	58
10	100 + 0	3.2	4.2	5.6	41	57	61
Signif. Level (%):		99	99	99	97	99	99
BLSD (.05) :		0.5	0.7	0.7	5	5	3
CV (%) :		10.	12.	8.4	7.8	6.3	3.0

The leaf opposite and below the ear was sampled at all locations in 1985 and was submitted for analysis (Table 7). At Lamberton, leaf K concentrations were increased significantly from 1.14% K to about 1.8% with the 100-lb K_2O rate. Concomitant decreases in leaf Ca, Mg, Mn, and Zn were found with the higher leaf K concentrations. Leaf P was not affected by the P treatements.

At Morris and Waseca, the 50 and 100-lb P_2O_5 treatements increased leaf P, Ca, Mg, and Fe above the 0-lb rates and decreased leaf Zn (Table 7).

Although soil test K was very high at Morris, the K treatments increased leaf K and decreased leaf Ca, Mg, and Cu. Leaf K concentrations at Waseca were extremely low (ca 0.80%) when no K was added. The 100-lb K_2O rate almost doubled the K concentrations while the 50-lb rate had a slight effect. Leaf Ca, Mg, and Mn concentrations were reduced by the 50 and 100-lb K_2O rates.

Final plant population was not affected by the P and K treatments at Morris and Waseca (Table 8). For some unexplainable reason, differences were found at Lamberton.

Slight but inconsistent differences in ear moisture were found at harvest at Lamberton (Table 8). Grain moisture was reduced significantly by the P treatments at Morris and to some extent at Waseca. The K treatments had no effect on grain moisture.

Silage yields were increased by about 30% with the 50 and 100-lb P_2O_5 treatments at Morris (Table 9). Although silage yields at Waseca were approximately 10% higher with the 100-lb K_2O treatments, this was only significant at the P=77% level. Silage and grain yields were not affected at Lamberton.

Grain yields were increased by about 30 and 15% with the 50 and 100-lb P_2O_5 rates at Morris and Waseca, respectively (Table 9). Yields were not increased with the 100-lb rate over the 50-lb rate. The K treatments did not affect yields at Morris, but did result in slight yield increases at Waseca. Considering the very low leaf K concentrations at silking, it is surprising that larger grain yield responses were not found.

Soybean yields at Lamberton were affected significantly (P=91% level) (Table 10). Lowest yields were associated with the 0-lb K_2O treatments and were increased rather consistently with the 100-lb K_2O rate. Soybean height was not influenced by the treatments.

Table 7. Effect of high P and K rates on the nutrient concentrations in the corn leaf at Lamberton Morris, and Waseca in 1985.

Treatment No.	Treatment Description	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb P_2O_5+K_2O/A	%				ppm				
		Lamberton								
1	0 + 0	.25	1.14	.51	.56	130	67	38	5.9	9.8
2	0 + 100	.24	1.78	.44	.33	120	43	29	6.1	11.2
3	50 + 100	.26	1.84	.46	.35	124	49	27	6.5	10.3
4	100 + 100	.26	1.76	.46	.34	128	46	26	5.7	9.3
5	0 + 100	.24	1.82	.44	.36	121	54	28	6.8	10.2
6	100 + 0	.26	1.14	.54	.56	128	67	33	4.6	10.1
7	100 + 50	.26	1.62	.47	.39	128	53	31	5.6	9.6
8	100 + 0	.26	1.51	.48	.42	130	55	26	6.2	8.9
9	0 + 100	.26	1.75	.46	.38	126	51	30	6.2	10.5
10	100 + 0	.25	1.25	.52	.52	126	54	29	5.0	11.4
	Signif. Level (%):	88	99	99	99	93	97	97	98	57
	BLSD (.05),(.10)*:		.20	.06	.06	8*	17	8	1.3	
	CV (%) :	3.7	9.3	7.6	11.	3.9	18.	16.	13.	15.
		Morris								
1	0 + 0	.20	1.60	.55	.51	198	96	38	8.2	6.8
2	0 + 100	.20	1.90	.51	.37	208	95	41	6.2	5.5
3	50 + 100	.28	1.95	.68	.44	266	112	28	6.4	9.2
4	100 + 100	.29	2.04	.64	.42	248	113	25	6.3	6.7
5	0 + 100	.28	2.10	.58	.42	244	99	30	6.1	8.4
6	100 + 0	.29	1.53	.74	.65	261	126	23	7.1	6.8
7	100 + 50	.30	1.90	.66	.50	247	109	23	6.1	8.6
8	100 + 0	.29	1.77	.74	.53	285	119	24	7.8	4.8
9	0 + 100	.27	1.73	.65	.55	250	106	33	6.4	8.8
10	100 + 0	.28	1.70	.69	.55	259	121	30	8.2	9.1
	Signif. Level (%):	99	99	99	99	99	99	99	99	87
	BLSD (.05) :	.03	.20	.11	.06	45	20	4	1.1	
	CV (%) :	9.2	7.7	11.	9.5	11.	11.	11.	11.	32.
		Waseca								
1	0 + 0	.21	.84	.58	.76	110	44	39	6.5	10.3
2	0 + 100	.19	1.52	.47	.46	108	37	38	7.2	10.9
3	50 + 100	.23	1.53	.50	.48	115	39	31	6.5	9.9
4	100 + 100	.25	1.43	.57	.52	117	42	27	5.7	9.7
5	0 + 100	.25	1.43	.52	.51	116	41	32	5.9	10.5
6	100 + 0	.27	.77	.67	.83	113	48	26	5.0	9.4
7	100 + 50	.25	1.14	.60	.63	119	41	26	5.1	10.1
8	100 + 0	.25	1.04	.59	.63	118	47	28	5.3	10.1
9	0 + 100	.22	1.38	.50	.52	108	37	32	6.3	10.0
10	100 + 0	.26	.80	.63	.75	110	46	28	5.0	9.5
	Signif. Level (%):	99	99	99	99	93	74	99	99	30
	BLSD (.05),(.10)*:	.02	.12	.05	.06	8.6*		5	1.2	
	CV (%) :	4.6	6.8	5.8	6.6	4.3	14.	9.7	11.	9.6

Table 8. Population and moisture at harvest as influenced by high P and K rates in 1985.

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	23.1	25.8	27.7	39.7	31.9	31.1
2	0 + 100	24.7	27.9	27.2	40.3	33.4	31.7
3	50 + 100	26.2	26.9	27.0	39.9	28.6	30.1
4	100 + 100	27.2	27.6	26.1	40.8	28.0	30.0
5	0 + 100	25.1	27.7	27.7	40.4	29.1	30.2
6	100 + 0	25.7	28.0	27.6	40.0	25.8	27.1
7	100 + 50	28.5	27.8	27.6	40.4	28.5	29.4
8	100 + 0	24.9	27.3	27.7	39.2	27.2	28.1
9	0 + 100	23.7	27.4	24.5	40.0	29.2	30.0
10	100 + 0	25.3	26.8	27.3	39.4	27.4	27.4
	Signif. Level (%):	97	67	32	96	99	99
	BLSD (.05) :	3.5			1.1	1.8	1.5
	CV (%) :	7.8	4.1	7.6	1.6	4.4	3.1

Table 9. Corn silage and grain yields as influenced by high P and K rates in 1985.

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	7.53	6.32	6.56	162.2	108.4	143.6
2	0 + 100	7.90	6.57	7.20	171.4	115.3	153.9
3	50 + 100	8.04	8.14	7.19	171.8	148.5	184.4
4	100 + 100	8.10	8.41	7.62	172.5	152.8	174.7
5	0 + 100	8.05	7.85	7.68	166.3	152.3	184.3
6	100 + 0	7.77	7.45	7.06	166.5	150.2	165.6
7	100 + 50	7.85	7.85	7.46	169.4	154.1	173.4
8	100 + 0	7.82	7.74	7.67	171.1	156.6	170.0
9	0 + 100	7.51	7.34	7.72	160.9	153.2	161.5
10	100 + 0	7.82	7.45	6.89	172.1	151.3	168.1
	Signif. Level (%):	74	99	77	85	98	99
	BLSD (.05) :		1.19			33.8	10.0
	CV (%) :	4.5	9.4	7.7	3.9	13.	3.7

Table 10. Soybean plant height and yields at Lamberton as influenced by high P and K rates in 1985.

Treatment No.	Treatment Description	Height at Maturity	Yield
	lb P_2O_5+K_2O/A	inches	bu/A
1	0 + 0	39.7	40.8
2	0 + 100	38.2	46.4
3	50 + 100	40.2	42.6
4	100 + 100	39.5	46.0
5	0 + 100	41.5	45.5
6	100 + 0	40.7	39.7
7	100 + 50	41.0	41.6
8	100 + 0	40.0	40.7
9	0 + 100	40.5	42.4
10	100 + 0	40.0	41.8
	Signif. Level (%):	19	91
	BLSD (.10) :	--	6.4
	CV (%) :	5.9	8.0

SUMMARY - 1985

These data were quite similar to past years in that yield responses were found with P at Morris and Waseca. However, slight yield responses to K were found at Waseca with corn and at Lamberton with soybeans. Concentrations of K in the earleaf were extremely deficient with the 0-lb treatment at Waseca. This is the first time in 12 years that a consistent yield response has been found to either P or K at Lamberton. Triennial applications of the 150-lb rates of P_2O_5 and K_2O appear to be equal to annual applications at the 50-lb rate.

12-YEAR SUMMARY

Corn and soybean yields for the 12-year period since the initiation of the study are presented in Tables 11 and 12 for Lamberton, Table 13 for Morris, and Table 14 for Waseca.

At Lamberton significant corn yield differences among the P and K treatments occurred in only 1 of 12 years; and in that year (1979) no relationship to either P or K was found. With soybeans, statistical yield differences were noted in 2 of 5 years with no consistent effect of either P or K in one of those two years. In the other year (1985) there was a fairly consistent response to K. Soil tests at that site have not dropped below 40 lb P/A and 240 lb K/A (Table 3) even without added P or K. Consequently the limited response to P and K over the 12-year period.

Table 11. Long-term corn yields as affected by P and K treatments at Lamberton.

	Years[1/]												12-Yr.
Trt. No.	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Avg.
	bu/A												
1	79.7	64.5	16.7	130.5	111.5	118.0	80.8	110.8	146.9	51.2	132.8	162.3	100.5
2	69.5	55.7	8.9	121.8	112.7	112.8	87.6	111.6	147.5	48.9	138.9	171.4	98.9
3	62.5	50.3	16.8	119.5	114.7	106.5	85.7	113.9	151.5	50.0	131.4	171.8	97.9
4	74.8	69.7	15.2	136.2	113.5	117.6	87.0	117.1	149.0	48.5	140.6	172.5	103.5
5	76.7	48.2	14.3	119.5	115.6	108.0	86.6	111.2	151.4	47.9	122.0	166.4	97.3
6	80.4	69.0	15.1	114.5	116.9	124.1	88.1	114.6	146.4	54.2	134.1	166.5	102.0
7	77.9	58.9	17.5	128.1	112.8	120.9	81.7	104.7	155.3	55.7	130.0	169.4	101.1
8	80.1	59.4	11.6	125.2	114.6	126.6	89.4	113.4	150.7	57.3	144.6	171.1	103.7
9	69.7	46.6	12.6	122.2	115.8	119.2	81.0	108.8	150.4	57.3	136.8	160.9	98.4
10	74.5	65.8	11.2	122.4	118.3	120.7	94.2	111.5	148.9	63.2	137.2	172.1	103.3
Signif(%)[2/]:	+	NS	NS	NS	NS	*	NS	80	34	59	82	85	
BLSD (.05) :						13.8							
CV (%)	:11.	30.	39.	11.	4.3	6.8	10.	5.0	4.1	18.	7.5	13.1	

1/ Continuous corn from 1974 to 1981. Corn following soybeans from 1982 to 1985.
2/ * and + are significant at the 95 and 90% levels, respectively. NS = not significant at the 90% level. Since 1981 all significance shown as a probability level.

Table 12. Long-term soybean yields as affected by P and K treatments at Lamberton.

	Years[1/]					5-Yr.
Trt. No.	1981	1982	1983	1984	1985	Avg.
	bu/A					
1	47.7	51.2	34.4	39.8	40.8	42.8
2	46.0	47.8	34.9	43.1	46.3	43.6
3	49.5	50.0	34.4	45.8	42.6	44.5
4	48.6	49.9	38.2	41.0	46.0	44.7
5	45.9	48.9	35.0	43.5	45.5	43.8
6	44.5	51.4	32.4	41.7	39.7	41.9
7	46.5	49.8	37.8	42.9	41.6	43.7
8	45.5	48.3	35.4	45.4	40.7	43.1
9	44.6	49.0	35.8	42.4	42.4	42.8
10	46.3	49.3	33.8	40.5	41.8	42.3
Signif. Level (%):	15	95	32	48	97	
BLSD (.05) :		2.8			6.4	
CV (%) :	9.8	3.1	11.7	9.7	8.0	

1/ Soybeans following corn for all years.

The most consistent yield responses have occurred at Morris (Table 13). Significant corn and soybean yield responses to the 50-lb P_2O_5 rate have occurred in 7 out of 12 years and in 6 of the last 7 years. The effect of the 0-lb P_2O_5 rate on soil test P shown in Figure 1 indicates a loss of 1 lb soil test P/A/year over the 12-year period. Since 1978 (5th year of the study) soil test P has averaged 10 lb P/A or less and thus, consistent yield responses have occurred. Yield responses have not occurred with the 100-lb P_2O_5 rate over the 50-lb rate and with any of the K_2O rates. Soil test K has varied considerably over the 12-yr period and does not show a statistical relationship to K application rate (Fig. 2). Based on the best fit linear regression lines (Fig.'s 1 and 2) soil test P values were changed by -1.0, +1.3, and +5.3 lb P/A/yr with the 0, 50, and 100-lb P_2O_5 rates, respectively (Table 15). Soil test K changes were positive regardless of K application rate (Table 15).

Table 13. Long-term corn and soybean yields as affected by P and K treatments at Morris.

Trt.	Years[1/]												Yield Avg.	
No.	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	10-Yr Corn	2-Yr Sb
	bu/A													
1	92.9	118.2	29.0	102.4	113.6	90.9	107.1	120.5	47.1	106.5	38.3	108.4	98.9	42.7
2	89.6	125.9	23.4	98.4	113.1	90.7	108.5	115.2	45.6	105.1	36.3	115.3	98.5	40.9
3	91.9	125.8	26.4	101.4	119.7	99.6	123.8	130.5	53.0	129.0	44.6	148.5	109.7	48.8
4	94.6	127.1	35.8	98.0	124.6	110.5	127.0	136.1	56.3	128.2	45.3	152.8	113.5	50.8
5	98.6	127.4	31.0	97.2	119.8	110.6	120.8	132.0	54.6	128.3	43.2	152.3	111.8	48.9
6	91.3	125.6	33.4	94.1	121.4	113.3	127.3	130.1	56.7	126.6	46.1	150.2	111.1	51.4
7	95.5	126.3	33.6	97.4	123.3	105.7	126.7	132.1	54.7	133.6	46.8	154.1	112.8	50.7
8	93.1	124.5	24.3	98.4	124.7	107.9	121.5	129.4	57.8	125.7	45.0	156.6	110.6	51.4
9	97.8	128.0	32.6	99.8	119.5	102.8	120.1	128.3	57.6	124.7	45.1	153.2	110.7	51.4
10	101.2	141.4	30.6	102.8	120.1	101.0	126.1	129.8	53.1	127.6	45.4	151.3	113.2	49.2
Signif:	NS	*	NS	NS	NS	*	NS	**	99	94	99	98		
BLSD(.05):		12.1				17.5		11.1	4.8	19.0	4.2	33.8		
CV(%)	:	3.	28.	6.	5.3	9.9	9.0	5.3	6.3	9.9	6.6	13.4		

1/ Continuous corn from 1974-1981; soybeans in 1982 and 1984; corn in 1983 and 1985.
2/ ** and * are significant at the 99 and 95% level, respectively. NS = not significant at the 90% level. Since 1982 all significance shown as a probability level.

At Waseca, corn and soybeans responded to the 50-lb P_2O_5 rate in 5 of 12 years with a slight response to K_2O in one year (1985) (Table 14). Similar to Morris, responses to P have been more frequent in the last 5 yrs when soil test values dropped below 20 lb P/A on the 0-lb P_2O_5 treatments (Fig. 3). Soil test P has been maintained with the 50-lb P_2O_5 rate and increased substantially with the 100-lb rate. Yield responses have not occurred over the 50-lb rate, however, with the 100-lb rate of application. Similar to Morris, soil test K varied considerably over the 12-yr period and did not relate well to K application rate (Fig. 4). Based on the best fit linear regression lines (Fig.'s 3 and 4) soil test P values were changed by -2.3, +0.6, and +3.7 lb soil P/A/yr with the 0, 50, and 100-lb P_2O_5/A rates, respectively (Table 15). For reasons not apparent at this time, soil test K was increased with all rates of K.

Because of frequent yield responses to P at Morris and Waseca, the relationship between yield response and soil test P level was examined (Fig's 5 and 6). The percent yield response for the 50-lb vs. 0-lb, 100-lb vs. 50-lb, and 150-lb (every 3rd year) vs. 0-lb rates were plotted and related to soil test each year. This resulted in 33 comparisons at Morris and 34 at Waseca (yields from 1976 at Morris and two outliers at Waseca were omitted). A highly significant negative relationship between percent yield response and soil test was found at both sites.

Based on the regression lines the percent yield response for a given soil test was calculated (Table 16). At Morris a 14% yield response can be expected with broadcast P when soil test P is 10 lb P/A while at Waseca a 10% yield response can be expected. Yield response continued to decrease at both locations as soil test P increased. At soil test P values greater than 30 lb P/A, yield responses of less than 4% can be expected with the broadcast application of P. These results emphasize the fact that continued application of P to soils testing higher than 40 lb Bray P_1/A does not result in a consistent economical return even under higher levels of management.

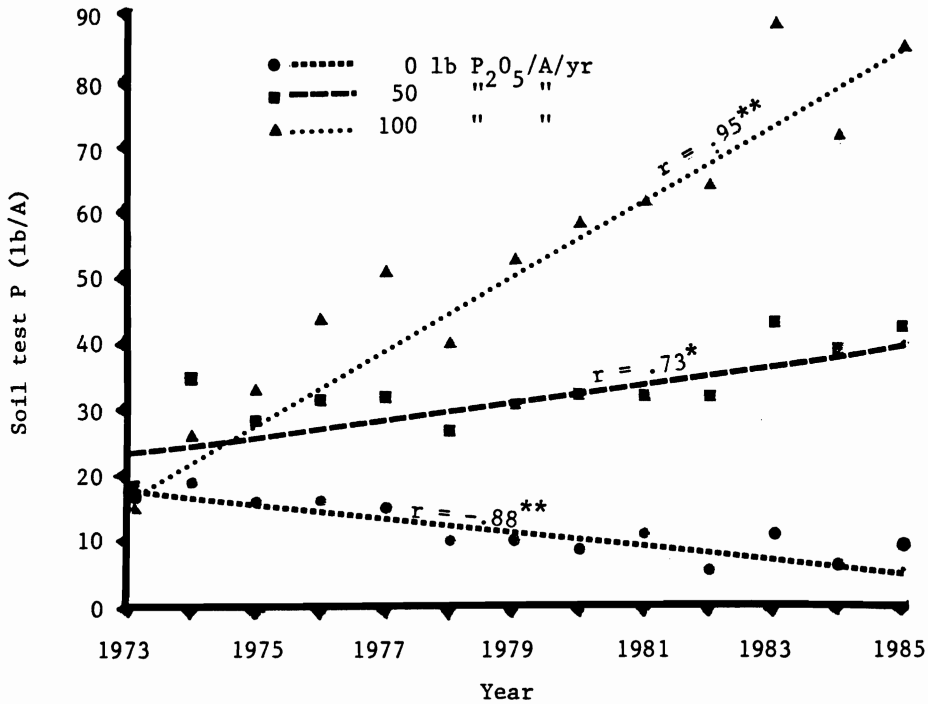

Fig. 1. Linear relationship between the amount of P applied and soil test P for the 13-yr period at Morris.

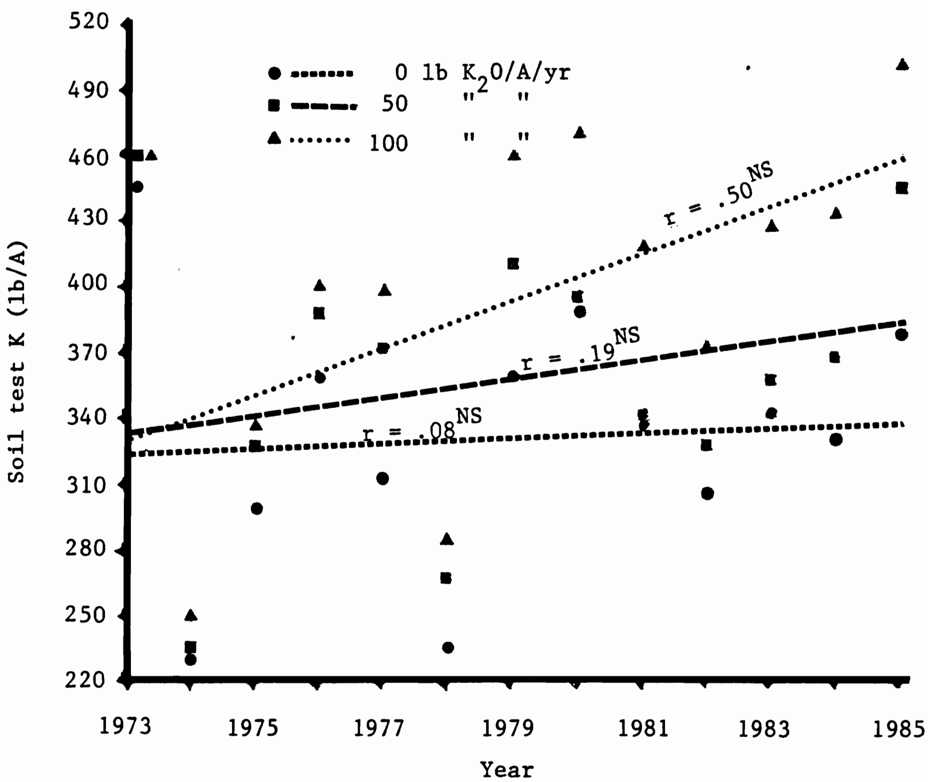

Fig. 2. Linear relationship between the amount of K applied and soil test K for the 13-yr period at Morris.

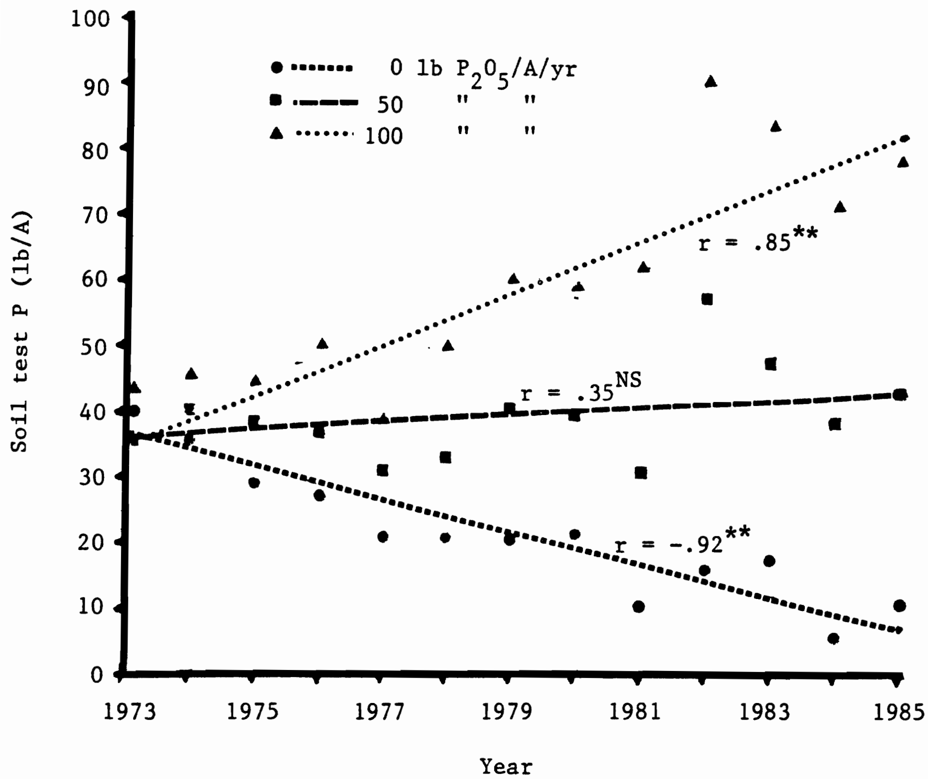

Fig. 3. Linear relationship between the amount of P applied and soil test P for the 13-yr period at Waseca.

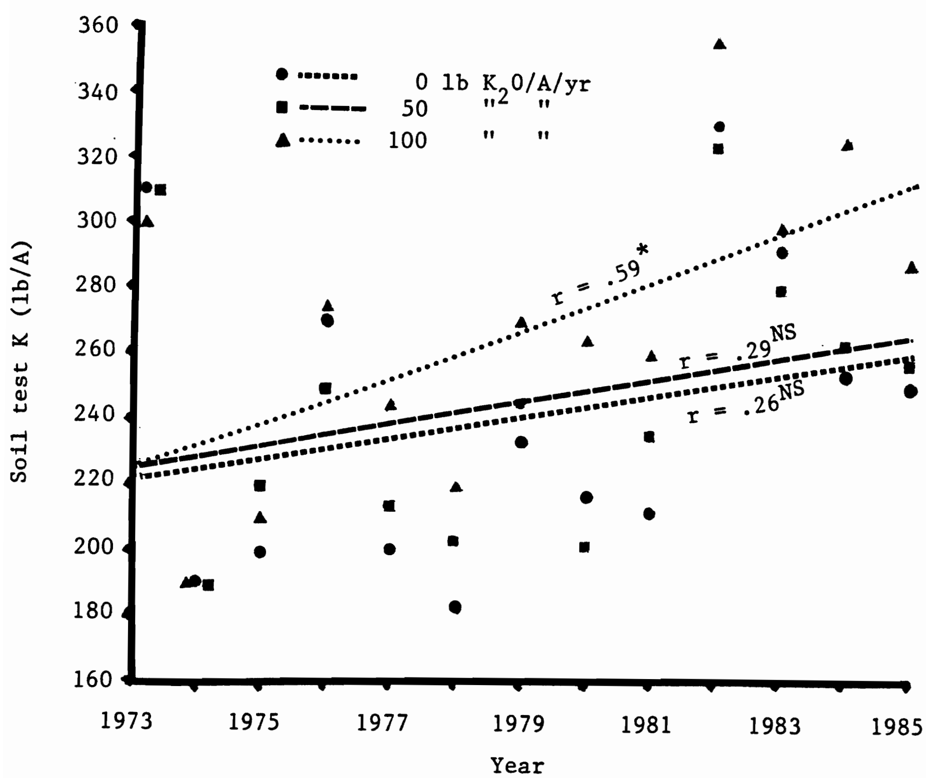

Fig. 4. Linear relationship between the amount K applied and soil K for the 13-yr period at Waseca.

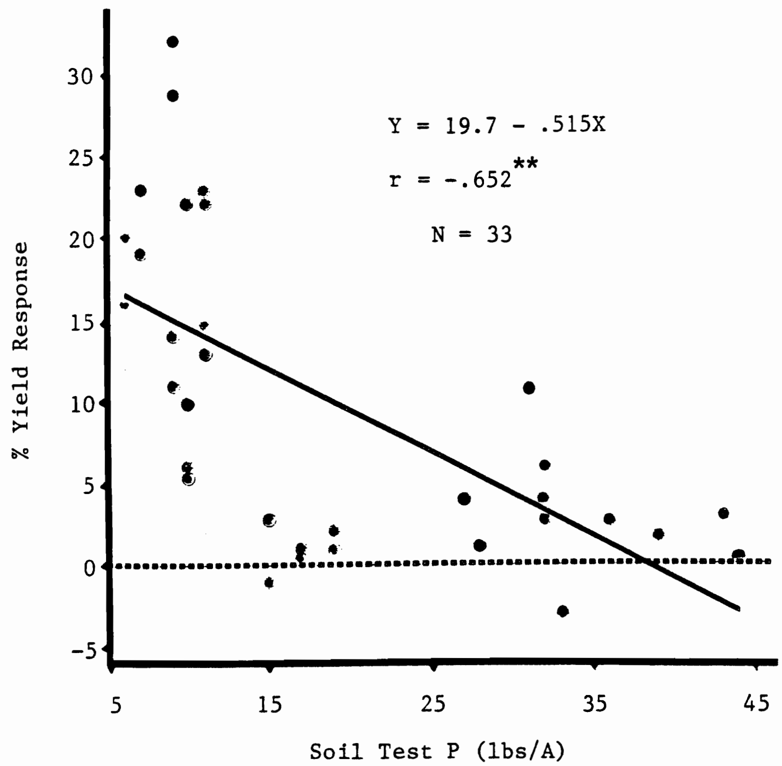

Fig. 5. Yield response as influenced by soil test P at Morris from 1974-1985.

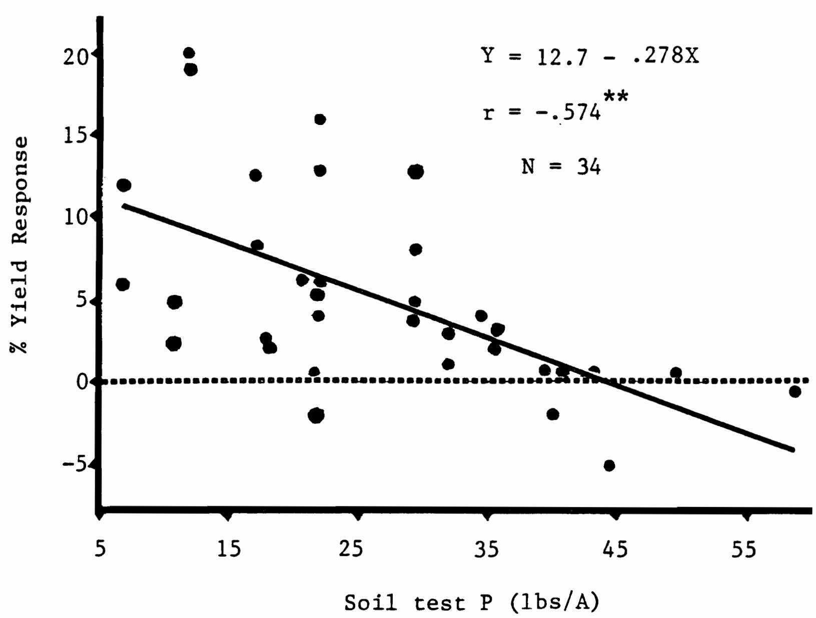

Fig. 6. Yield response as influenced by soil test P at Waseca from 1974-1985.

Table 14. Long-term corn and soybean yields as affected by P and K treatments at Waseca.

Trt. No.	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Yield Avg. 10-Yr Corn	Yield Avg. 2-Yr Sb
	Years[1/]													
	bu/A													
1	124.8	103.2	74.7	148.7	160.2	163.6	136.8	182.9	53.3	128.1	44.2	143.5	136.6	48.7
2	125.9	105.1	97.9	159.0	160.5	164.8	129.9	181.2	51.5	126.9	44.3	153.9	140.5	47.9
3	128.6	118.7	101.9	155.6	170.5	175.5	146.4	190.4	58.4	130.1	47.1	184.4	150.2	52.7
4	127.9	87.3	86.4	157.7	177.8	176.6	143.8	195.7	57.9	129.8	47.5	174.7	145.8	52.7
5	129.6	110.4	105.5	159.9	167.6	174.0	150.8	185.7	55.9	130.5	49.5	184.3	149.8	52.7
6	129.6	104.4	93.7	158.4	167.8	171.2	137.4	188.2	57.7	134.7	46.9	165.6	145.1	52.3
7	132.0	108.3	118.0	158.1	173.9	172.6	145.7	199.3	58.0	125.8	47.8	173.4	150.7	52.9
8	125.7	109.9	98.6	160.2	173.5	176.6	143.0	194.6	55.9	137.0	48.0	170.0	148.9	51.9
9	131.8	102.1	98.5	157.6	164.6	167.6	143.1	193.5	55.1	127.6	44.9	161.5	144.8	50.0
10	125.7	92.6	91.7	156.6	156.7	171.2	146.9	194.1	56.0	128.3	44.2	168.1	143.2	50.1
Signif:	NS	NS	*	NS	**	NS	NS	99	99	06	76	99		
BLSD(.05):			24.8		11.9			7.8	3.2			10.0		
CV (%):	4.	14.	15.	5.	4.4	5.2	9.3	2.8	3.8	7.7	5.9	3.7		

1/ Continuous corn from 1974-1981; soybeans in 1982 and 1984; corn in 1983 and 1985.

2/ ** and * are significant at the 99 and 95% levels, respectively. NS = not significant at the 90% level. Since 1982 all significance shown as a probability level.

Table 15. Change in soil test P and K/year over the 12-yr period as influenced by annual P and K rates.

Annual P_2O_5 or K_2O rate	P Morris	P Waseca	K Morris	K Waseca
lb/A	-- lb soil P/A/yr --		-- lb soil K/A/yr --	
0	-1.0	-2.3	+1.3	+3.1
50	+1.3	+0.6	+3.2	+3.1
100	+5.3	+3.7	+9.4	+7.0

Table 16. Percent yield response to broadcast P as influenced by soil test at Morris and Waseca.

Soil P Test	Location: Morris	Location: Waseca
lb P/A	-- % Yield Response --	
10	14	10
20	9	7
25	7	6
30	4	4
35	2	3
40	0	2

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

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Background:

Until recently, farmers had few choices with respect to placement of P and/or K for corn and soybean production. They could either broadcast and incorporate before planting, apply it in a band to the side of and below the seed at planting (starter fertilizer) or use a combination of both of these methods.

Our thinking about placement of P and/or K has changed substantially in recent years. Two factors are primarily responsible for this change. One factor is the increased popularity of the adoption of conservation tillage production systems. Without some form of primary tillage, P and K (both immobile nutrients) remain relatively close to the soil surface if broadcast applications are used. This may or may not be a disadvantage for broadcast applications.

Secondly, Dr. Stan Barber demonstrated that fertilizer banded on the soil surface and subsequently plowed under produced corn yields that were higher than yields produced by the broadcast application of similar rates. Therefore, this study was initiated to evaluate the effect of placement of P and K on corn and soybean production under two tillage systems where the soil test values for P and K vary over a wide range.

Experimental Procedure:

This study was initiated at the branch experiment stations in Morris, Lamberton, and Waseca in the fall of 1983. Relevant soil properties for the experimental sites are listed in Table 1.

Four factors (tillage system, rate of P_2O_5 and K_2O, placement of these nutrients, and starter fertilizer use) are being evaluated at both low and high fertility sites at the Waseca location. At Morris, there is no low fertility site. Space was limiting at the Lamberton location, so rate of applied P_2O_5 and K_2O is not considered. Both low and high fertility sites are used, however, at the Lamberton location. A randomized complete block design with 4 replications is used at all locations.

Treatments were repeated in late October and early November of 1984 at Waseca and Lamberton. Treatments were applied in late May of 1985 at the Morris location. For the fall chisel system, treatments are applied before the fall tillage operation. Fall tillage is not needed for the ridge-till system. The plots were chisel plowed in late May of 1985 at the Morris location.

The rates of P_2O_5 and K_2O used are either 44 + 87 or 66 + 131. A 4-12-24 suspension material is used to supply the P_2O_5 and K_2O.

The rates of P_2O_5 and $K_2O$are 1) broadcast on the soil surface, 2) applied in a band on the soil surface. Distance between band in 30 inches 3) applied in a subsurface bands at a depth of 6-8 inches. The distance between subsurface bands is 30 inches.

The starter fertilizer was 100 lb. 7-21-7 per acre at Waseca and Lamberton and 110 lb. 10-34-0 per acre at the Morris site. The starter fertilizer was placed to the side of and below seed level at all sites.

Whole plant samples were collected at 4 to 5 weeks after emergence, dried, and weighed. Ear leaf samples were collected at silking. All plant samples were analyzed for P and K. Uptake by young plants of these two nutrients was computed by multiplying plant weight by nutrient concentration.

Grain yields were measured with plot combines at all locations and were corrected to a 15.5% moisture basis before reporting. Standard analysis of variance procedures were used for separation of treatment means.

Table 1. Selected soil properties for the experimental sites.

Soil Property	Location and Fertility Level				
	Waseca		Lamberton		Morris
	High	Low	High	Low	High
pH	6.6	6.1	5.8	6.0	7.5
P, lb./acre (Bray & Kurtz #1)	48	14	33	14	39
K, lb./acre (1 N $NH_4C_2H_3O_2$)	433	190	305	222	259
organic matter, %	3.5	3.5+	3.0	3.0	3.5+
Texture	clay loam	clay loam	clay loam	clay loam	silt loam

Tillage Effects:

The effect of tillage system on the variables measured in this study is summarized in Table 2. Except for the Morris site, average yield was higher when the ridge-till system was used. Excessively wet conditions hampered planting operations for the ridge till system at Morris causing a reduction in stand. The stand reduction is the most obvious explanation for the lower yields in the ridge till-system at this site.

Early plant growth in the ridge-till system was also reduced by the excessively wet planting conditions at Morris. In contrast, early plant growth at both the high and low fertility sites at Waseca was enhanced in the ridge-till system.

Tillage system used had no effect on the P concentration of young plants at all locations. The K concentration of these plants, however, was higher when the chisel system was used.

In general, the placement X rate interaction was not significant and, likewise, the rate X starter interaction. The tillage X placement and tillage X starter interactions, however, were significant in many cases. Therefore, these variables will be shown in the interaction tables that follow.

Morris Results

A combination of late planting because of excessive moisture and an early frost prevented harvest of grain at Morris. Considering total dry matter yield, there were some 3-way interactions that were significant. There is no ready explanation for the interactions. Since main effects were not significant, these significant interactions might be considered to be artifacts of the statistical analysis. In general, 3-way interactions were not significant at other locations.

The P concentration of young plants at Morris was increased by the use of the starter fertilizer (Table 3) and this increased concentration was also reflected in P uptake (data not shown). The same observation was noted for the K concentration of young plants (data not shown). The practical significance of this observation is questioned because the soil has a very high level of soil test K.

Table 2. Effect of tillage system on variables measured in 1985.

Location	Variable	Ridge Till	Chisel
Morris	Yield (ton DM/acre)	5.56	6.03*
Morris	Early Growth, g/6 plants	5.9	7.5*
Morris	P Conc - Whole Plant, %	.482	.488
Morris	K Conc - Whole Plant, %	3.20	3.77*
Morris	P Uptake, mg/6 plants	28.7	37.2*
Morris	K Uptake, mg/6 plants	189.3	283.3*
Lamberton, low fertility	Yield, bu./acre	134.0	120.2*
Lamberton, low fertility	Early Growth, g/6 plants	17.9	16.6
Lamberton, low fertility	P Conc. Whole Plant, %	.409	.410
Lamberton, low fertility	K Conc. Whole Plant, %	3.14	3.35*
Lamberton, low fertility	P Uptake, mg/6 plants	74.8	68.2
Lamberton, low fertility	K Uptake, mg/6 plants	566.8	555.1
Lamberton, low fertility	P Conc - Ear Lear, %	.230	.240*
Lamberton, low fertility	K Conc - Ear Leaf, %	1.55	1.66*
Lamberton, low fertility	Yield, bu./acre	137.5	133.3*
Lamberton, low fertility	Early Growth, g/6 plants	22.2	21.3
Lamberton, low fertility	P Conc. Whole Plant, %	.438	.426
Lamberton, low fertility	K Conc. Whole Plant, %	3.74	3.79
Lamberton, low fertility	P Uptake, mg/6 plants	96.8	89.4
Lamberton, low fertility	K Uptake, mg/6 plants	831.9	799.4
Lamberton, low fertility	P Conc - Ear Leaf, %	.280	.276
Lamberton, low fertility	K Conc - Ear Leaf, %	1.93	1.95
Waseca, low fertility	Yield, bu./acre	124.6	119.2*
Waseca, low fertility	Early Growth, g/6 plants	21.4	17.0*
Waseca, low fertility	P Conc - Whole Plant, %	.383	.376
Waseca, low fertility	K Conc - Whole Plant, %	2.26	2.70*
Waseca, low fertility	P Uptake, mg/6 plants	81.8	64.6*
Waseca, low fertility	K Uptake, mg/6 plants	492.9	475.4
Waseca, low fertility	P Conc - Ear Leaf, %	.175	.193*
Waseca, low fertility	K Conc - Ear Leaf, %	.897	.923
Waseca, high fertility	Yield, bu./acre	154.8	148.6*
Waseca, high fertility	Early Growth, g/6 plants	29.9	25.2*
Waseca, high fertility	P Conc - Whole Plant, %	.434	.439
Waseca, high fertility	K Conc - Whole Plant, %	3.83	4.02
Waseca, high fertility	P Uptake, mg/6 plants	130.0	111.2*
Waseca, high fertility	K Uptake, mg/6 plants	1139.3	1010.4*
Waseca, high fertility	P Conc - Ear Leaf, %	.270	.264
Waseca, high fertility	K Conc - Ear Leaf, %	1.75	1.72

*Difference between names is significant at PR>F = .10 or lower.

Table 3. Effect of tillage system, fertilizer placement and starter fertilizer use on the P concentration of young corn plants. Morris. 1985.

Placement	Ridge-Till: With Starter	Ridge-Till: No Starter	Ave.	Chisel: With Starter	Chisel: No Starter	Ave.
	% P					
----	.490	.468	.479	.504	.478	.491
Broadcast	.485	.468	.477	.511	.482	.497
Surface Band	.505	.465	.485	.520	.452	.486
Subsurface Band	.494	.471	.483	.486	.479	.483
	.494	.468		.505	.473	

Use of the starter fertilizer produced the largest increase in P concentration when additional P_2O_5 and K_2O were applied in a surface band. This was true for both tillage systems. When soil test P levels are in the low range, increases in P uptake by young plants can lead to enhanced early growth and ultimately higher yields.

Lamberton Results

Grain yields at the low fertility site at Lamberton were influenced by both tillage system and starter fertilizer use. Placement of P_2O_5 and K_2O had no effect on yield (Table 4). Use of the starter in addition to 44 lb. P_2O_5 and 87 lb. K_2O/acre applied by some other method produced a 6 bu./acre increase with the ridge-till system and a 12 bu./acre increase with the chisel system.

Table 4. Effect of tillage system, fertilizer placement and starter fertilizer use on the grain yield at the low fertilizer site at Lamberton. 1985.

Placement	Ridge-Till: With Starter	Ridge-Till: No Starter	Ave.	Chisel: With Starter	Chisel: No Starter	Ave.
	bu./acre					
----	---	105.9	---	----	97.9	---
Broadcast	135.2	131.0	131.1	125.5	112.5	119.5
Surface Band	138.0	127.4	132.7	131.2	118.1	124.7
Subsurface Band	137.8	134.4	136.1	122.2	111.5	116.9
	137.0	130.9		126.3	114.0	

Use of the starter fertilizer also increased grain yield at the Lamberton high fertility site (Table 5). When averaged over other placement methods, the increase was 9 bu./acre for the ridge-till system and 7 bu./acre for the chisel system. The positive response to starter fertilizer at this location in 1985 demonstrates the importance of starter fertilizer as a management tool for corn production with all tillage systems under Minnesota planting conditions.

Table 5. Effect of tillage system, fertilizer placement and starter fertilizer use on the grain yield at the high fertility site at Lamberton, 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	bu./acre					
---	---	133.8	--	---	124.2	--
Broadcast	139.9	136.4	138.2	135.3	131.5	133.4
Surface Band	143.5	134.0	138.8	142.5	125.8	134.2
Subsurface Band	141.2	129.8	135.5	134.0	131.1	132.6
	141.5	133.4		137.3	129.5	

Early growth at the Lamberton low fertility site was also improved by the use of a starter fertilizer. When averaged over all other factors, six plants weighed 11 gm when no starter was used. This weight increased to 23.5 gm when the starter was applied. Early growth was also increased by starter use at the high fertility site. When averaged over other factors studied, 6 plants weighed 17.6 gm when no starter was used and the weight increased to 25.7 gm when the starter was applied. The stimulation of early plant growth by the starter was reflected in yield.

The use of the starter fertilizer was the only factor that influenced the P concentration in young corn plants at the low fertility site. When averaged over other factors the P concentration increased from .398% to .421% when the starter was used. The use of the starter had no effect on P concentration in young corn plants at the high fertility site.

Tillage was the only factor to affect the K concentration in young plants at the low fertility site. None of the factors used had any effect on the K concentration in young plants at the high fertility site. The effects of tillage system, placement, and starter use on uptake of P and K by young plants reflect the effects of these factors on early plant growth.

The K concentration in the ear leaf samples collected from the low fertility site was significantly influenced by tillage system, fertilizer placement and starter use (Table 6). The tillage X placement interaction was significant. With the ridge-till planting system, the K concentration was higher when subsurface bands were used. The reduction in K concentration with the use of the starter fertilizer cannot be explained at this time. The K concentration in the ear leaf samples collected from the high fertility site was not significantly affected by any of the factors used in the study.

Table 6. Effect of tillage system, fertilizer placement and starter fertilizer use on the K concentration in ear leaf tissue at the Lamberton low fertilizer site. 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	% K					
---	---	1.35	--	---	1.39	--
Broadcast	1.48	1.58	1.53	1.70	1.81	1.76
Surface Band	1.43	1.54	1.49	1.62	1.60	1.61
Subsurface Band	1.56	1.68	1.62	1.61	1.64	1.63
	1.49	1.60		1.64	1.68	

The P concentration in the ear leaf samples collected from the low fertility site was influenced by fertilizer placement and there was a significant placement x tillage interaction (Table 7). Starter fertilizer use, however, had no effect on the percentage of P in the ear leaf tissue from this site. For both tillage systems, the P concentration was highest when the P_2O_5 was broadcast. The P concentration was lowest when the P_2O_5 was applied in a surface band with the chisel system.

The P concentration in the ear leaf was also influenced by P_2O_5 placement at the high fertility site but there was no tillage by placement interaction. When averaged over all other factors, the P concentration was highest when the P_2O_5 was broadcast and lowest when it was placed in a subsurface band. Examination of the data for P and K concentrations in the ear leaf tissue indicates that there is no strong relationship between these values and grain yield.

Table 7. Effect of tillage system, fertilizer placement and starter fertilizer use on the P concentration in the ear leaf tissue at the Lamberton low fertility site in 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	% P					
---	---	.173	--	---	.178	--
Broadcast	.234	.243	.239	.241	.263	.240
Surface Band	.225	.222	.224	.240	.239	.240
Subsurface Band	.232	.225	.229	.229	.225	.227
	.230	.230		.237	.242	

Waseca Results

Tillage system was the major factor that had a significant effect on the variables measured at the high fertility site at Waseca. Grain yields from this site are summarized in Table 8. Neither placement, rate of P_2O_5 and K_2O used, nor starter fertilizer use had any significant effect on yield.

Table 8. Effect of tillage system, fertilizer placement and starter fertilizer use on the yield of corn at Waseca high fertility site. 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	bu./acre					
---	144.8	154.3	149.6	153.9	138.1	146.0
Broadcast	147.6	157.5	152.6	147.9	147.9	147.9
Surface Band	157.5	150.9	154.2	152.0	148.2	150.1
Subsurface Band	159.1	158.4	158.8	153.9	154.1	154.0
	154.7	155.6		151.3	150.1	

Tillage system also had a significant effect on early plant growth at the high fertility site (Table 2). When averaged over all factors, the weight of 6 plants was 25.2 gm in the chisel planting system and 29.9 gm in the ridge-till planting system. This effect on early growth was also reflected in uptake of P and K by the young plants.

The P concentration of whole plants at this site was significantly increased only by rate applied. The K concentration in these plants was significantly influenced by tillage system and rate of K_2O applied. There was also a significant tillage X fertilizer placement interaction (Table 9). In the ridge-till system, K concentration in the whole plant tissue was highest when the fertilizer was broadcast. In the chisel system, the highest K concentration resulted from the use of the subsurface band.

The P concentration in the ear leaf at the high fertility site was influenced only by the tillage system used (Table 2). The K concentration was only influenced by placement. When averaged over other factors, the percentage of K was 1.71, 1.67, and 1.83 when the K_2O was broadcast, applied in a surface band, and applied in a subsurface band respectively. A significant increase resulted from the placement in the subsurface band.

Table 9. Effect of tillage system, fertilizer placement and starter fertilizer on the K concentration in young corn plants at the Waseca high fertility site. 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	% K					
---	3.53	3.32	3.43	3.73	3.64	3.69
Broadcast	3.74	3.80	3.77	3.95	3.68	3.82
Surface Band	3.87	3.64	3.76	3.90	4.01	3.96
Subsurface Band	3.69	3.60	3.65	4.34	4.06	4.20
	3.77	3.68		4.06	3.92	

Grain yield at the low fertility site at Waseca was significantly influenced by all factors studied. There was also a significant tillage by fertilizer placement interaction. The effects of tillage system, fertilizer placement and starter use measured in 1985 were consistent with results measured at this site in 1984.

At a rate of 44 lb. P_2O_5 and 87 lb. K_2O per acre, the use of the subsurface band produced the highest yield for both tillage systems (Table 10). With the ridge-till system, the broadcast application of this rate of P_2O_5 and K_2O produced the lowest yield. The use of the surface band produced the lowest yield when the chisel system was used.

Table 10. Effect of tillage system fertilizer placement and starter fertilizer use on the grain yield at the Waseca low fertility site. 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	bu./acre					
---	93.1	83.8	88.5	87.1	79.3	83.2
Broadcast	115.1	114.1	114.6	118.0	119.4	118.7
Surface Band	126.3	117.1	121.7	105.8	105.1	105.5
Subsurface Band	135.1	124.7	129.5	129.1	120.5	124.6
	125.5	118.6		117.6	115.0	

The use of the starter fertilizer in addition to the P_2O_5 and K_2O applied by some other method increased yields by 7 bu./acre with the ridge-till system and 3 bu./acre with the chisel system.

These were no significant interactions between rate and the other factors studied. When averaged over all other factors, the rate of 44 lb. P_2O_5 and 87 lb. K_2O per acre produced 119.2 bu./acre. The yield from the use of 66 lb. P_2O_5 and 131 lb. K_2O per acre averaged 124.6 bu./acre.

The effects of tillage system, fertilizer placement, fertilizer rate, and starter use on early growth were consistent with the effects of these factors on grain yield. The increase in early growth at this site was measured in final grain yield.

The P concentration in young plants was not significantly influenced by the factors used in this study. Because of the large differences in early plant growth, P concentration could have been influenced by plant dilution effects.

Use of a starter fertilizer increased the K concentration in young plants for both tillage systems (Table 11). Fertilizer placement also influenced K concentration in the tissue and there was a significant interaction with tillage system. The use of the subsurface band produced the highest concentration for the chisel system. In the ridge-till system, however, the surface band produced the highest concentration. These results indicate that young plants can utilize the K_2O applied on the soil surface. This would be expected where the surface band is incorporated with the chisel operation. There is, however, no incorporation of the surface band in the ridge-till system. There must be some downward movement of applied K between the time of application in the fall and corn emergence the following spring.

Table 11. Effect of tillage system, fertilizer placement and starter fertilizer use on the K concentration in young plants at the Waseca low fertility site. 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	% K					
---	1.30	1.23	1.27	1.47	1.44	1.46
Broadcast	1.91	1.71	1.81	2.44	2.41	2.43
Surface Band	2.55	2.49	2.52	2.35	2.13	2.24
Subsurface Band	2.20	1.95	2.08	3.26	2.34	2.60
	2.22	2.05		2.68	2.29	

The effects of the four factors on P uptake by young plants parallel the effects of these factors on early plant growth. Uptake of K by young plants, however, was influenced only by rate of P_2O_5 and K_2O applied and starter fertilizer use.

The P concentration in the ear leaf tissue was significantly influenced by tillage system, fertilizer placement, fertilizer rate and starter fertilizer use. This is consistent with the effects of these 4 factors on the P concentration in young plants. Use of the starter increased the P concentration for the ridge-till system only (Table 12).

Table 12. Effect of tillage system, fertilizer placement and starter fertilizer use on the P concentration in the ear leaf tissue at the Waseca low fertility site. 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	% P					
---	.169	.142	.156	.173	.155	.164
Broadcast	.176	.168	.172	.205	.194	.200
Surface Band	.158	.155	.157	.167	.164	.166
Subsurface Band	.186	.176	.181	.192	.200	.196
	.173	.166		.188	.186	

The broadcast placement produced the highest P concentration for the chisel system. Placement in a subsurface band produced the highest P concentration in the ridge-till system. The surface band produced the lowest P concentration for both planting systems. The use of a subsurface band without a starter fertilizer resulted in P concentrations that were almost equal to the P concentration in ear leaves of the control treatment. These results suggest that mobility of the applied P is slight.

In addition to the treatments needed to complete the factorial, others were added at the Waseca and Morris sites to provide for several comparisons of interest. The "t" test was used to separate means in these added comparisons. The results of these comparisons at the Waseca low fertility site are discussed in the following paragraphs. At the time of this writing "t" tests had not been completed for the variables measured at the Waseca high fertility site and the Morris site.

The use of 100 lb. 7-21-7 per acre produced a significant increase in 6 of the 8 variables measured (Table 13). The amount of K_2O applied in the starter was apparently not sufficient to increase the K concentration in young corn plants as well as the amount of K absorbed by these plants. Interpretation of the data is not changed if tillage systems are analyzed separately. So, data from both systems were combined for the averages shown in Table 13. Considering the low soil test values at this site, the positive response to the use of the starter fertilizer was expected.

The "t" test was also used to determine if small amounts of P_2O_5 and K_2O applied in a starter fertilizer were equal to larger amounts applied in some other way without the addition of a starter. Grain yields were higher when higher amounts were broadcast, applied in a surface band, or used in a subsurface band (t = 6.74***, 6.13***, 3.07** respectively). As would be expected, P and K concentrations in the plant tissue at the 2 stages sampled were also significantly higher when the higher amounts of P_2O_5 and K_2O were used.

In the fall of 1983, a single application of 440 lb. P_2O_5 and 870 lb. K_2O was applied at a depth of 12 inches either directly below the corn row or in the middle between two rows. In addition to the fertilizer applied in 1983, both treatments received an annual subsurface band of 44 lb. P_2O_5 and 87 lb. K_2O per acre. A starter was also used each year. Grain yield in 1984 when the fertilizer was applied below the row was 150.5 bu./acre. When the fertilizer was applied between the rows, the yield was 145.6 bu./acre. This difference in yield was not significant (t = 1.42).

Table 13. Effect of the use of starter only when compared to the control on the variables recorded the Waseca low fertility site. 1985.

Variable	Control	Starter Use Only
Yield, bu./acre	81.6	90.1*
Early Plant Growth, g/6 plants	13.0	15.2**
P Conc. Whole Plant, %	.350	.380**
K Conc. Whole Plant, %	1.33	1.38
P Uptake, mg/6 plants	46.0	57.8**
K Uptake, mg/6 plants	175.0	212.0
P Conc.-Ear Leaf, %	.150	.170**
K Conc.-Ear Leaf, %	.52	.56***

*,**,*** Treatment means are significantly different at the .10, .05, and .01 confidence levels respectively.

The annual application of the subsurface band did not improve yields when the high rates were applied in 1983. When the high rates was applied between the rows and a subsurface band used each year, the yield was 145.6 bu./acre. The yield from the same placement of high rates without the annual application was 147.3 bu./acre. The difference was not significant (t = .40).

The 1985 grain yields were improved by the application of the high rates of P_2O_5 and K_2O in 1983. However, yields will have to be recorded for a number of years before the benefit of the use of high rates placed at a depth of 12 inches can be accurately assessed.

EFFECT OF POTASSIUM PLACEMENT ON CORN PRODUCTION IN HIGH YIELD ENVIRONMENTS IN SOUTHEAST MINNESOTA

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The interest in the use of conservation tillage systems for corn production continues to increase in southeastern Minnesota. Soil test values for K are usually medium to low for the majority of soils in this region. These low soil test values create several questions that relate to management of K fertilizers. This study is designed to evaluate the effect of rate and placement of fertilizer K with and without the use of K in a starter fertilizer on corn production with two tillage systems.

Experimental Procedure:

This study was initiated in the spring in 1984 in a farmer's field in Wabasha County. Treatments were reapplied in the spring of 1985. The soil is classified as a Fayette silt loam and is characteristic of soils in the region. The pH was 6.5. The Bray and Kurtz #1 test showed 72 lb. P/acre while the 1 N $NH_4C_2H_3O_2$ extraction showed 219 lb. K/acre.

Tillage system (no till, chisel), rate of applied K (0, 40, 80, 120 lb./acre) placement (broadcast, subsurface band), and starter with and without K are the factors included in the study. A randomized complete block design is used with 4 replications.

In 1985, treatments were applied in late April. The K source for subsurface and broadcast application was 0-0-60. A 7-21-7 fluid fertilizer at a rate of 195 lb./acre was used to supply K in the starter. The fluid product, 10-34-0 (128 lb./acre) was used as a starter for plots that did not receive K in the starter.

All plots received a preplant application of 180 lb. N/acre supplied as 28-0-0. Corn was planted on May 14, 1985 at a population of 25,400 plants per acre in 38 in. rows. The variety was Pioneer 3737. Counter was used for corn rootworm control and the Lasso - Bladex combination (applied preemergence) was used for weed control. Corn was cultivated once in mid June. This cultivation was used to build ridges in the no-till system so that corn would be planted on ridges in 1986.

Whole plant samples (4 plants/plot) were taken 4 weeks after emergence. Ear leaf samples were collected at silking. Dry matter production was measured at physiological maturity and whole plant samples were collected at this time. All plant samples were dried, weighed when appropriate and analyzed for K. Grain yields were harvested in late October and corrected to 15.5% moisture.

Results and Discussion:

In 1985, there were no significant interactions among the variables used for any of the parameters measured in this study. Therefore, main effects will be summarized in the tables that follow.

Before discussing the data, it's important to emphasize that rainfall was very limited during the first half of the growing season. Little effective rainfall was recorded between planting and July 24. There were small showers during this period but amounts received in each shower were small. Therefore, the corn was stressed during the first two weeks in July and this stress will explain, in part, the low yields.

The effect of tillage system on corn growth and yield, K concentration in the plant tissue, and K uptake by corn is summarized in Table 1. Early plant growth was greater when the chisel system was used. This improved early growth was reflected in both grain yield and total dry matter production.

Except for the mature plant at physiological maturity, the K concentration in the tissue was higher when the chisel system was used. Consequently K uptake was high when corn was grown in the chisel system. These results are consistent with data reported from other studies in Minnesota.

Table 1. Effect of tillage system used on early growth, corn yield, K concentration in the tissue and K uptake. 1985.

	Tillage System	
	Chisel	No-Till
early growth, weight of 4 plants, g	32.5	17.3
yield, bu./acre	119.5	90.1
dry matter yield, ton/acre	4.90	3.74
K concentration, young plants, %	3.55	3.05
K concentration, ear leaf, %	1.84	1.67
K concentration, mature plant, %	.92	1.03
K uptake, young plants, mg/4 plants	1148.7	525.2
K uptake, mature plants, lb./acre	90.1	77.1

Problems were encountered with the no-till planting system in 1985. Consequently, soil to seed contact was poor. This reduced stand and subsequently caused a reduction in both dry matter and grain yield.

The influence of rate of K applied was inconsistent (Table 2). In the chisel system, grain yield was increased by the use of 40 lb. K/acre with additional K producing no further increases in yield. The K concentration in the young plants and the ear leaf tissue was also significantly increased by the initial 40 lb. K/acre increment. Rate of K applied had no significant effect on K uptake by young plants and total K uptake by mature corn.

The rate of fertilizer K applied affected the K concentration in the young plants and ear leaf tissue when corn was planted in the no-till system (Table 2). Because of the planting problems described above, however, there was a large amount of variability in the data. Therefore, it is difficult to attach a large amount of importance to data collected from the no-till system in 1985. The grain yieldsfrom the no-till system were especially low. With a medium K test in the soil, the soil itself was apparently able to supply adequate K for these low yields.

Placement of fertilizer K had a significant effect on grain yield was well as the concentration of K in plant tissue when corn was planted in the chisel system (Table 3). Placement of the fertilizer K in a subsurface band was superior to a broadcast application. These results are analagous to results of studies where subsurface application of fertilizer P has been superior for small grain production.

Table 2. Effect of rate of applied K on early growth, corn yield, K concentration in the tissue, and K uptake by corn. 1985.

	K Applied (lb./acre)			
	0	40	80	120
Chisel System:				
early growth, weight of 4 plants, g	34.0	32.2	33.8	31.4
yield, bu./acre	115.9	119.0	119.2	120.3
dry matter yield, ton/acre	4.86	5.03	4.80	4.87
K conc. young plants, %	2.96	3.47	3.51	3.68
K conc. ear leaf, %	1.67	1.82	1.82	1.87
K conc. mature plant, %	.88	.90	.94	.92
K uptake, young plants, mg/4 plants	1010	1109	1181	1157
K uptake, mature plants, lb./acre	86.0	90.8	90.2	89.2
No-Till System:				
early growth, weight of 4 plants, g	18.0	16.2	17.8	17.9
yield, bu./acre	89.0	87.0	92.5	90.7
dry matter yield, ton/acre	3.36	3.71	3.73	3.77
K conc. young plants, %	2.51	2.95	3.04	3.14
K conc. ear leaf, %	1.49	1.61	1.65	1.75
K conc. mature plant, %	.96	1.00	1.04	1.05
K uptake, young plants, mg/4 plants	454	472	539	565
K uptake, mature plants, lb./acre	64.6	74.4	77.3	79.4

Table 3. Effect of K placement on early growth, corn yield, K concentration in the tissue, and K uptake by corn. 1985.

	Placement	
	Broadcast	Subsurface Band
Chisel System:		
early growth, weight of 4 plants, g	32.9	32.0
yield, bu./acre	116.9	122.0**
dry matter yield, ton/acre	4.97	4.83
K conc. young plants, %	3.39	3.71**
K conc. ear leaf, %	1.81	1.86
K conc. mature plant, %	.89	.95**
K uptake, young plants, mg/4 plants	1111	1187
K uptake, mature plants, lb./acre	88.5	91.7
No-Till System:		
early growth, weight of 4 plants, g	17.3	17.3
yield, bu./acre	91.0	89.2
dry matter yield, ton/acre	3.70	3.77
K conc. young plants, %	2.64	3.45**
K conc. ear leaf, %	1.63	1.70*
K conc. mature plant, %	1.04	1.02
K uptake, young plants, mg/4 plants	458	591**
K uptake, mature plants, lb./acre	77.3	76.8

*,** Difference between means is significant at the .05 and .01 confidence levels respectively.

With subsurface placement, the K was placed where soil was moist while broadcast applications were incorporated in dry soil. The subsurface application would have placed the fertilizer K in a more active portion of the root zone.

For the no-till system, placement had no significant effect on yield. With no significant response to rate of applied K, this result would be expected. Placement of fertilizer K did have a significant effect on the K concentration in the plant tissue. The concentration was higher in the young plants and the ear leaf tissue when K was applied below the soil surface rather than broadcast. With no incorporation of broadcast K in the tillage system, this result would be expected. This is especially true in a dry year.

Except for the K concentration in the ear leaf tissue from the no-till planting system, there was no significant effect of the use of K in a starter fertilizer in 1985 (Table 4). Because of the warm, dry conditions in spring and early summer, these results would be expected when averaged over all rates of applied K and both methods of placement. In 1985, the starter fertilizer would have been placed in soil that was relatively dry. Consequently, plant use of K applied in this way was probably low.

Table 4. Effect of K applied in a starter fertilizer on early growth, corn yield, K concentration in the tissue, and K uptake by corn. 1985.

	K Applied in the Starter	
	Yes	No
Chisel System:		
early growth, weight of 4 plants, g	31.8	33.2
yield, bu./acre	119.4	119.6
dry matter yield, ton/acre	4.88	4.92
K conc. young plants, %	3.60	3.51
K conc. ear leaf, %	1.85	1.82
K conc. mature plant, %	.93	.91
K uptake, young plants, mg/4 plants	1146	1152
K uptake, mature plants, lb./acre	90.4	89.7
No-Till System:		
early growth, weight of 4 plants, g	16.8	17.8
yield, bu./acre	91.2	89.0
dry matter yield, ton/acre	3.79	3.68
K conc. young plants, %	3.07	3.01
K conc. ear leaf, %	1.70	1.64+
K conc. mature plant, %	1.03	1.03
K uptake, young plants, mg/4 plants	509	542
K uptake, mature plants, lb./acre	77.8	76.2

+, Difference between treatment means in significantly different at the .10 confidence level.

CAULIFLOWER RESPONSE TO GYPSUM ON A COARSE-TEXTURED SOIL - 1985

C. J. ROSEN AND H. J. BUCHITE

Interest in growing freshmarket vegetables in north central Minnesota has increased over the past few years. Many of the soils in this area tend to be coarse-textured and low in exchangeable Ca. Cauliflower grown on these soils often develop a disorder known as "tipburn" which is characterized by tip necrosis of the young leaves surrounding the curd. Because younger leaves are not separated from the curd at harvest, tipburned leaves can lower the quality of marketable heads. Previous studies have suggested a correlation between tipburn and low leaf tissue calcium. The objective of the present study was to determine the effects of gypsum on cauliflower yield, tipburn and postharvest qualities.

Materials and Methods:

This experiment was located in Princeton, MN on a Hubbard loamy sand. Soil chemical properties (0-24 inches) before gypsum application were as follows:

	---------Soil Depth---------			
	0-3"	3-6"	6-12"	12-24"
P (lb/A)	52	50	40	55
K (lb/A)	88	82	113	211
Ca (lb/A)	256	331	456	904
S (lb/A)	6	5	9	30
pH	5.4	5.3	5.3	5.3

Treaments included a control and three rates of gypsum (500, 1000, and 2000 lb/A) and were applied on 1 July. Two methods of incorporation were used: disked and moldboard plow. A split plot randomized complete block design was used with 4 replications. Main plots were tillage method and subplots were the gypsum treatments. Cauliflower (cv. 'Snowcrown') transplants were planted on 8 July and banded with 50 lb/A N, 50 lb/A P_2O_5, 150 lb/A K_2O, 1/2 lb/A B, 30 lb/A S, and 40 lb/A Mg. Additional N was sidedressed at the rate of 50 lb/A three and 8 weeks after planting. Plant spacing was 16 inches within the row and 40 inches between row centers. Soil samples were collected on 11 September. Leaves immediately surrounding the head (immature leaves) and fully expanded leaves (mature leaves) were sampled on 6 September. Nutrient composition of dried leaf samples was determined using a Kjeldahl/conductimetric procedure for N and an inductively coupled plasma (ICP) spectrometer for the other elements. Each plot was observed for development of leaf tipburn. Two center rows of each plot were harvested on 6 dates from 3 September to 26 September. Measurements included total yield and curd size.

Results:

Gypsum treatments had no significant effect on cauliflower yield or head diameter (Table 1). Incorporation of gypsum by disking resulted in a larger curd size compared to incorporation by plowing. The reasons for this increase in curd size due to tillage are not clear from the present experiment.

Soil calcium levels increased with increasing gypsum rates (Table 2). It is interesting to note that in this soil, calcium levels increased at the 12-24 inch depth which indicates a downward movement of calcium over the growing season. Soil sulfur followed the same pattern as soil calcium (Table 3). For both nutrients, method of gypsum incorporation had little effect on extractable levels.

Gypsum treatments increased concentrations of sulfur and tended to decrease concentrations of nitrogen, magnesium and boron in recently matured leaves (Tables 4 and 5). In younger leaves gypsum increased concentrations of calcium and sulfur but decreased concentrations of magnesium (Tables 6 and 7). Levels of tissue calcium and sulfur were greater in the disked treatment compared to the moldboard plow treatment. This indicates that on these sandy soils, incorporation by disking is adequate for increasing tissue levels of calcium and sulfur in shallow rooted crops such as cauliflower. Despite the fact that gypsum increased tissue calcium, plants from all plots developed the tipburn symptom. This indicates that more than soil calcium is involved in the tipburn disorder. It it possible that the cultivar used in this study has an inefficient calcium translocating system. Although this field was well irrigated, slight water stress coupled with high temperatures may also be involved. For both mature and immature leaf samples molybdenum values are presented, however because most values were below the detection limit of the ICP only the means are provided. In general, molybdenum concentrations decreased with gypsum applications.

General Conclusions:

Calcium and sulfur soil levels increased with increasing gypsum application. During the growing season, calcium and sulfur tended to leach through the soil profile. Although gypsum treatments significantly increased soil and tissue levels of calcium and sulfur, there was no significant effect of these treatments on cauliflower tipburn incidence, final yield or postharvest quality. It is possible that the cultivar 'Snowcrown' is susceptible to this disorder and that a different cultivar may be better suited for these coarse-textured soils.

The cooperation of Dr. Roger C. Gibson, U. S. Gypsum Corporation, during the course of this research is gratefully acknowledged.

Table 1. Influence of gypsum on yield and head diameter of cauliflower.

Gypsum Treatment	Yield		Head Diameter	
	D[1]	MB	D	MB
lb/A	------T/A-------		-----inches----	
0	5.72	4.31	9.2	8.2
500	5.00	5.49	9.0	8.9
1000	5.23	4.50	9.2	8.5
2000	4.58	5.20	8.8	8.8

Statistics	Significance[2]	
Tillage	NS	**
Gypsum	NS	NS
Linear	NS	NS
Quadratic	NS	NS
Gyp X Till	**	*

[1] D = Disked, MB = Moldboard plow
[2] + = .2, ++ = .1, * = .05, ** = .01

Table 2. Influence of gypsum treatments on ammonium acetate extractable Ca at various depths.

Gypsum Treatment	Soil Depth 0 - 3" D[1]	MB	3 - 6" D	MB	6 - 12" D	MB	12 - 24" D	MB	0 - 24" D	MB
lb/A	lb/A									
0	209	287	229	198	463	395	840	680	1740	1561
500	370	328	283	259	558	400	1115	840	2325	1835
1000	426	310	261	279	413	553	1065	1060	2174	2201
2000	333	340	351	411	505	585	1200	1100	2389	2436

Statistics	0 - 3"	3 - 6"	6 - 12"	12 - 24"	0 - 24"
	Significance[2]				
Tillage	NS	NS	NS	++	NS
Gypsum	++	*	NS	*	**
Linear	+	**	++	**	**
Quadratic	*	NS	NS	+	+
Gyp X Till	NS	NS	+	NS	NS

[1]D = Disked, MB = Moldboard plow.
[2]+ = .2, ++ = .1, * = .05, ** = .01

Table 3. Influence of gypsum on monocalcium phosphate extractable sulfur at various depths.

Gypsum Treatment	Soil Depth 0 - 3" D[1]	MB	3 - 6" D	MB	6 - 12" D	MB	12 - 24" D	MB	0 - 24" D	MB
lb/A	lb/A									
0	5	4	3	2	7	5	18	18	32	27
500	4	4	5	3	9	7	23	23	40	38
1000	6	5	3	25	11	22	37	41	56	91
2000	6	17	12	57	26	44	82	51	125	168

Statistics	0 - 3"	3 - 6"	6 - 12"	12 - 24"	0 - 24"
	Significance[2]				
Tillage	NS	++	NS	NS	NS
Gypsum	++	*	*	**	**
Linear	*	**	**	**	**
Quadratic	NS	NS	NS	NS	NS
Gyp X Till	++	+	NS	+	NS

[1]D = Disked, MB = Moldboard plow.
[2]+ = .2, ++ = .1, * = .05, ** = .01

Table 4. Macronutrient concentrations in recently mature cauliflower leaves as affected by gypsum.

Gypsum	N		P		K		Ca		S		Mg	
Treatment	D[1]	MB	D	MB	D	MB	D	MB	D	MB	D	MB
lb/acre	%											
0	4.05	4.21	0.50	0.49	3.45	3.08	0.81	0.87	0.76	0.63	0.27	0.28
500	3.79	3.74	0.46	0.50	3.64	3.35	1.01	0.90	0.91	0.81	0.25	0.28
1000	4.03	3.76	0.47	0.49	3.51	3.40	0.93	0.84	0.94	0.79	0.24	0.24
2000	3.72	3.80	0.49	0.47	3.29	3.41	0.97	0.93	0.91	0.91	0.24	0.21

Statistics	Significance[2]					
	N	P	K	Ca	S	Mg
Tillage	NS	NS	+	NS	**	NS
Gypsum	+	NS	NS	NS	**	++
Linear	++	NS	NS	NS	**	*
Quadratic	NS	NS	+	NS	**	NS
Gyp X Till	NS	NS	NS	NS	+	NS

[1]D = Disked, MB = Moldboard plow.
[2]+ = .2, ++ = .1, * = .05, ** = .01

Table 5. Micronutrient concentrations in recently mature cauliflower leaves as affected by gypsum.

Gypsum	Fe		Mn		Zn		Cu		B		Mo	
Treatment	D[1]	MB	D	MB	D	MB	D	MB	D	MB	D	MB
lb/acre	ppm											
0	60	62	98	101	47	49	4	5	51	35	.7	.5
500	54	57	97	65	48	41	4	5	42	30	.4	.8
1000	57	56	109	75	52	52	4	4	44	32	.6	.2
2000	57	59	84	83	47	47	4	4	34	32	.4	.2

Statistics	Significance[2]					
	Fe	Mn	Zn	Cu	B	Mo
Tillage	NS	*	NS	+	**	
Gypsum	NS	NS	+	NS	+	
Linear	NS	NS	NS	NS	*	
Quadratic	NS	NS	NS	NS	NS	
Gyp X Till	NS	+	NS	NS	NS	

[1]D = Disked, MB = Moldboard plow.
[2]+ = .2, ++ = .1, * = .05, ** = .01

Table 6. Macronutrient concentrations in immature cauliflower leaves as influenced by gypsum.

Gypsum Treatment	N		P		K		Ca		S		Mg	
	D[1]	MB	D	MB	D	MB	D	MB	D	MB	D	MB
lb/acre	%											
0	4.03	3.85	0.54	0.51	3.54	3.19	0.36	0.34	0.72	0.63	0.24	0.24
500	3.90	3.59	0.50	0.52	3.51	3.33	0.42	0.42	0.80	0.77	0.23	0.24
1000	3.97	3.81	0.52	0.51	3.46	3.42	0.46	0.39	0.89	0.77	0.23	0.23
2000	3.90	3.67	0.52	0.49	3.46	3.41	0.50	0.44	0.89	0.82	0.22	0.22

Statistics	N	P	K	Ca	S	Mg
	Significance[2]					
Tillage	*	NS	*	*	**	NS
Gypsum	NS	NS	NS	**	**	+
Linear	NS	NS	NS	**	**	**
Quadratic	NS	NS	NS	NS	**	NS
Gyp X Till	NS	NS	NS	NS	+	NS

[1]D = Disked, MB = Moldboard plow.
[2]+ = .2, ++ = .1, * = .05, ** = .01

Table 7. Micronutrient concentrations in immature cauliflower leaves as influenced by gypsum.

Gypsum Treatment	Fe		Mn		Zn		Cu		B		Mo	
	D[1]	MB	D	MB	D	MB	D	MB	D	MB	D	MB
lb/acre	ppm											
0	66	63	68	56	52	49	4	5	39	29	.6	.6
500	65	61	65	50	54	46	4	4	32	28	.2	.5
1000	64	59	77	54	57	55	5	4	34	27	.3	.6
2000	66	64	79	59	53	50	4	4	35	27	.3	.3

Statistics	Fe	Mn	Zn	Cu	B	Mo
	Significance[2]					
Tillage	+	**	++	NS	**	
Gypsum	NS	NS	NS	NS	NS	
Linear	NS	+	NS	NS	NS	
Quadratic	NS	NS	+	NS	+	
Gyp X Till	NS	NS	NS	++	NS	

[1]D = Disked, MB = Moldboard plow.
[2]+ = .2, ++ = .1, * = .05, ** = .01

INFLUENCE OF SEED INOCULATION, SOIL APPLIED NITROGEN AND FOLIAR APPLIED NITROGEN ON PRODUCTIVITY OF PROCESSING PEAS

C. J. ROSEN, C. KAHRMANN, H. J. BUCHITE AND J. B. HEBEL

Minnesota usually ranks second or third nationally in the production of processing peas. Despite relatively large acreages, little attention has been given to nitrogen response by peas. The objectives of the present study were to : 1) determine the effect of inoculation on pea productivity in a coarse and a fine textured soil, 2) characterize pea response to soil applied nitrogen and 3) evaluate the use of a foliar nitrogen source on pea productivity.

Materials and Methods:

The experiment was conducted at two sites: Southern Experiment Station in Waseca, MN and the Sand Plains Research Farm in Becker, MN. Prior to planting and fertilizer application, soil at the Waseca site - Nicollet clay loam, and at the Becker site - Hubbard loamy sand, had the following test values:

	Becker	Waseca
pH (0-6")	6.3	7.4
P lb/A, (0-6")	53	34
K lb/A, (0-6")	185	436
N lb/A (0-12")	16	25

The previous crop at Waseca was corn and at Becker was rye. There were six N treatments which included 1) a control, 2) 40 lb N/A (preplant soil applied), 3) 80 lb N/A (preplant soil applied), 4) 30 lb N/A as a foliar (15 lb at flowering, and 15 lb during pod formation), 5) 60 lb N/A as a foliar (30 lb at flowering, 30 lb during pod formation), 6) 40 lb N/A (preplant soil applied) and 30 lb N/A as a foliar (15 lb N/A at flowering and 15 lb N/A during pod formation). The nitrogen source for all soil applications was ammonium nitrate and the source for foliar nitrogen was Formolene (30-0-2). The Formolene was mixed with water (10:1) and applied with WEX a surfactant.

Two pea varieties, 'Target' and 'Venus' were planted at Becker on 14 April and at Waseca on 19 April. Plant populations were appoximately 500,000/A. A split plot design with 4 replications was used where variety and inoculation were whole plots and N treatments were subplots. The Waseca plot was nonirrigated. At Becker, rainfall was supplemented with irrigation to supply approximately 1" of water per week. Whole plant samples were collected 4 weeks after planting for N determination (prior to foliar N applications). At Becker 'Target' was harvested 19 June and 'Venus' 24 June. At Waseca 'Target was harvested 21 June and 'Venus' 24 June. Harvested vines and pods were placed in a viner to separate the peas from the shell and vine plant material. Subsamples of peas were obtained for tenderometer reading, N determination and % moisture. Subsamples of the vines plus shells were taken for N determination and % moisture. Orthogonal contrasts were used to detect N treatment differences over inoculation and variety. High N vs Low N compares treatments 3, 5, and 6 to treatments 1, 2, and 4. Soil vs foliar compares treatments 2 and 3 to treatments 4 and 5. Linear and quadratic responses are for treatments 1, 2, and 3.

Results and Discussion:

Pea yields at both locations increased with soil applied nitrogen (Table 1). The nitrogen response at Becker was linear compared to a quadratic reponse (maximum yield at 40 lb N/A) at Waseca. Foliar applied N tended to depress yields at both locations. Inoculation had no significant effect on yields at either site; however, at Becker, yields tended to increase in the inoculated plots when supplemental N was not provided, the opposite response was observed at Waseca. Nodule weight per plant was significantly increased with inoculation at Becker (Table 2). Soil applied nitrogen significantly depressed nodule weight. 'Target' appeared to nodulate better than 'Venus'. Although detailed measurements were not obtained at Waseca, visual examination of the plants indicated that all plants were well nodulated.

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

Fresh weight of vines and shells increased with soil applied N at Waseca but response was inconsistent at Becker (Table 3). Inoculation increased vines and shells at Becker, whereas a decrease was recorded at Waseca. The reasons for these differences are not clear from this experiment.

Tenderometer readings (a measure of maturity at harvest) were not significantly affected by any of the treatments (Table 4). This was not expected since N applications generally are believed to delay maturity.

Nitrogen concentrations in whole plants samples collected 4 weeks after planting significantly increased with soil applied N (Table 5). Inoculation had an inconsistent effect and appeared to depend on variety. Because foliar N treatments were not applied for another 2 weeks, the comparison between foliar and soil applied N is not valid at this sampling time. Nitrogen concentrations in peas at harvest tended to increase with foliar application (Table 6), however, this was not related to yield. Inoculation had no effect on N concentrations in peas. In general, soil applied N decreased pea N concentrations. Similarly, N concentrations in vines and shells at harvest tended to decrease with increasing soil applied N (Table 7). The lower N concentrations in both vines + shells and peas with higher soil applied N is difficult to explain at this time. Application of foliar N significantly increased N concentrations in vines and shells.

Nitrogen content in peas was about one third that in the vines and shells (Tables 8 and 9). The nitrogen content in the vines and shells (80 - 140 lb/A) could be a significant N contribution for subsequent crops if incorporated after harvest. The effects of soil applied N on N content in peas generally followed pea yields. Inoculation did not significantly affect pea N content. Nitrogen content in vines and shells was not affected by inoculation at Becker and depended on variety at Waseca. High rates of soil and foliar applied N increased N content of vines and shells at Becker.

General Comments:

Pea yields at both sites were generally increased with soil applied N. A greater response was observed at Becker than at Waseca. Future experiments using smaller increments of soil applied N are necessary to refine N response by peas. Yield increases with applied N may not be desirable if vine production is too great. Inoculation of pea seed had no effect on production at Waseca (nonirrigated, fine textured soil), but a trend of increased yields with inoculation was observed in the control plot at Becker (irrigated, coarse textured soil). At Becker nodulation was dependent on inoculation, soil applied N, and pea variety. Foliar N fertilizer increased N concentrations in peas as well as in vines and shells; however, this did not correlate to an increase in yield. Because processing peas are harvested at a physiologically immature stage of growth, the applications of foliar N may have been too late to be of any benefit to yield.

Table 1. Influence of soil applied nitrogen, foliar applied nitrogen, and seed inoculation on pea yields.

	Becker				Waseca			
	Venus		Target		Venus		Target	
Treatment	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	T/A							
0	1.65	1.84	1.27	1.64	2.42	2.35	1.95	1.84
40 Soil	2.37	1.92	1.24	1.39	2.79	2.59	1.98	1.91
80 Soil	2.07	2.43	1.55	1.19	2.43	2.44	1.98	1.84
30 Foliar	1.97	1.75	1.12	1.48	2.39	2.50	1.76	1.98
60 Foliar	1.78	2.05	1.09	1.35	2.44	2.30	1.89	1.84
40 S + 30 F[2]	1.79	1.88	1.26	1.32	2.44	2.39	1.80	1.89

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.2541	0.3921
Variety	0.0001	0.0001
Nitrogen	0.3792	0.1830
High N vs. Low N	0.9418	0.1814
Soil vs. Foliar	0.0565	0.0734
N rate linear	0.1446	0.6977
N rate quadratic	0.8165	0.0288
Nitrogen x Inoculation	0.6581	0.5008
Nitrogen x Variety	0.3380	0.7035
Inoculation x Variety	0.5363	0.5712
Nitrogen x Inoculation x Variety	0.2098	0.9290

Table 2. Influence of soil applied nitrogen, foliar applied nitrogen and seed inoculation on nodule dry weight at harvest.

	Becker			
	Venus		Target	
Treatment	NI[1]	I	NI	I
lb N/A	mg/plant			
0	40	49	78	100
40 Soil	27	60	46	75
80 Soil	31	54	23	42
30 Foliar	36	66	20	126
60 Foliar	29	26	9	82
40 S + 30 F[2]	31	68	28	107

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F
Inoculation	0.0002
Variety	0.0191
Nitrogen	0.3623
High N vs. Low N	0.1087
Soil vs. Foliar	0.7037
N rate linear	0.0893
N rate quadratic	0.9716
Nitrogen x Inoculation	0.6053
Nitrogen x Variety	0.7719
Inoculation x Variety	0.0299
Nitrogen x Inoculation x Variety	0.7150

Table 3. Influence of soil applied nitrogen, foliar applied nitrogen, and seed inoculation on vine and shell yield.

	Becker				Waseca			
	Venus		Target		Venus		Target	
Treatment	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	T/A							
0	12.36	13.79	13.25	13.23	11.68	13.45	12.30	10.91
40 Soil	14.42	12.44	11.91	11.15	14.31	12.31	12.15	11.75
80 Soil	12.90	15.27	12.81	12.87	14.12	13.07	13.20	12.18
30 Foliar	12.84	13.88	12.28	12.78	14.16	12.85	12.60	12.40
60 Foliar	12.83	13.13	12.91	13.92	12.51	12.34	12.28	11.34
40 S + 30 F[2]	14.37	16.28	12.74	13.25	11.40	12.31	13.34	11.67

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.0325	0.0286
Variety	0.0934	0.0454
Nitrogen	0.3666	0.1065
High N vs. Low N	0.0909	0.9452
Soil vs. Foliar	0.8512	0.1696
N rate linear	0.6846	0.0197
N rate quadratic	0.2083	0.9632
Nitrogen x Inoculation	0.5490	0.5666
Nitrogen x Variety	0.3881	0.3127
Inoculation x Variety	0.5519	0.3870
Nitrogen x Inoculation x Variety	0.8415	0.0211

Table 4. Influence of soil applied nitrogen, foliar applied nitrogen, and seed inoculation on tenderometer readings.

	Becker				Waseca			
	Venus		Target		Venus		Target	
Treatment	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	TD							
0	94.8	91.0	84.0	83.8	80.5	78.6	86.1	90.1
40 Soil	97.3	94.0	82.0	83.8	80.6	80.4	88.5	88.4
80 Soil	97.3	94.5	85.3	81.0	81.4	80.3	86.6	86.0
30 Foliar	96.0	90.0	81.0	85.0	78.6	81.1	87.4	88.3
60 Foliar	97.0	96.3	82.0	83.5	80.3	80.8	86.0	88.9
40 S + 30 F[2]	86.5	88.5	82.5	83.0	81.6	80.8	86.0	87.5

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.5323	0.4716
Variety	0.0001	0.0001
Nitrogen	0.0841	0.9653
High N vs. Low N	0.6536	0.6998
Soil vs. Foliar	0.6563	0.8748
N rate linear	0.5056	0.7746
N rate quadratic	0.8306	0.3696
Nitrogen x Inoculation	0.7735	0.7244
Nitrogen x Variety	0.0875	0.4965
Inoculation x Variety	0.3323	0.3524
Nitrogen x Inoculation x Variety	0.5314	0.5084

Table 5. Influence of applied soil nitrogen, foliar applied nitrogen, and seed inoculation on nitrogen concentration in whole plants sampled 4 weeks after planting.

	Becker				Waseca			
	Venus		Target		Venus		Target	
Treatment	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	% N							
0	3.22	3.26	3.71	3.89	3.72	2.80	3.40	3.29
40 Soil	3.86	3.46	4.28	4.26	3.57	3.90	3.88	3.73
80 Soil	4.46	4.42	4.45	4.86	4.01	3.68	4.19	4.61
30 Foliar	3.04	2.97	2.95	3.27	3.01	3.49	3.49	3.57
60 Foliar	2.99	3.05	3.07	3.78	3.11	2.79	3.36	2.96
40 S + 30 F[2]	3.93	4.22	4.41	4.51	3.94	3.66	3.83	3.68

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.0726	0.2939
Variety	0.0002	0.0873
Nitrogen	0.0001	0.0001
High N vs. Low N	0.0001	0.0475
Soil vs. Foliar	0.0001	0.0001
N rate linear	0.0001	0.0001
N rate quadratic	0.5008	0.6470
Nitrogen x Inoculation	0.2276	0.0715
Nitrogen x Variety	0.2358	0.3534
Inoculation x Variety	0.0422	0.5795
Nitrogen x Inoculation x Variety	0.5656	0.1139

Table 6. Influence of soil applied nitrogen, foliar applied nitrogen, and seed inoculation on nitrogen concentrations in peas sampled at harvest.

	Becker				Waseca			
	Venus		Target		Venus		Target	
Treatment	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	% N							
0	4.42	4.49	4.10	4.03	3.82	3.79	4.04	4.03
40 Soil	4.32	4.54	4.09	3.87	3.84	3.82	4.17	4.13
80 Soil	4.32	4.41	3.89	3.99	3.73	3.77	4.13	3.99
30 Foliar	4.44	4.47	4.14	3.89	3.90	3.77	4.20	4.18
60 Foliar	4.48	4.48	4.09	4.03	3.88	3.83	4.12	4.23
40 S + 30 F[2]	4.52	4.40	3.88	4.04	3.89	3.93	3.98	3.16

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.9773	0.7898
Variety	0.0001	0.0001
Nitrogen	0.3832	0.1060
High N vs. Low N	0.4906	0.8285
Soil vs. Foliar	0.0810	0.0648
N rate linear	0.0700	0.7407
N rate quadratic	0.9508	0.0677
Nitrogen x Inoculation	0.6686	0.4949
Nitrogen x Variety	0.9525	0.3925
Inoculation x Variety	0.3854	0.5506
Nitrogen x Inoculation x Variety	0.0616	0.4793

Table 7. Influence of soil applied nitrogen, foliar applied nitrogen, and seed inoculation on nitrogen concentrations in vines and shells sampled at harvest.

Treatment	Becker				Waseca			
	Venus		Target		Venus		Target	
	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	% N							
0	2.04	2.67	2.48	2.36	2.20	2.42	2.61	2.51
40 Soil	1.95	2.00	2.66	2.17	2.54	2.46	2.28	2.52
80 Soil	1.91	1.73	2.11	2.30	2.04	2.23	2.29	2.48
30 Foliar	2.20	2.09	2.83	2.57	2.19	2.35	2.78	2.53
60 Foliar	2.44	2.42	3.07	2.93	2.45	2.37	2.88	2.37
40 S + 30 F[2]	2.27	2.35	2.52	2.69	2.22	2.48	2.73	2.64

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.3344	0.8658
Variety	0.0001	0.0185
Nitrogen	0.0001	0.0258
High N vs. Low N	0.1259	0.6689
Soil vs. Foliar	0.0001	0.0226
N rate linear	0.0093	0.0352
N rate quadratic	0.6116	0.1389
Nitrogen x Inoculation	0.5148	0.0752
Nitrogen x Variety	0.5942	0.0717
Inoculation x Variety	0.2619	0.2353
Nitrogen x Inoculation x Variety	0.3139	0.1656

Table 8. Total nitrogen removed in peas as influenced by soil applied nitrogen, foliar applied nitrogen and seed inoculation.

Treatment	Becker				Waseca			
	Venus		Target		Venus		Target	
	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	lbs N/A							
0	29.4	33.2	19.3	26.2	35.3	35.6	26.6	26.7
40 Soil	42.9	35.5	19.3	21.5	40.5	38.6	28.8	27.8
80 Soil	36.6	44.2	23.5	18.1	34.7	35.2	28.3	25.8
30 Foliar	36.1	31.6	17.4	22.3	35.4	36.4	25.8	28.4
60 Foliar	32.4	37.2	16.5	21.0	36.6	34.6	27.8	26.5
40 S + 30 F[2]	32.7	30.4	18.9	19.9	37.6	36.6	25.8	27.4

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.3865	0.3359
Variety	0.0001	0.0001
Nitrogen	0.3750	0.2250
High N vs. Low N	0.8570	0.1952
Soil vs. Foliar	0.0798	0.2448
N rate linear	0.1899	0.6487
N rate quadratic	0.6652	0.0163
Nitrogen x Inoculation	0.6595	0.7299
Nitrogen x Variety	0.3103	0.6728
Inoculation x Variety	0.5186	0.9312
Nitrogen x Inoculation x Variety	0.3220	0.8524

Table 9. Total nitrogen uptake by vines and shells as influenced by soil applied nitrogen, foliar applied nitrogen and seed inoculation.

	Becker				Waseca			
	Venus		Target		Venus		Target	
Treatment	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	lbs N/A							
0	96.8	116.6	121.4	122.1	84.7	104.4	104.8	89.9
40 Soil	111.4	101.5	110.5	92.9	118.5	101.4	90.1	95.3
80 Soil	89.9	105.0	108.2	109.0	95.8	96.9	101.6	96.1
30 Foliar	105.2	105.5	125.7	117.6	105.1	90.1	110.0	97.2
60 Foliar	120.0	124.7	138.6	140.4	104.3	97.4	112.9	87.9
40 S + 30 F[2]	120.3	125.1	122.6	131.7	85.8	104.0	112.9	92.6

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.6936	0.0662
Variety	0.0495	0.9567
Nitrogen	0.0071	0.8790
High N vs. Low N	0.0659	0.9071
Soil vs. Foliar	0.0024	0.7239
N rate linear	0.1833	0.7780
N rate quadratic	0.5317	0.2914
Nitrogen x Inoculation	0.7094	0.4033
Nitrogen x Variety	0.7575	0.1773
Inoculation x Variety	0.3812	0.0654
Nitrogen x Inoculation x Variety	0.9845	0.0352

RESPONSE OF POTATO GROWN UNDER LONG ROTATIONS TO CALCIUM AND MAGNESIUM AMENDMENTS ON A COARSE-TEXTURED SOIL - 1985

C. J. ROSEN and H. J. BUCHITE

Soil management practices for potato production differ from those used for most other agricultural crops in that liming of low pH soils is avoided. The reason for not raising soil pH is due to the potential for increasing the incidence of common scab when the soil pH is above 5.2. Approximately 30% of potatoes grown in Minnesota are on irrigated coarse-textured soils. Because recommendations are not to lime, soil calcium, magnesium and pH have dropped to low ranges. The potential for Al and Mn toxicity also exists due to the increased solubilities of these elements with low pH. Over the past 10-15 years, yields of potatoes grown on these coarse-textured soils have generally declined. Part of this problem may be due to lack of proper rotation coupled with an imbalanced soil fertility.

In a study conducted at this site in 1984, calcium and magnesium applied as fine dolomitic lime or as sulfate salts tended to increase potato yields. However, potatoes died back early (due to Verticillium wilt) which resulted in low yields in all treatments. In this study disease problems appeared to be an overriding factor. The objective of the present study was to determine the influence of Ca/Mg amendments and fumigation on potato production on a coarse-textured soil with a history of continuous potatoes.

Materials and Methods:

The experimental site was located in Cambridge, MN on an Anoka loamy sand. Soil chemical properties before treatment application were as follows:

Soil Depth --inches--	pH	P	K	Ca	Mg
		-------lb/A-------			
0 - 6	4.9	519	306	298	66
6 - 12	4.6	476	233	290	60
12 - 24	4.7	255	455	532	130

Potatoes had been grown on this site for the past 10 - 15 years. Treatments included:

1) Check
2) 2.0 T/A Lime
3) 4.0 T/A Lime
4) 6.0 T/A Lime
5) Check
6) 1.8 T/A Gypsum + 2.1 T/A Epsom Salts
7) 3.6 T/A Gypsum + 4.2 T/A Epsom Salts
8) 5.4 T/A Gypsum + 6.3 T/A Epsom Salts

All amendments were applied 12 November 1984 as a broadcast and disked in. The liming material used was a 100 mesh dolomitic limestone. The gypsum/Epsom salt combination was used to provide an equal amount of Ca and Mg as a non-lime source. The following spring the entire field was plowed to a depth of 8 - 10". On 18 April 1985 strips of the field were fumigated with Telone C (injected to a depth of 6") at a rate of 50 gal/A. An equal area was left unfumigated. The field was then packed after injection. Potatoes, cv. 'Norland', were planted on 5 May 1985. Spacing used was 3 feet between row centers. At planting, 120 lb N/A, 70 lb P_2O_5/A, 280 lb K_2O/A and 90 lb S/A was banded. An additional 60 lb N/A was applied at emergence and at hilling. Soil samples were collected on 10 May 1985 and 28 August 1985. Plant tissue samples consisting of the most recently matured whole leaf (blade and petiole) were collected 58 (at flowering) and 81 (onset of dieback) days after planting. Two center 15' rows from each plot were harvested on 12 September 1985 with the following measurements recorded: total yield, A-Size (greater than 2") B-Size (less than 2") and scab ratings. A split plot design with 4 replications was used. Fumigation was the main plot and Ca/Mg treatments were the subplots. Orthogonal contrasts were used to determine linear and quadratic responses to lime (treatments 1, 2, 3, and 4) and gypsum plus Epsom salts (treatments 5, 6, 7, and 8). Lime vs. gypsum plus Epsom salts compares treatments 2, 3, and 4 to treatments 6, 7, and 8.

Results and Discussion:

Potato yields were significantly increased with addition of calcium and magnesium amendments (Table 1). Yield increases were due primarily to increases in A-size potatoes. There was a linear response to lime applications compared to a more quadratic response to gypsum plus Epsom salts. Potato yields were low in all treatments due to early dieback. Fumigation had no effect on dieback incidence and in general depressed yields. This negative effect on yield may have been due to toxicity of the fumigant on potato growth. Had the fumigant been applied the previous fall or at lower rates in the spring, toxicity may not have occurred. The reason why fumigation had no effect on early dieback cannot be determined from this study. However, Verticillium wilt did not appear to be the major cause of dieback this year.

At the begining of the season soil Ca increased linearly with increasing gypsum application at the 0-6" and 6-12" depths (Table 2). Lime treatments had no significant effect on soil Ca at this time. Neither amendment affected soil Ca at the 12-24" depth. Late in the growing season, soil Ca increased linearly with gypsum application at all depths while lime amendments increased Ca at the 0-6" and 6-12" depths (Table 3). Because of higher solubility of gypsum compared to dolomitic lime, soil Ca levels were greater with the gypsum source. Soil Mg increased linearly with increasing lime and Epsom salt applications (Table 4). As with Ca, the sulfate salt was more soluble than the lime source. This resulted in higher Mg levels with Epsom salts compared to lime. At the end of the growing season, soil Mg trends were similar to those at the begining of the season with higher levels resulting from the Epsom salt source (Table 5). Soil pH increased linearly with increasing lime application at the begining and end of the growing season (Tables 6 and 7). Even with relatively large applications of lime (6T/A), soil pH incresed less than one-half a pH unit. Liming did not have any effect on scab incidence (data not presented). However, soil pH was less than 5.2 in all treatments which is below the range considered optimum for scab development. Because of the low solubility of lime, it is possible that soil pH will increase in subsequent years. In contrast to lime, gypsum and Epsom salts significantly decreased soil pH at the begining of the season, however, the effect was not as pronounced by the end of the season. Soil pH levels were greater when the soil was fumigated, possibly because of decreased nitrification.

Leaf tissue macro and micronutrient levels during flowering are presented in Tables 8 and 9. Lime applications increased concentrations of N, Mg, and Ca and decreased concentrations of Mn and B. Gypsum and Epsom salt applications increased concentrations of N, Mg, and Fe and decreased concentrations of Mn and B. Fumigation increased concentrations of P and decreased concentrations of Ca, Mg, and Mn. At the onset of dieback, lime applications increased tissue levels of N, Ca, Mg, and Zn and decreased levels of Mn and B (Tables 10 and 11). Gypsum and Epsom salt applications increased concentrations of Ca, Mg, and Fe and decreased concentrations of K and Mn. Fumigation increased concentrations of N, P, and B and decreased concentrations of Ca, Mg, and Mn. It is interesting to note that although soil levels of Ca and Mg were higher with gypsum and Epsom salts compared to lime, tissue levels of these nutrients were similar for both amendment sources. Fumigation effects on nutrient composition may possibly be due to stunting of plant growth (concentrating N and P) and a reduction in transpiration rate (depressing Ca and Mg uptake).

General Conclusions:

Potato yields increased with applications of calcium/magnesium amendments. Because of higher solubility of the sulfate sources, lower rates can be applied compared to the lime sources. Although scab incidence was not increased by liming in this experiment, the sulfate salts would be the safer source to use if scab is a problem. Dolomitic lime would be a suitable source of Ca and Mg if soil pH is less than 5.0 and scab resistant varieties are used. None of the amendments or fumigation had any effect on early dieback problems. Rotating potatoes with other crops may be the only solution to prevent potato yields from declining in this area.

Table 1. A-size, B-size, and total yield as influenced by calcium-magnesium amendments and fumigation.

Treatment[1]	B-size +Fum	B-size -Fum	A-size +Fum	A-size -Fum	Total +Fum	Total -Fum
	CWT/A					
Check	40.2	33.9	78.4	105.5	118.6	139.4
1X Lime	41.1	31.9	99.2	118.1	139.9	150.1
2X Lime	41.1	38.7	123.4	137.0	164.1	175.7
3X Lime	41.1	39.7	117.1	160.2	158.3	200.4
Check	40.2	36.3	92.9	109.9	131.1	146.2
1X G + E[2]	37.3	38.7	118.1	148.6	155.4	186.9
2X G + E	34.9	40.2	123.4	143.8	158.3	184.0
3X G + E	33.9	35.3	105.5	137.0	139.4	171.8

Statistics	Significance[3] B-size	A-size	Total
Fumigation	NS	NS	+
Treatment	NS	**	**
Linear Lime	NS	**	**
Quad Lime	NS	NS	NS
Linear G + E	NS	++	+
Quad G + E	NS	**	**
Lime vs G + E	NS	NS	NS
Tmt X Fum	NS	NS	NS

[1]See Materials and Methods section for actual rates.
[2]G + E = Gypsum + Epson Salts.
[3]NS = >.2, + = .1-.2, ++ = .05-.1, * = .01-.05, ** = <.01.

Table 2. Influence of calcium-magnesium amendments and fumigation on ammonium acetate extractable Ca at various depths, 10 May.

	Depth (inches)							
	0-6		6-12		12-24		0-24	
	(lb/A)							
Treatment[1]	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	283	299	277	291	372	257	1302	1103
1X Lime	313	311	277	307	339	303	1267	1224
2X Lime	426	367	354	341	329	289	1438	1285
3X Lime	380	369	327	421	302	520	1312	1830
Check	286	278	273	276	330	373	1220	1298
1X G + E[2]	338	417	477	578	367	349	1549	1693
2X G + E	406	528	860	903	378	387	2020	2205
3X G + E	514	1059	800	994	416	460	2145	2971

Statistics	Significance[3]			
	0-6	6-12	12-24	0-24
Fumigation	+	+	NS	NS
Treatment	**	**	NS	**
Linear Lime	NS	NS	NS	+
Quad Lime	NS	NS	NS	NS
Linear G + E	**	**	NS	**
Quad G + E	+	++	NS	NS
Lime vs G + E	*	**	NS	**
Tmt X Fum	NS	NS	NS	NS

Table 3. Influence of calcium-magnesium amendments and fumigation on ammonium acetate extactable Ca at various depths, 28 August.

	Depth (inches)							
	0-6		6-12		12-24		0-24	
	(lb/A)							
Treatment[1]	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	370	329	371	384	414	389	1569	1492
1X Lime	452	376	439	414	392	507	1675	1636
2X Lime	420	385	487	419	443	427	1793	1657
3X Lime	460	538	525	568	352	488	1690	2082
Check	350	341	426	334	381	401	1539	1477
1X G + E[2]	476	505	603	556	616	489	2061	2038
2X G + E	462	532	664	786	538	563	2202	2444
3X G + E	840	563	913	1078	685	648	3123	2936

Statistics	Significance[3]			
	0-6	6-12	12-24	0-24
Fumigation	NS	NS	NS	NS
Treatment	**	**	**	**
Linear Lime	*	+	NS	*
Quad Lime	NS	NS	NS	NS
Linear G + E	**	**	**	**
Quad G + E	NS	NS	NS	NS
Lime vs G + E	**	**	**	**
Tmt X Fum	NS	NS	NS	NS

[1]See Materials and Methods for actual rates.
[2]G + E = Gypsum + Epsom Salts.
[3]NS = >.2, + = .1-.2, ++ = .05-.1, * = .01-.05, ** = <.01.

Table 4. Influence of calcium-magnesium amendments and fumigation on ammonium acetate extractable Mg at various depths, 10 May.

	Depth (inches)							
	0-6		6-12		12-24		0-24	
	(lb/A)							
Treatment[1]	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	61	68	62	64	88	55	298	242
1X Lime	77	75	71	82	77	78	302	313
2X Lime	104	106	105	105	77	63	362	337
3X Lime	108	98	92	128	76	115	352	454
Check	57	61	69	56	74	72	273	262
1X G + E[2]	116	121	121	137	171	188	579	635
2X G + E	144	158	171	207	218	271	750	906
3X G + E	166	178	192	180	346	293	1050	944

Statistics	Significance[3]			
	0-6	6-12	12-24	0-24
Fumigation	NS	NS	NS	NS
Treatment	**	**	**	**
Linear Lime	**	**	NS	++
Quad Lime	NS	NS	NS	NS
Linear G + E	**	**	**	**
Quad G + E	*	**	NS	+
Lime vs G + E	**	**	**	**
Tmt X Fum	NS	NS	NS	NS

Table 5. Influence of calcium-magnesium amendments and fumigation on ammonium acetate extractable Mg at various depths, 28 August.

	Depth (inches)							
	0-6		6-12		12-24		0-24	
	(lb/A)							
Treatment[1]	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	47	41	42	49	74	58	237	206
1X Lime	80	64	91	79	77	116	325	374
2X Lime	86	62	99	79	84	102	353	344
3X Lime	95	87	127	127	72	110	366	434
Check	53	49	62	39	63	51	240	190
1X G + E[2]	76	86	52	74	91	94	309	348
2X G + E	98	95	65	73	116	178	393	524
3X G + E	81	76	91	61	140	98	451	333

Statistics	Significance[3]			
	0-24	6-12	12-24	0-24
Fumigation	NS	NS	NS	NS
Treatment	**	**	**	**
Linear Lime	**	**	NS	++
Quad Lime	NS	NS	NS	NS
Linear G + E	*	++	**	**
Quad G + E	*	NS	*	NS
Lime vs G + E	NS	**	++	**
Tmt X Fum	NS	NS	+	NS

[1]See Materials and Methods for actual rates.
[2]G + E = Gypsum + Epsom Salts.
[3]NS = >.2, + = .1-.2, ++ = .05-.1, * = .01-.05, ** = <.01.

Table 6. Influence of calcium-magnesium amendments and fumigation on soil pH (1:1 soil - water) at various depths, 10 May.

	Depth (inches)					
	0-6		6-12		12-24	
Treatment	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	4.9	4.9	4.6	4.7	4.8	4.8
1X Lime	4.9	4.9	4.7	4.9	4.8	4.8
2X Lime	5.3	5.2	5.1	5.0	4.9	4.9
3X Lime	5.3	5.0	5.0	5.1	4.9	4.9
Check	5.0	4.8	4.9	4.7	4.8	4.7
1X G + E[2]	4.6	4.7	4.5	4.4	4.4	4.4
2X G + E	4.5	4.5	4.4	4.5	4.4	4.4
3X G + E	4.5	4.4	4.4	4.5	4.5	4.4

Statistics	Significance[3]		
	0-6	6-12	12-24
Fumigation	++	NS	NS
Treatment	**	**	**
Linear Lime	**	**	++
Quad Lime	NS	NS	NS
Linear G + E	**	**	**
Quad G + E	+	**	**
Lime vs G + E	**	**	**
Tmt X Fum	NS	+	NS

Table 7. Influence of calcium-magnesium amendments and fumigation on soil pH (1:1 soil - water) at various depths, 28 Aug.

	Depth (inches)					
	0-6		6-12		12-24	
Treatment	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	4.7	4.5	4.7	4.6	4.5	4.4
1X Lime	4.9	4.7	5.0	4.6	4.6	4.6
2X Lime	5.1	4.7	5.0	4.6	4.7	4.4
3X Lime	5.1	5.0	5.3	5.1	4.7	4.6
Check	4.8	4.5	4.9	4.4	4.5	4.4
1X G + E[2]	4.7	4.6	4.7	4.4	4.4	4.4
2X G + E	4.7	4.5	4.5	4.3	4.5	4.3
3X G + E	4.6	4.5	4.6	4.3	4.5	4.3

Statistics	Significance[3]		
	0-6	6-12	12-24
Fumigation	++	*	NS
Treatment	**	**	**
Linear Lime	**	**	NS
Quad Lime	NS	NS	NS
Linear G + E	NS	+	**
Quad G + E	NS	NS	NS
Lime vs G + E	**	**	**
Tmt X Fum	NS	NS	NS

[1]See Materials and Methods for actual rates.
[2]G + E = Gypsum + Epsom Salts.
[3]NS = >.2, + = .1-.2, ++ = .05-.1, * = .01-.05, ** = <.01.

Table 8. Macronutrient levels in recently mature leaves 58 days after planting as influenced by calcium-magnesium amendments and fumigation.

	N		P		K		Ca		Mg	
	--------	--------	--------	--------	--%	--------	--------	--------	--------	--------
Treatment[1]	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	4.94	4.47	0.43	0.36	4.76	4.87	0.39	0.53	0.35	0.36
1X Lime	4.97	4.85	0.41	0.37	4.75	5.08	0.48	0.51	0.38	0.40
2X Lime	5.05	4.93	0.42	0.41	5.01	4.93	0.46	0.61	0.38	0.45
3X Lime	5.01	5.20	0.43	0.37	4.79	4.95	0.44	0.63	0.38	0.48
Check	4.77	4.89	0.43	0.36	4.70	5.13	0.40	0.53	0.29	0.38
1X G + E[2]	5.11	5.10	0.44	0.38	4.91	4.85	0.47	0.60	0.41	0.47
2X G + E	5.38	4.99	0.43	0.40	4.84	4.85	0.47	0.53	0.42	0.50
3X G + E	5.19	5.17	0.47	0.38	4.80	4.98	0.40	0.60	0.36	0.54

Statistics	----------	----------	Significance[3]	----------	----------
	N	P	K	Ca	Mg
Fumigation	NS	**	NS	**	*
Treatment	*	NS	NS	NS	**
Linear Lime	*	NS	NS	+	*
Quad Lime	NS	NS	NS	NS	NS
Linear G + E	*	+	NS	NS	**
Lime vs G + E	++	+	NS	NS	+
Tmt X Fum	NS	NS	NS	NS	NS

Table 9. Micronutrient levels in recently mature leaves 58 days after planting as influenced by calcium-magnesium amendments and fumigation.

	Fe		Mn		Zn		B	
	--------	--------	--------	ppm	--------	--------	--------	--------
Treatment	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	155	161	326	431	39	31	32	30
1X Lime	173	195	339	417	34	34	29	30
2X Lime	150	179	267	361	33	35	29	28
3X Lime	171	153	278	342	35	40	28	29
Check	159	184	382	475	39	33	31	34
1X G + E[2]	256	226	365	445	41	37	30	30
2X G + E	215	267	296	411	40	40	29	30
3X G + E	255	281	346	380	43	40	30	33

Statistics	----------	Significance[3]	----------	----------
	Fe	Mn	Zn	B
Fumigation	NS	+	NS	NS
Treatment	**	+	+	**
Linear Lime	NS	++	NS	**
Quad Lime	NS	NS	NS	NS
Linear G + E	**	++	++	NS
Quad G + E	NS	NS	NS	**
Lime vs G + E	**	++	*	**
Tmt X Fum	NS	NS	NS	++

[1]See Materials and Methods for actual rates.
[2]G + E = Gypsum + Epsom Salts.
[3]NS = >.2, + = .1-.2, ++ = .05-.1, * = .01-.05, ** = <.01.

Table 10. Macronutrient levels in recently mature leaves 81 days after planting as influenced by calcium-magnesium amendments and fumigation.

	N		P		K		Ca		Mg	
	%									
Treatment[1]	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	4.65	4.28	0.29	0.24	5.25	5.21	0.67	1.06	0.32	0.44
1X Lime	4.77	4.66	0.28	0.24	4.87	5.33	0.89	1.24	0.45	0.65
2X Lime	5.06	4.72	0.29	0.26	5.04	5.26	0.93	1.29	0.52	0.67
3X Lime	4.78	4.74	0.28	0.24	5.00	5.27	0.92	1.31	0.52	0.73
Check	4.72	4.36	0.34	0.23	5.36	5.29	0.71	0.99	0.34	0.39
1X G + E[2]	5.56	4.77	0.29	0.25	5.06	4.95	0.77	1.16	0.46	0.62
2X G + E	5.01	4.59	0.30	0.24	5.19	4.93	1.06	1.27	0.61	0.72
3X G + E	4.87	4.94	0.31	0.26	4.78	4.73	0.83	1.24	0.58	0.77

Statistics	Significance[3]				
	N	P	K	Ca	Mg
Fumigation	*	*	NS	**	*
Treatment	++	NS	*	**	**
Linear Lime	+	NS	NS	**	**
Quad Lime	NS	NS	NS	++	*
Linear G + E	NS	NS	**	**	**
Lime vs G + E	NS	++	+	NS	NS
Tmt X Fum	NS	++	NS	NS	NS

Table 11. Micronutrient levels in recently mature leaves 81 days after planting as influenced by calcium-magnesium amendments and fumigation.

	Fe		Mn		Zn		B	
	ppm							
Treatment[1]	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	184	201	609	729	25	24	58	53
1X Lime	199	221	594	783	31	26	60	52
2X Lime	185	192	450	664	29	29	55	52
3X Lime	176	189	517	582	24	23	53	48
Check	194	208	613	800	30	22	57	55
1X G + E[2]	212	233	451	707	27	26	54	52
2X G + E	237	336	537	774	30	31	60	57
3X G + E	306	334	518	623	29	29	57	60

Statistics	Significance[3]			
	Fe	Mn	Zn	B
Fumigation	NS	+	NS	+
Treatment	**	+	**	++
Linear Lime	NS	*	NS	*
Quad Lime	NS	NS	**	NS
Linear G + E	**	+	*	+
Quad G + E	NS	NS	NS	NS
Lime vs G + E	**	NS	++	*
Tmt X Fum	NS	NS	NS	NS

[1]See Materials and Methods for actual rates.
[2]G + E = Gypsum + Epsom Salts.
[3]NS = >.2, + = .1-.2, ++ = .05-.1, * = .01-.05, ** = <.01.

EVALUATION OF FOLIAR FERTILIZERS FOR STRAWBERRY PRODUCTION - 1985

C. J. Rosen, H. J. Buchite, E. E. Hoover, and J. J. Luby

Foliar fertilizers have been promoted in recent years to improve yield and quality of many horticultural crops. The basic idea behind foliar feeding is that applied nutrients may be more immediately available for metabolic processes compared to conventional soil applications. In most cases, instructions are to apply foliar fertilizers during "critical" growth periods to alleviate any nutrient stress that may be occurring at that time. The objective of this experiment was to determine the influence of foliar fertilizer rate and application time on strawberry yield and quality.

Materials and Methods:

Treatments were applied to a third year planting (second fruiting season) of 'Earliglow' strawberries on a Gotham loamy sand. A soil sample (0-6") was collected before treatments were applied in 1985 and had the following test values: P (lb/A), 119; K (lb/A), 238; pH, 5.1. A randomized complete block design was used with 4 replications. The planting system was a matted row with 4 feet between row centers. Each plot consisted of a 20 ft row. The treatments included:

Treatment number:

1. Control - soil applied fertilizer, 1984, after renovation.
2. 16-4-4 applied before (9 May 1985) and during (16 May 1985) flowering, 3.2 gal/A per application.
3. 16-4-4 applied during fruit maturation (23 May 1985 and 30 May 1985), 3.2 gal/A per application.
4. 16-4-4 applied before (9 May 1985) and during (16 May 1985) flowering, and during fruit maturation (23 May 1985 and 30 May 1985), 1.6 gal/A per application.
5. 16-4-4 applied during flowering (16 May 1985) and during fruit maturation (30 May 1985), 6.4 gal/A per application.
6. 16-4-4 applied during flower initiation (6 September and 20 September 1984), 1.6 gal/A per application.
7. 16-4-4 applied before (9 May 1985) and during (16 May 1985) flowering and during fruit maturation (23 May 1985 and 30 May 1985), 3.2 gal/A per application.
8. 16-4-4 same as treatment 7 except that fertilizer was applied directly to the soil in the row.
9. 9-18-9 applied before (9 May 1985) and during (16 May 1985) flowering and during fruit maturation (23 May 1985 and 30 May 1985), 2.5 gal/A per application.
10. 9-18-9 same as treatment 9 except 5.0 gal/A per application.

The rates were selected so that 1.6 gal/A 16-4-4 and 2.5 gal/A 9-18-9 provided 2.5 lb N/A. All plots received the same rates of soil applied fertilizer after renovation in 1984 (according to U of M recommendations). Foliar fertilizer treatments were applied with a CO_2 sprayer fit with two fan type nozzles. The spray pattern covered approximately a 36 inch width. The foliar fertilizers were applied with 12 gal water/A at 40 psi. All treatments included WEX, a surfactant, at the rate of 3 ml/gal. Yield measurements were recorded on the following harvest dates: 7, 12, 17, 21, and 26 June 1985. Berry wieghts and percent soluble solids were determined on subsamples from each plot at each harvest. Nutrient concentrations were determined in the most recently mature leaves (leaflets + petiole) sampled on 12 June 1985.

Results and Discussion:

There were no significant differences due to treatment in total yield, or yield at any of the individual harvest dates (Table 1). However, there was a tendency for the foliar fertilizer treatments to delay maturity compared to the control. Berry weight decreased with harvest date for all treatments (Table 2). There was no significant positive increase in berry weight due to foliar fertilizer, although at the final harvest there was a tendency for foliar fertilized plots to have a larger berry size. Percent soluble solids in ripe berries was not significantly affected by treatment (Table 3). Nutrient concentrations in strawberry leaves sampled during harvest are presented in Table 4. Because samples were collected two weeks after the last foliar application and leaf samples were rinsed thoroughly in distilled water before drying, it was assumed that most of the nutrients were inside the leaf tissue and not on the surface. Leaf N concentrations were highest in the spring soil applied treatment (treatment #8) and lowest in the control. Foliar fertilizer treatments tended to increase leaf N compared to the contol. There were no significant differences in leaf P concentrations which may be due to the relatively high soil P levels. Leaf K concentrations were lowest in the control. Foliar fertilizer and spring soil applications tended to increase leaf K. Although significant differences in leaf Fe and Cu were detected, these were not related to treatment. Leaf Zn was lowest in the control plot, and highest in the spring soil applied teatment. Reasons for low leaf Zn in the control plot cannot be explained from the present study.

Conclusions:

The foliar fertilizers used in this study did not significantly increase strawberry yield or quality. Applications of foliar fertilizers did increase leaf concentrations of N and K. This indicates that foliar fertilizers could be used to temporarily correct nutrient deficiencies of these elements. Provided that soil fertility is managed properly, foliar fertilizers appear to have minimal effects on strawberry production.

Table 1. Influence of foliar fertilizers on strawberry yield.

Treatment Number and Fertilizer[1]	Harvest Date					Total
	6 June	12 June	17 June	21 June	26 June	Yield
	T/A					
1. Control	0.47	1.26	1.20	1.20	1.03	5.16
2. 16-4-4	0.19	0.96	1.17	1.22	1.46	5.00
3. 16-4-4	0.19	0.83	1.37	1.46	1.53	5.38
4. 16-4-4	0.25	0.97	1.47	1.38	1.54	5.62
5. 16-4-4	0.25	0.91	1.07	1.15	1.17	4.41
6. 16-4-4	0.30	1.01	1.43	1.22	1.32	5.29
7. 16-4-4	0.32	1.16	1.22	1.38	1.35	5.42
8. 16-4-4 (Soil)	0.36	1.04	1.27	1.20	1.27	5.14
9. 9-18-9	0.37	1.18	1.34	1.19	1.69	5.76
10. 9-18-9	0.31	1.19	1.22	1.44	1.76	5.91
Pr > F	.349	.638	.747	.266	.430	.505

[1]See Materials and Methods for rates and times of applications.

Table 2. Influence of foliar fertilizers on berry weights.

Treatment Number and Fertilizer[1]	Harvest Date: 6 June	12 June	17 June	21 June	26 June	Average Weight[2]
	grams/berry					
1. Control	16.6	14.5	10.7	8.2	6.5	10.7
2. 16-4-4	16.0	14.3	12.8	9.6	8.0	11.0
3. 16-4-4	14.9	14.6	12.7	10.2	8.2	11.1
4. 16-4-4	15.1	13.7	12.7	10.4	7.2	10.9
5. 16-4-4	15.6	13.4	10.2	8.7	7.4	10.3
6. 16-4-4	18.2	14.9	11.6	8.3	7.1	10.7
7. 16-4-4	16.5	14.4	10.7	9.7	7.3	10.7
8. 16-4-4 (Soil)	17.9	13.9	13.1	8.8	7.5	11.2
9. 9-18-9	16.8	13.9	12.1	9.4	8.2	11.1
10. 9-18-9	17.7	15.8	12.0	9.8	8.1	11.4
Pr > F	.023	.692	.068	.625	.429	.211
BLSD (0.10)	2.4	--	2.6	--	--	--

[1]See Materials and Methods for rates and times of applications.
[2]Averages are adjusted to yield

Table 3. Influence of foliar fertilizers on percent soluble solids in ripe berries.

Treatment Number and Fertilizer[1]	Harvest Date: 6 June	12 June	17 June	21 June	26 June
	%				
1. Control	9.66	9.17	9.40	9.09	9.01
2. 16-4-4	9.17	9.35	8.89	8.57	8.75
3. 16-4-4	9.64	9.45	8.27	8.78	8.68
4. 16-4-4	9.16	9.79	9.25	8.83	8.80
5. 16-4-4	9.32	9.48	8.71	8.57	8.36
6. 16-4-4	9.61	9.56	9.25	9.17	9.20
7. 16-4-4	9.64	9.12	9.35	8.65	8.04
8. 16-4-4 (Soil)	9.69	9.35	9.46	8.84	8.99
9. 9-18-9	9.32	9.60	9.25	8.27	9.04
10. 9-18-9	9.38	9.50	9.20	7.92	8.32
Pr > F	.126	.813	.393	.157	.221

[1]See Materials and Methods for rates and times of application.

Table 4. Influence of foliar fertilizers on elemental concentrations in strawberry leaves (leaflets + petiole) sampled on 12 June during harvest.

Treatment Number and Fertilizer[1]	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%					ppm				
1. Control	1.74	0.26	1.87	1.10	0.34	78	307	18	7	40
2. 16-4-4	1.94	0.27	2.25	0.86	0.31	72	327	21	8	37
3. 16-4-4	1.92	0.26	2.14	1.07	0.35	76	305	21	7	46
4. 16-4-4	1.85	0.26	2.03	0.99	0.33	72	326	19	7	39
5. 16-4-4	1.93	0.25	2.13	0.96	0.32	74	327	19	7	38
6. 16-4-4	1.82	0.26	2.13	1.04	0.34	89	304	20	7	39
7. 16-4-4	1.98	0.27	2.15	0.97	0.33	73	315	21	7	42
8. 16-4-4 (Soil)	2.12	0.25	2.16	0.96	0.33	83	368	22	7	40
9. 9-18-9	1.93	0.28	2.28	0.97	0.33	78	350	21	7	45
10. 9-18-9	1.91	0.28	2.05	1.08	0.34	79	342	20	6	40
Pr > F	.084	.111	.058	.304	.589	.029	.429	.016	.094	.678
BLSD (0.10)	0.27	--	0.28	--	--	12	--	2	1	--

[1]See Materials and Methods for rates and times of applications.

NITROGEN MANAGEMENT FOR PROCESSING SWEET CORN ON IRRIGATED COARSE-TEXTURED AND NONIRRIGATED FINE-TEXTURED SOILS -1985

C. J. ROSEN, H. J. BUCHITE AND J. B. HEBEL

Management of fertilizer nitrogen is highly dependent on soil and climatic conditions. With excessive rainfall, coarse-textured soils are subject to excessive drainage which can increase nitrate-nitrogen losses from the root zone. In fine-textured soils under these same conditions, nitrate can be lost through denitrification and/or leaching processes. Because of potential nitrogen loss during the growing season which may detrimentally affect yield and groundwater quality, the practice of sidedressing or use of nitrification inhibitors have become issues of concern for sweet corn growers. Although many studies dealing with nitrogen management have been conducted with field corn, the differences in growing season and harvested product make it difficult to extrapolate the data from these studies to processing sweet corn. The objectives of this on going study were to: 1) characterize the response of sweet corn to nitrogen when grown on a coarse-textured irrigated soil and a fine-textured nonirrigated soil, and 2) evaluate the effectiveness of split nitrogen applications and a nitrification inhibitor on sweet corn production under these contrasting conditions.

Experimental Procedures:

This experiment was conducted at two locations: Sand Plains Research Farm in Becker, MN (Hubbard Loamy Sand) and the Southern Experiment Station in Waseca, MN (Nicollet Clay Loam). Soil chemical properties before fertilizer application are listed below:

	Becker	Waseca
pH (0-6)	6.5	7.6
P (lb/A, 0-6")	73	34
K (lb/A, 0-6")	245	436
N (lb/A, 0-12")	14	20

Phosphorus and K (150 lb/A 0-14-30) were banded at Becker at planting. No supplemental P or K was provided at Waseca. There were nine treatments which included a control, 4 nitrogen rates (50, 100, 150, 200 lb N/A) 100 lb N/A plus N-serve (0.5 lb ai/A), 150 lb N/A plus N-Serve (0.5 lb ai/A), 100 lb N/A split (1/2 preplant, 1/2 6-8 leaf stage), 150 lb N/A split (1/3 preplant, 1/3 6-8 leaf stage, 1/3 12 leaf stage). All preplant nitrogen was with anhydrous ammonia. For the split treatments ammonium nitrate was used as the nitrogen source. Two hybrids, Code 5 (early maturing) and Jubilee (mid-season maturing) were planted on 30 April at Waseca and 1 May at Becker. Stands were thinned to populations of approximately 26,000. Spacing was set at 2.5 ft between rows. A split plot randomized complete block design with 4 replications was used at each location. Nitrogen treatment was the main plot and hybrid the subplot.

Whole plant samples collected at the 6-8 leaf stage (before any sidedress application) and leaf samples from opposite and above ear at mid-silking were dried and ground for total N determination. Concentrations of other nutrients were determined on leaf samples from the 100 lb N/A and 150 lb N/A treatment with and without inhibitor.

Total yield (green - ear and husk), husked yield, and stover yield were obtained by harvesting two 15 ft center rows within each plot. Subsamples of ears, husk and stover were taken to determine % moisture for nitrogen uptake calculations. The following quality measurements were also made: ear length, % moisture in kernels, and % useable ears (5.5 inches or greater with unfilled tip removed - COC eligible).

From May through July precipitation at Waseca totaled 6.9 inches and at Becker totaled 11.7 inches. Approximately 6.4 inches of water was supplied by an overhead irrigation system at Becker. Code 5 was harvested 2 August at Waseca and 5 August at Becker; Jubilee was harvested 8 August at Waseca and 12 August at Becker.

Results were statistically analyzed by comparing means within a hybrid and by using factorial combinations for the 100 lb N/A and 150 lb N/A rate preplant with and without inhibitor and these same rates preplant and split applied.

Results and Discussion:

Becker:

Response to preplant nitrogen was apparent in both hybrids up to 200 lb N/A (Table 1). Quality factors such as ear length, and % useable ears were also improved with nitrogen rates up to 200 lb N/A. The use of inhibitor did not significantly increase yield for either variety when compared to the preplant rate without inhibitor. However, there was a trend for Code 5 to yield more with the inhibitor than without the inhibitor. No trend was observed for Jubilee. Differences in ammonium utilization by the hybrids may play a role in the inhibitor effect. Further experiments are needed to study this aspect of nitrification inhibitors. The percentage of useable ears was greater for both hybrids when inhibitor was used indicating that the inhibitor treatment improved ear fill. Split application at 100 lb N/A was inferior to the same rate preplant. Sidedressed N was applied as ammonium nitrate and several rainfall events occured 1-2 weeks after application. Most of the nitrate probably leached out of the root zone. The second sidedress of N (150 split) was apparently enough to maintain yields. However, this split application did not significantly increase yields compared to the same rate preplant. Higher nitrogen rates, use of inhibitor and split applications tended to be associated with higher moisture content of the kernals.

Nitrogen concentrations in whole plant samples collected at the 4-6 leaf stage were not affected by the various N treatments although plants from the control plot tended to be the lowest in N concentration for both hybrids (Table 2 and 3). Concentrations of N in mid-silk leaf samples increased with increasing preplant N application. Inhibitor tended to increase mid-silk leaf N concentrations while split applications had a negative effect. Concentration of N in the ears was not consistently related to treatments, although 150 split application, 200 lb N/A preplant, and inhibitor were associated with higher N concentrations. Husk and stover N concentrations followed similar trends to that of mid-silk leaf sample. Total N removal was greatest for the high N treatments. Inhibitor increased N uptake in Code 5 but had no effect on uptake by Jubilee. Split applications increased N uptake at the 150 lb N/A rate but not at the 100 lb N/A rate. The effect of inhibitor and N rate (100 and 150 lb N/A) on mid-silk leaf elemental concentrations is presented in Table 4. In general, inhibitor increased leaf N and P, and decreased leaf Mg concentrations. Increasing N rate increased leaf concentrations of N, P, Ca, Mg, Fe, Mn, Zn, and Cu.

Waseca:

Limited precipitation during June and July at Waseca had a negative effect on yield and quality of the sweetcorn. The effect was more pronounced with Code 5 compared to Jubilee. This difference was primarily due to a late July rainfall which came too late for Code 5 (early maturing) but early enough to improve yield and quality of Jubilee (midseason maturing). Increasing rates of preplant nitrogen increased yield and quality of both hybrids (Table 5). Preplant N with inhibitor had no effect on yield or quality of sweetcorn compared to the same rates without inhibitor. Because of the extremely dry conditions, this is not surprising. Split applications of N, in general, had a negetive effect on yield compared to the same preplant rates. The lack of response to the split applied N was due to lack of rainfall to transport the N to the roots. Most of the sidedressed N was on the soil surface until the end of July. Response may have occurred had the N been injected rather than applied to the soil surface.

Nitrogen concentrations in whole plant samples (6-8 leaf) were generally related to whether N had been applied at planting (Tables 6 and 7). Plants from the control plot consistently had the lowest N concentrations. Plants from plots that received at least 50 lb N/A preplant generally had similar N concentrations. Concentrations of N in leaves sampled at mid-silking increased with N applications. Inhibitor had no effect on leaf N concentrations and split applied N had a negative effect. Ear, husk, and stover N concentrations generally followed the same trend as mid-silk leaf sample. Total N uptake by the above ground portions of the plant followed yield and rate of N application. The influence of inhibitor and N rate (100 and 150 lb N/A) on elemental concentrations in leaves sampled at mid-silking is presented in Table 8. Inhibitor had no significant effect on leaf elemental concentrations while increasing N rate increased leaf concentrations of N, Mg, Mn, and Cu.

General Comments:

These two contrasting locations clearly show how soil and climate affect N management for sweet corn production. At the Becker location (irrigated sandy soil), at least 150 lb N/A was necessary for optimum yields and quality. Split applications or inhibitor at 100 lb N/A did not approach yields and quality of higher rates. Split applications or inhibitor at 150 lb N/A had statistically similar yields to preplant 150 and 200 lb N/A. Use of inhibitor tended to increase ear fill. Conversely, no response to inhibitor and a negative response to split N applications were observed on the nonirrigated clay loam soil under dry conditions at Waseca. Response to preplant N at Waseca was much higher than expected. This may have been due to the high plant populations used coupled with the exceedingly dry soil conditions.

Table 1. Effect of nitrogen rate, nitrification inhibitor and sidedress applications on sweet corn yield and quality. Becker 1985.

	Code 5					Jubilee				
Treatment lb N/A	Yield (T/A) Green	Husked	Ear Length Inches	% Moisture	% COC Eligible	Yield (T/A) Green	Husked	Ear Length Inches	% Moisture	% COC Eligible
0	0.92	0.59	5.6	71.3	16.7	0.81	0.56	4.6	77.6	0.0
50	2.34	1.37	4.9	71.6	20.0	2.43	1.63	5.1	71.0	1.5
100	4.28	2.78	6.6	70.4	42.3	6.47	4.54	6.4	72.4	30.3
150	7.87	5.68	7.8	70.2	77.8	8.69	6.45	7.1	73.2	68.0
200	9.22	6.58	8.4	73.6	93.7	10.21	7.56	7.5	73.8	88.1
100+NI	5.33	3.63	6.5	70.8	52.2	6.33	4.48	6.4	72.9	41.0
150+NI	9.18	6.64	7.8	72.2	86.7	8.89	6.05	7.2	73.8	70.0
100 Split	3.24	1.82	4.8	73.3	18.3	5.26	3.80	6.2	72.7	24.1
150 Split	7.70	5.60	7.6	72.8	93.7	9.67	6.72	7.3	76.5	76.8
Signif.	**	**	**	ns	**	**	**	**	**	**
BLSD (.05)	1.63	1.22	1.2	--	24.9	1.36	1.01	0.4	2.71	13.1

Factorial Arrangement (Hybrid x N rate x Inhibitor)

	Yield Green	Yield Husked	Ear Length	Moisture	COC Eligible
Hybrid	*	+	+	**	*
N rate	**	**	*	+	**
Inhibitor	ns	ns	ns	++	+
Hybrid x N rate	+	+	ns	ns	ns
Hybrid x Inhibitor	+	+	ns	ns	ns
N rate x Inhibitor	ns	ns	ns	ns	ns
Hybrid x N rate x Inhibitor	ns	ns	ns	ns	ns

Factorial Arrangement (Hybrid x N rate x Split)

	Yield Green	Yield Husked	Ear Length	Moisture	COC Eligible
Hybrid	**	**	ns	*	ns
N rate	**	**	**	ns	**
Split	ns	ns	+	*	ns
Hybrid x N rate	ns	+	*	+	ns
Hybrid x Split	ns	ns	*	ns	ns
N rate x Split	++	+	*	ns	*
Hybrid x N rate x Split	ns	ns	ns	ns	ns

+ = .20, ++ = .10, * = .05, ** = .01

Table 2. Effect of nitrogen rate, nitrification inhibitor and sidedress applications on nitrogen concentration in various plant tissues during the growing season and on total nitrogen uptake (Code 5). Becker.

	% N					N Content			Total
Treatment lb N/A	Whole Plant (6-8 leaf)	Leaf Above Ear (Silking)	Ear	Husk	Stover	Ear	Husk	Stover	N Uptake lb N/A
			Harvest			lb N/A			
0	4.02	1.39	1.31	0.54	0.68	3.2	0.6	23.9	27.7
50	4.09	1.78	1.31	0.38	0.58	8.7	1.5	26.5	36.7
100	4.13	2.24	1.25	0.44	0.64	18.2	2.5	30.1	50.7
150	4.12	2.65	1.30	0.52	1.05	39.9	4.0	48.0	91.9
200	4.17	2.90	1.36	0.57	1.36	47.9	5.5	55.6	109.0
100+NI	4.28	2.47	1.34	0.48	0.87	26.9	3.0	40.3	70.3
150+NI	4.18	2.70	1.42	0.58	1.09	52.0	5.1	50.0	107.1
100 Split	4.08	2.07	1.16	0.45	0.53	10.9	2.6	28.2	41.6
150 Split	4.09	2.59	1.39	0.55	1.24	40.3	4.2	59.7	104.2
Signif.	ns	**	*	**	**	**	**	**	**
BLSD (.05)	--	0.20	0.16	0.11	0.24	10.1	1.1	11.4	19.3

Table 3. Effect of nitrogen rate, nitrification inhibitor and sidedress applications on nitrogen concentrations in various plant tissues during the growing season and on total nitrogen uptake. (Jubilee) Becker.

	% N					N Content			Total
Treatment lb N/A	Whole Plant (6-8 leaf)	Leaf Above Ear (Silking)	Ear	Husk	Stover	Ear	Husk	Stover	N Uptake lb N/A
			Harvest			lb N/A			
0	4.16	1.22	1.46	0.61	0.61	2.2	0.4	14.9	17.5
50	4.39	1.38	1.38	0.44	0.46	8.6	0.9	14.7	24.2
100	4.35	1.97	1.29	0.48	0.61	28.6	2.7	29.6	61.0
150	4.35	2.52	1.37	0.53	0.82	44.4	3.7	41.8	89.9
200	4.44	2.97	1.51	0.67	1.11	56.6	5.6	54.6	116.9
100+NI	4.36	2.25	1.30	0.50	0.55	28.8	2.9	24.1	55.8
150+NI	4.39	2.63	1.42	0.61	0.80	43.2	5.2	37.6	85.9
100 Split	4.40	1.84	1.33	0.50	0.56	23.6	2.3	24.1	50.0
150 Split	4.31	2.65	1.51	0.65	0.94	51.8	5.2	44.5	101.6
Signif.	ns	**	ns	**	**	**	**	**	**
BLSD (.05)	--	0.25	--	0.10	0.22	9.0	1.5	10.1	15.3

Table 4. Influence of N-serve and N rate on leaf elemental concentrations at mid-silking: Becker, 1985.

Treatment lb N/A	Hybrid	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
		-------------%-------------					------------ppm-----------				
100	Code 5	2.24	0.26	2.56	0.53	0.33	87	53	13	9	6
150	Code 5	2.65	0.29	2.65	0.53	0.36	112	79	14	10	5
100+NI	Code 5	2.47	0.29	2.72	0.50	0.31	92	59	13	9	6
150+NI	Code 5	2.70	0.30	2.63	0.55	0.34	95	87	16	10	5
100	Jubilee	1.97	0.26	2.75	0.55	0.38	82	61	15	9	5
150	Jubilee	2.52	0.28	2.77	0.59	0.39	92	89	18	10	5
100+NI	Jubilee	2.25	0.28	2.81	0.49	0.33	86	59	14	9	5
150+NI	Jubilee	2.63	0.29	2.72	0.63	0.41	92	108	19	11	6
Statistics											
Hybrid		*	*	**	*	**	*	+	**	*	ns
N rate		**	+	ns	**	**	**	**	*	**	ns
Inhibitor		+	+	ns	ns	++	ns	ns	ns	ns	ns
Hybrid x N rate		ns	ns	ns	ns	ns	ns	ns	ns	ns	+
Hybrid x Inhibitor		ns	ns	ns	*	ns	ns	ns	ns	+	ns
N rate x Inhibitor		+	+	*	**	*	+	ns	+	ns	ns
N rate x Hybrid x Inhibitor		ns	ns	ns	ns	+	ns	ns	ns	ns	ns

+ = .20, ++ = .10, * = 0.5, ** = .01

Table 5. Effect of nitrogen rate, nitrification inhibitor, and sidedress applications on sweetcorn yield and quality. Waseca 1985.

	Code 5					Jubilee				
Treatment lb N/A	Yield (T/A) Green	Yield (T/A) Husked	Ear Length Inches	% Moisture	% COC Eligible	Yield (T/A) Green	Yield (T/A) Husked	Ear Length Inches	% Moisture	% COC Eligible
0	1.38	1.02	4.5	69.9	31.4	2.99	1.89	5.0	72.7	11.0
50	3.01	2.08	5.8	67.6	30.1	5.00	3.40	5.8	70.9	30.6
100	5.17	3.58	5.4	68.2	52.5	6.15	4.02	6.5	71.4	43.8
150	6.87	5.36	6.5	69.3	76.6	7.64	5.33	6.8	67.0	59.3
200	6.30	4.60	6.6	71.4	71.4	8.33	5.47	7.4	72.6	71.6
100+NI	5.36	3.91	5.5	68.7	49.6	6.61	4.52	6.4	68.6	50.0
150+NI	6.00	4.23	6.1	68.8	60.5	7.16	4.81	6.7	70.8	46.8
100 Split	4.12	2.86	5.0	71.2	43.1	4.68	3.17	5.8	70.1	31.6
150 Split	3.54	2.50	5.1	66.9	45.8	7.33	4.86	6.4	69.0	46.4
Signif.	**	**	*	ns	**	**	**	**	ns	**
BLSD (.05)	1.20	0.97	1.2	--	20.0	1.69	1.20	0.7	--	23.9

Factorial Arrangement
(Hybrid x N rate x Inhibitor)

	Yield Green	Yield Husked	Ear Length	Moisture	COC Eligible
Hybrid	*	ns	**	ns	ns
N rate	**	**	*	ns	*
Inhibitor	ns	ns	ns	ns	ns
Hybrid x N rate	ns	ns	ns	ns	ns
Hybrid x Inhibitor	ns	ns	ns	ns	ns
N rate x Inhibitor	ns	++	ns	+	ns
Hybrid x N rate x Inhibitor	ns	ns	ns	*	ns

Factorial Arrangement
(Hybrid x N rate x Split)

	Yield Green	Yield Husked	Ear Length	Moisture	COC Eligible
Hybrid	**	**	**	ns	+
N rate	**	**	*	*	*
Split	**	**	**	ns	**
Hybrid x N rate	*	+	ns	ns	ns
Hybrid x Split	*	*	ns	ns	ns
N rate x Split	ns	++	+	ns	ns
Hybrid x N rate x Split	*	*	++	*	ns

+ = .20, ++ = .10, * = .05, ** = .01

Table 6. Effect of nitrogen rate, nitrification inhibitor and sidedress applications on nitrogen concentration in various plant tissue during the growing season and on total nitrogen uptake. (Code 5). Waseca.

Treatment lb N/A	Whole Plant (6-8 leaf)	Leaf Above Ear (Silking)	Ear	Husk	Stover	Ear	Husk	Stover	Total N Uptake lb N/A
	% N		Harvest			N Content lb N/A			
0	2.62	1.43	1.39	0.54	0.75	7.2	1.0	27.8	35.9
50	3.28	1.87	1.36	0.56	0.85	14.7	2.4	39.1	56.1
100	3.32	2.02	1.41	0.62	1.03	25.5	4.5	46.3	76.3
150	3.24	2.23	1.50	0.68	1.15	40.1	4.6	52.1	96.9
200	3.42	2.56	1.46	0.71	1.28	32.9	5.2	54.4	92.6
100+NI	3.31	2.15	1.46	0.72	0.99	28.4	4.8	43.3	76.6
150+NI	3.53	2.15	1.44	0.69	1.16	29.2	5.3	49.6	84.2
100 Split	3.33	1.56	1.39	0.61	0.83	19.8	3.4	36.8	60.1
150 Split	3.09	1.89	1.53	0.64	0.91	18.1	3.2	37.3	58.6
Signif.	**	**	ns	**	**	**	**	**	**
BLSD (.05)	0.31	0.29	--	0.07	0.31	7.2	1.3	13.4	15.5

Table 7. Effect of nitrogen rate, nitrification inhibitor and sidedress applications on nitrogen concentration in various plant tissues during the growing season and on total nitrogen uptake (Jubilee). Waseca.

Treatment lb N/A	Whole Plant (6-8 leaf)	Leaf Above Ear (Silking)	Ear	Husk	Stover	Ear	Husk	Stover	Total N Uptake lb N/A
	% N		Harvest			N Content lb N/A			
0	2.61	1.32	1.62	0.58	0.73	14.1	2.1	23.2	29.4
50	3.44	1.37	1.41	0.57	0.79	22.1	2.9	29.5	54.5
100	3.26	1.76	1.57	0.67	1.17	27.9	4.6	47.1	79.7
150	3.23	2.10	1.71	0.69	1.44	43.1	5.4	62.2	110.6
200	3.42	2.27	1.82	0.77	1.34	43.5	6.9	65.5	115.9
100+NI	3.25	1.79	1.59	0.64	1.11	34.2	4.4	46.3	84.9
150+NI	3.66	1.90	1.58	0.69	1.23	34.6	5.1	51.4	91.1
100 Split	3.36	1.61	1.58	0.63	0.93	21.5	2.9	36.0	60.4
150 Split	3.13	1.53	1.46	0.64	1.01	34.8	5.0	38.9	78.7
Signif.	**	**	**	**	**	**	**	**	**
BLSD (.05)	0.38	0.23	0.21	0.10	0.17	8.4	1.5	12.3	20.1

Table 8. Influence of N-serve and N rate on an leaf elemental concentrations at mid-silking: Waseca, 1985.

Treatment lb N/A	Hybrid	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
		------------	------------	%	------------	------------	------------	------------	ppm	------------	------------
100	Code 5	2.02	0.28	2.32	0.71	0.35	91	47	15	8	11
150	Code 5	2.23	0.28	2.40	0.74	0.34	89	54	17	8	10
100+NI	Code 5	2.15	0.30	2.45	0.68	0.34	100	44	18	8	11
150+NI	Code 5	2.15	0.27	2.93	0.67	0.34	81	52	16	8	10
100	Jubilee	1.76	0.26	2.34	0.78	0.42	75	34	20	7	11
150	Jubilee	2.10	0.28	2.48	0.86	0.46	87	55	23	9	13
100+NI	Jubilee	1.79	0.27	2.49	0.72	0.40	83	41	21	7	11
150+NI	Jubilee	1.90	0.26	2.43	0.81	0.44	75	49	19	8	12
Statistics											
Hybrid		**	*	ns	**	**	*	ns	**	ns	++
N rate		+	ns	ns	ns	+	ns	*	ns	**	ns
Inhibitor		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Hybrid x N rate		ns	+	ns	ns	+	+	ns	ns	++	+
Hybrid x Inhibitor		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
N rate x Inhibitor		*	*	ns	+	ns	*	ns	*	+	ns
N rate x Hybrid x Inhibitor		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

+ = .20, ++ = .10, * = 0.5, ** = .01

FIELD TRIALS WITH "BASIC-H" IN 1983, 1984, AND 1985.

George Rehm and Bill Fenster

Procedure:

This study was initiated in 1983, continued in 1984, and terminated in 1985. Trials were conducted at the branch experiment stations at Waseca, Lamberton, Morris, and Crookston as well as the experimental field at Becker. The treatments used at each location are listed in Tables 1 through 6.

The "Basic-H" was applied according to label directions for all crops at all locations. Fertilizer recommendations were based on the results of the analysis of soil samples taken in the spring of 1983 and the fall of 1983, and the fall of 1984. The fertilizer needed to supply the recommended rate of N, P_2O_5, and K_2O was broadcast and incorporated before planting each year.

Specific management practices varied with crop and location. The management practices that were used for each crop were consistent with those needed for production of maximum yields of the specific crop.

Results and Discussion:

Corn grain yields recorded at the Waseca and Lamberton locations are summarized in Table 1. As would be expected, the use of recommended rates of N, P_2O_5, and K_2O produced significant increases in yield. The use of "Basic-H" alone or in conjunction with the recommended fertilizer program did not produce a significant yield increase at either location. The relatively low C.V. values provide evidence that the accuracy in measurement of yields was good.

The effect of "Basic-H" on the moisture content of corn at harvest is summarized in Table 2. Except for the Waseca location in 1985, the moisture content of corn was higher for the control treatment and the treatment where "Basic-H" only was applied at a rate of 1 gal./acre. Moisture content of the grain was not influenced by treatment at the Lamberton location in 1983 and 1984.

Wheat yields from the Morris location are summarized in Table 3. Treatment had no significant effect on grain yield in 1984. Effects of treatments used in 1983 and 1985 were similar to those recorded for corn at the Waseca and Lamberton locations. Wheat yields were increased by the use of fertilizer but the use of "Basic-H" either alone or with the recommended fertilizer program had no significant effect on yield. Treatment had no significant effect on the moisture content of the wheat crop at harvest.

Sunflower yields from the Crookston site are summarized in Table 4. Yields were quite variable and the C.V. was higher in all years. The treatment used had no significant effect on sunflower production in 1983 and 1984. The 1985 yields were severely reduced by an early frost and it is difficult to attach a large amount of importance to the yields measured.

Treatment used had no significant effect on the oil content of the sunflower seeds. Because of the low yield and poor seed quality in 1985, oil content was not measured in this year of the study.

The potato yields from the irrigated site at the Becker experimental field are summarized in Table 5. Yields were increased significantly by the use of fertilizer. The use of "Basic-H", however, either alone or with fertilizer had no positive effect on tuber yield.

The effect of the use of "Basic-H" on both yield and quality of sugarbeets was evaluated at the Crookston location. The treatment used had no significant effect on either yield or recoverable sugar in both 1983 and 1984. The 1985 yields were incrased by the use of fertilizer. The recoverable sugar was also increased by fertilizer use.

The use of "Basic-H" alone had no significant effect on yield in 1985. The use of 2 gal./acre of this material, when used with the recommended fertilizer instead of 1 gal./acre produced a significant increase in yield. The yield increase from the 2 gal./acre treatment compared to the fertilizer control was not significant. Therefore, very little importance can be attached to this observation. The use of "Basic-H" had no significant effect on recoverable sugar.

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Table 1. Effect of Basic-H on corn yield.

Treatment	Location and Year					
	Waseca			Lamberton		
	1983	1984	1985	1983	1984	1985
	bu./acre					
control	56	68	61	62	94	38
Fertilizer* (U of M recommednations)	121	141	150	85	115	105
Fertilizer + Basic-H (1 gal./acre)	111	141	159	87	116	107
Fertilizer + Basic-H (2 gal./acre)	117	145	161	87	121	104
Basic-H (1 gal./acre)	53	58	66	54	95	42
Significance	**	**	**	**	**	**
BLSD (.05)	10	8	12	14	7	7
C.V.%:	7.6	5.0	6.4	9.0	4.5	6.5

*Recommended Fertilizer:

- Waseca (1983) 175N 50 P_2O_5 150 K_2O
- Waseca (1984) 170N -- --
- Waseca (1985) 170N 50 P_2O_5 150 K_2O
- Lamberton (1983) 150N 60 P_2O_5 60_2O
- Lamberton (1984) 150N 60 P_2O_5 60 K_2O
- Lamberton (1985) 150N 60 P_2O_5 60 K_2O

Table 2. Effect of Basic-H on the moisture content of corn grain at harvest.

Treatment	Location and Year					
	Waseca			Lamberton		
	1983	1984	1985	1983	1984	1985
	% H_2O					
control	21.6	21.5	26.2	23.2	31.5	47.3
Fertilizer (U of M recommendations)	20.5	19.5	27.5	21.7	30.0	38.6
Fertilizer + Basic-H (1 gal./acre)	20.4	19.3	26.0	22.1	31.5	38.4
Fertilizer + Basic-H (2 gal./acre)	20.6	20.3	26.5	21.4	31.3	39.3
Basic-H (1 gal./acre)	21.8	22.6	26.1	23.1	31.8	44.6
Significance	**	**	**	NS	NS	**
BLSD(.05)	.6	2.5	1.0	--	--	2.4
C.V. %	.8	7.3	2.2	4.2	2.9	4.0

Table 3. Effects of Basic-H on wheat yield and moisture content of the grain at harvest. Morris.

Treatment	Grain Yield 1983	1984	1985	Moisture Content 1983	1984	1985
	-------bu./acre-----			----------%--------		
control	41	84	31	13.2	12.2	17.1
Fertilizer* (U of M recommendations)	55	75	72	12.2	12.6	17.7
Fertilizer + Basic-H (1 gal./acre)	59	80	72	13.8	12.6	17.9
Fertilizer + Basic-H (2 gal./acre)	56	81	73	13.9	12.6	17.9
Basic-H (1 gal./acre)	46	80	30	13.0	12.3	17.5
Significance	**	NS	**	NS	NS	NS
BLSD(.05)	5	--	5	--	--	--
C.V.%	6.1	6.6	6.2	2.8	1.6	3.1

Fertilizer Recommended:

-1983 50N 0P_2O_5 0K_2O
-1984 80N 0P_2O_5 30K_2O
-1985 80N 0P_2O_5 0K_2O

Table 4. Effect of Basic-H on yield of sunflower and oil content.

Treatment	Yield 1983	1984	1985	Oil Content 1983	1984
	-----lb./acre-----			---------%-------	
control	964	1743	445	37.5	42.6
Fertilizer* (U of M recommendations)	1180	1825	554	38.0	42.5
Fertilizer + Basic-H (1 gal./acre)	1192	1949	431	37.4	42.5
Fertilizer + Basic-H (2 gal./acre)	1169	1873	450	37.1	42.7
Basic-H (1 gal./acre)	996	1795	477	37.8	42.9
Significance	NS	NS	**	NS	NS
C.V.	11.4	8.9	11.8	3.4	1.5
LSD(.05)	--	--	86	--	--

*Fertilizer Recommended:

-1983 90N 50 P_2O_5 100 K_2O
-1984 18N 46 P_2O_5 0 K_2O
-1985 42N 40 P_2O_5 0 K_2O

Table 5. Effect of Basic-H on the yield of potatoes. Becker, MN.

Treatment	Yield 1983	Yield 1984	Yield 1985
	cwt/acre		
control	334	330	343
Fertilizer* (U of M recommendations)	460	478	583
Fertilizer + Basic-H (1 gal./acre)	446	453	584
Fertilizer + Basic-H (2 gal./acre)	424	445	600
Basic-H (1 gal./acre)	318	340	298
Significance	**	**	**
BLSD(.05)	98	37	60
C.V. %	11.0	6.3	8.7

Fertilizer Recommended:

-1983 150N 150 P_2O_5 400 K_2O 15S
-1984 210N 100 P_2O_5 300 K_2O 15S
-1985 210N 100 P_2O_5 300 K_2O 15S

Table 6. Effects of Basic-H on the yield and recoverable sugar in sugarbeets.

Treatment	Yield 1983	Yield 1984	Yield 1985	Recoverable Sugar 1983	Recoverable Sugar 1984	Recoverable Sugar 1985
	ton/acre			lb./acre		
control	21.5	17.9	15.3	5228	5409	4426
Fertilizer* (U of M recommendation)	23.1	19.7	21.3	5456	5740	6023
Fertilizer + Basic-H (1 gal./acre)	21.2	20.5	20.3	5255	5905	5737
Fertilizer + Basic-H (2 gal./acre)	23.2	19.3	21.9	5572	5770	6131
Basic-H (1 gal./acre)	23.2	17.9	15.7	5636	5150	4443
Significance	NS	NS	**	NS	NS	**
BLSD(.05)	--	--	1.5	--	--	537

*Fertilizer Recommended:
-1983 90N 80 P_2O_5 80 K_2O
-1984 70N 80 P_2O_5 80 K_2O
-1985 75N 80 P_2O_5 80 K_2O

MICRONUTRIENTS AND RELATIONSHIP TO MICRONUTRIENT SOIL TESTS, MARTIN CO. 1985

George Rehm, Bill Fenster, and Curtis Overdahl

Relationships between micronutrient recommendations and soil test are not well documented.

A study was initiated in 1981 at 5 locations in the state. All but one were discontinued in 1984. The following is a summary on the remaining site in Martin County.

Plot received treatments of all micronutrients minus one nutrient and each of these with the missing element are compared to the complete treatment of all micronutrients. Only one rate of each element was used. Adequate N, P, and K were added to all plots. Secondary nutrients, sulfur, and magnesium, were also included in the trial. Micronutrient additions were discontinued after the first 2 years but in 1985 were again applied.

Corn and soybeans were alternated over 5 years resulting in 3 crops of corn and 2 of soybeans.

The following tables show yields, plant analysis and the soil tests reported from 4 soil testing laboratories.

Table 1. Yield comparisons of complete treatment of micronutrients[1] plus magnesium with individual plots having a nutrient omitted. Martin[2] Co. 1981, 82, 83, 84, 85.

Treatment[3] omitted(-) added (+)	Yield 1981	1982	1983	1984	1985
	Corn	Bean	Corn	Bean	Corn
None	179	56	143	48	157
-Mg	181	51	144	46	130
-Zn	181	52	145	46	158
-Fe	182	53	148	48	153
-Mn	180	54	148	49	151
-B	178	52	148	46	159
-Cu	178	52	146	47	151
+complete includes S	184	54	141	49	149
Significance	ns	ns	ns	ns	ns
C.V.	4.9	5.0	6.7	7.3	3.9

1 average of 4 replications.
2 fine textured non-irrigated soil.
3 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, 1984. Nutrients added in spring 1985.

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

Table 2. Plant analysis[1] from micronutrient and magnesium treatments in trials at Martin County, 1981, 1982, 1983, 1984.

Treatment omitted (-) added (+)	Martin (-) 81	82	83	84	Martin (+) 81	82	83	84
Mg (%)	.58	.48	.45	.47	.58	.42	.53	.48
Zn ppm	21	42	14	38	24	48	20	44
Fe ppm	93	113	100	116	97	131	99	111
Mn ppm	56	61	46	87	61	97	57	58
B ppm	5	50	8	46	5	50	7	48
Cu ppm	3	10	3	9	3	11	3	10

1 average of 2 replications from leaf opposite and below ear at silking time. No analysis was made in 1985.
2 symbol (+) is from treatment of all nutrients and (-) is where nutrient was omitted. Pounds of nutrients added Mg=50, Zn=10, Mn=10, B=1, Cu=5, in 1981 and 1982. Residual in 1983, 1984.

Table 3. Yields, [1] plant sulfur and soil test sulfur with and without sulfur treatments, Martin County[2] 1981, 1982, 1983, 1984, and 1985.

Sulfur Treatment	Yield (bu/A) 81[3] C	82[3] B	83 C	84 B	85 C	Leaf test (% S) 81 C	82 B	83 C	84 B	U of M Soil Test (PPM S) 81 C	82 B	83 C	84 B
None	183	54	144	47	154	.23	.31	.20	.30	16	1	6	12
50#/A	180	53	152	48	153	.29	.31	.22	.32	--	--	5	11
Signif.	ns	ns	ns	ns	ns								

1 average of 4 replications.
2 non-irrigated clay loam soil.
3 C = Corn, B = Soybeans

Table 4a. Soil test means for micronutrients. University of Minnesota Lab. 1981, 1982, 1983, 1984, and 1985.

Treatment omitted (-) added (+)	(ppm except Mg which is lbs/A) (-) 81[1]	82	83	84	85	(+) 82	83	84	85	deficient level
Mg	881	990	1124	632	902	970	1096	1134	1049	NE[2]
Zn	1.0	1.2	2.2	1.2	1.1	2.3	5.4	6.8	6.0	0.5 ppm
Fe	21	42	25	26	43	26	24	30	35	NE[2]
Mn	41	40	22	25	11	40	17	18	9	NE[2]
B	1.20	2.1	2.2	2.0	1.6	1.8	2.4	1.7	2.0	1 ppm[3]
Cu	1.28	1.8	1.7	1.8	1.2	2.5	3.0	3.7	2.7	2.5 ppm[3]

1 1981 soil test results before treatment applied.
2 NE indicates Not Established
3 for organic soils only, not established for mineral soils.

Table 4b. Soil test means for micronutrients. Minnesota Valley soil test lab. 1983 and 1984.

Treatment omitted (-) added (+)	------(ppm except Mg which is lbs/A)------- (-)		(+)	
	1983	1984	1983	1984
Mg	1325	1350	1200	1675
Zn	2.1	2.0	4.0	6.7
Fe	8	18	8	12
Mn	2	10	2	8
B	3	3	4	3
Cu	0.4	1.9	0.4	3.6

Table 4c. Soil test means for micronutrients. Harris Lab. 1983 and 1984.

Treatment omitted (-) added (+)	---------------(ppm except Mg)------------- (-)		(+)	
	1983	1984	1983	1984
Mg	629	585	56	567
Zn	2.0	1.2	4.7	6.6
Fe	22	21	20	26
Mn	14	15	12	13
B	1.9	1.5	2.0	1.6
Cu	1.5	1.3	2.6	3.0

Table 4d. Soil tests means for micronutrients. A & L Lab. Fall 1983 & 1984.

Treatment omitted (-) added (+)	--------------(ppm except Mg)--------------- (-)		(+)	
	1983	1984	1983	1984
Mg	549	592	525	582
Zn	1.7	1.2	4.7	6.7
Fe	19	23	19	27
Mn	15	13	11	12
B	2.8	1.5	3.0	1.4
Cu	1.4	1.4	2.4	3.0

Summary

No yield benefits were observed from sulfur, magnesium or the micronutrients in any of the 5 years of the study.

Soil tests were not below the deficient level (where these levels have been established). For the other nutrients not having established deficiency levels the deficiency levels are apparently lower than observed in this experiment. Some of the soil testing laboratories recommended nutrients at these levels and it is obvious that these were not satisfactory recommendations. Soil tests for magnesium, sulfur, zinc, boron, and copper all showed good sensitivity to treatment. Of the other nutrients studied, iron and manganese, this sensitivity was lacking. Frequently test readings were lower after treatment than without treatment. The micronutrient trial sites were originally chosen when established 5 years ago because several laboratories had recommended secondary and micronutrients for these specific sites.

CORRELATION OF SEVERAL TESTS FOR PHOSPHORUS WITH RESIN EXTRACTABLE PHOSPHORUS ON ALKALINE SOILS

P. Nesse and J. Grava

The University of Minnesota Soil Testing Laboratory uses the Olsen $NaHCO_3$ method to extract P from soils with pH levels exceeding 7.4. In 1983 a study was initiated on alkaline soils to correlate the Olsen method with resin extractable phosphorus, an indicator of phosphorus availability to the plant. Several other methods were also compared to resin extractable P, including the Bray-1 method that is used by the U of M to extract P from soils with pH less than 7.4.

Experimental Procedure. Thirty western Minnesota soils were sampled (0-6") in fall, 1983, and characterized in the laboratory. All were alkaline with an average pH of 8.1 and a range of 7.7 to 8.4. Free calcium carbonate ($CaCO_3$) averaged about 12 percent and ranged from 0 to 62 percent. Average clay percent was 27 with a low of 7 and a high of 55 percent. Organic matter averaged 7 percent and ranged from about 3 to 26 percent.

Phosphorus was determined by Olsen, Soltanpour AB-DTPA, Mehlich 2, Mehlich 3, and resin methods, and also by Bray-1 at 1:10, 1:50, and 1:100 soil to solution ratios. Soltanpour (1.0 N NH_4HCO_3--0.005 M DTPA), Mehlich 2 (0.2 N NH_4Cl--0.2 N HOAc--0.015 N NH_4F--0.012 N HCl), and Mehlich 3 (0.2 N HOAc--0.25 NH_4NO_3--0.015 N NH_4F--0.013 N HNO_3--0.001 M EDTA) are universal extractants designed to simultaneously extract a number of elements. Interest has been growing in their use. Increasing the soil to solution ratio (from 1:10 to 1:50 or 1:100) has generally improved the relationship between Bray-1 and P availability. Resin extractable phosphorus was obtained by shaking 0.5 g. of soil for 24 hours with 0.4 g of Dowex 1 x 8 resin (HCO_3). The resin was washed free of soil and P was extracted from the resin with 0.5 N HCl and shaken overnight. Phosphorus was read as percent absorbance on a colorimeter.

Soils were separated into groups on the basis of their reaction to dropwise addition of 10% HCl, a field test utilized by the National Cooperative Soil Survey to roughly assess the alkalinity of the soil. Fifteen soils that were neutral (no reaction with HCl), slightly effervescent (bubbles readily observable), or strongly effervescent (bubbles form a low foam) were found to have free calcium carbonate ($CaCO_3$) of less than 7 percent. Fifteen soils that were violently effervescent (thick foam jumps up) in reaction to HCl had $CaCO_3$ greater than 7 percent, with one exception.

Results. Means and ranges of P extracted by the various methods for all 30 soils is given in Table 1, as well as means for 15 soils with free calcium carbonate ($CaCO_3$) less than 7 percent (Low Group) and means for the remaining 15 soils that contained $CaCO_3$ greater than 7 percent (High Group). Low Bray-1 values for the high CCE soils is due to the neutralization of Bray-1 extractant by calcium carbonates.

The relationship between various soil tests and resin extractable P for all 30 soils is shown in Table 2. Olsen P values were most highly correlated with resin P values (r=0.943). The Soltanpour method was closely related to resin P after 9 clayey soils (> 35 percent clay) were removed from the study group. The relationship between $CaCO_3$% and effervescence is shown in Figure 2. All of the extractants were closely related (r > 0.9) to resin extractable P for the 15 low $CaCO_3$) soils. The Olsen extractant was the only extractant to have a close relationship (r=0.936) with resin P for the 15 high $CaCO_3$ soils. The Soltanpour extractant was closely related to resin P for high $CaCO_3$ soils after removal of the clayey soils from the study group.

The U of M Soil Testing Laboratory assumes that 1 mg kg^{-1} of Olsen P is equivalent to 1 mg kg^{-1} of Bray-1 (1:10) P when making fertilizer recommendations. This may be an oversimplification. The relationship of Bray-1 (1:10) to Olsen P (r=0.693) for 30 soils is shown in Figure 3. Mean values for Bray-1 (1:10) and Olsen are 13.2 and 14.6 mg kg^{-1}, respectively, for all 30 soils.

The relationship of Bray-1 (1:10) to Olsen P for the high $CaCO_3$, violently effervescing soils (r=0.280) and for the low $CaCO_3$ soils is shown in Figures 3 and 4. The correlation coefficient for Bray-1 (1:10) and Olsen for the low $CaCO_3$ soils was r = 0.974 after the removal of one outlier, a sample that contained 26% organic matter. Mean values for Bray-1 (1:10) and Olsen P are 3.3 and 13.5 mg kg^{-1}, respectively, for the high $CaCO_3$ group. Mean values for the low $CaCO_3$ soils for Bray-1 (1:10) and Olsen P were 23.1 and 15.6 mg kg^{-1}.

Conclusions. Olsen P is closely related to resin extractable P, an indicator of available P, over all levels of free calcium carbonate ($CaCO_3$). Soltanpour P is closely related to resin P for high and low $CaCO_3$ groups when clayey soils (> 35% clay) are removed from the study group. Mehlich and Bray-1 extractants were closely related to resin P at low $CaCO_3$ but not at high $CaCO_3$. Bray-1 (1:10) and Olsen P do not appear to be equal. Bray-1 (1:10) values are higher than Olsen values at low $CaCO_3$ percentage and much lower than Olsen values at high $CaCO_3$. The effervescence test as used by the National Cooperative Soil Survey appears to be a fast, reliable method to separate problematic, high $CaCO_3$ soils from lower $CaCO_3$ soils.

Table 1. Means, minimum values, and maximum values of phosphorus extracted from 30 alkaline soils and means of phosphorus extracted from 15 low and high $CaCO_3$ soils by various extractants.

Method	Mean (n=30)	Minimum (n=30)	Maximum (n=30)	Free $CaCO_3$ Low Group (n=15)	Free $CaCO_3$ High Group (n=15)
	ppm			%	
Resin	26.8	5.0	62.0	27.0	26.7
Olsen	14.6	4.0	39.0	15.6	13.5
Soltanpour	8.0	1.0	22.0	22.0	7.8
Bray-1 (1:10)	13.2	1.0	55.0	23.1	3.3
Bray-1 (1:50)	36.4	5.0	117.0	45.2	27.5
Bray-1 (1:100)	52.4	6.0	155.0	55.0	49.9
Mehlich 2	29.3	1.0	78.0	27.0	30.9
Mehlich 3	32.7	1.0	86.0	31.9	33.4

Table 2. Correlation coefficients (r) for methods of phosphorus extraction for 30 alkaline soils.

	Resin	Olsen	Solt.	Bray-1 (1:10)	Bray-1 (1:50)	Bray-1 (1:100)	Mehl.2	Mehl.3
	r							
Resin	1.000							
Olsen	0.943	1.000						
Soltanpour	0.889	0.939	1.000					
Bray-1 (1:10)	0.617	0.693	0.606	1.000				
Bray-1 (1:50)	0.603	0.612	0.694	0.618	1.000			
Bray-1 (1:100)	0.659	0.587	0.710	0.315	0.806	1.000		
Mehlich 2	0.786	0.690	0.759	0.408	0.786	0.933	1.000	
Mehlich 3	0.809	0.723	0.768	0451	0.796	0.923	0.994	1.000

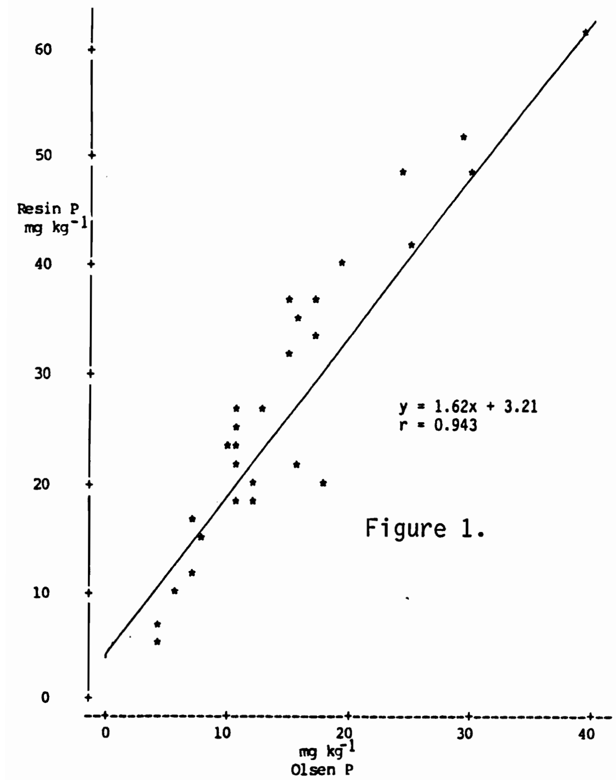

Figure 1.

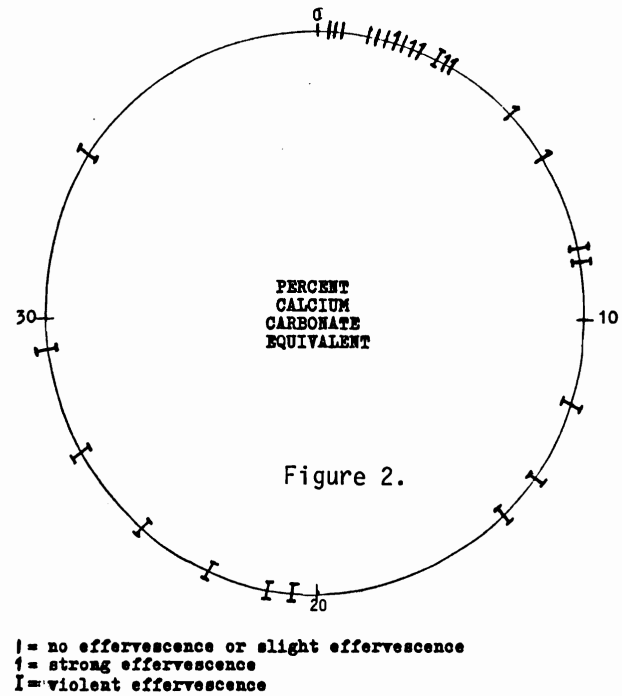

Figure 2.

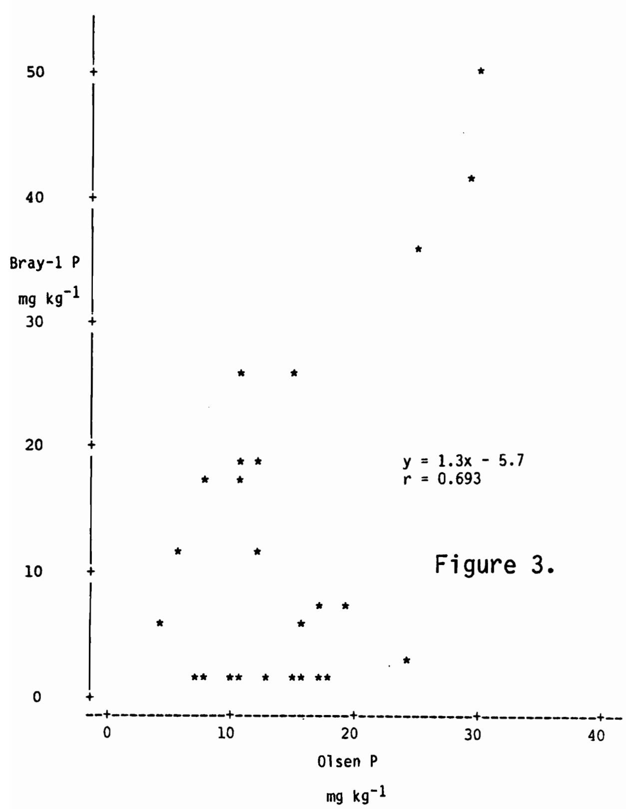

Figure 3.

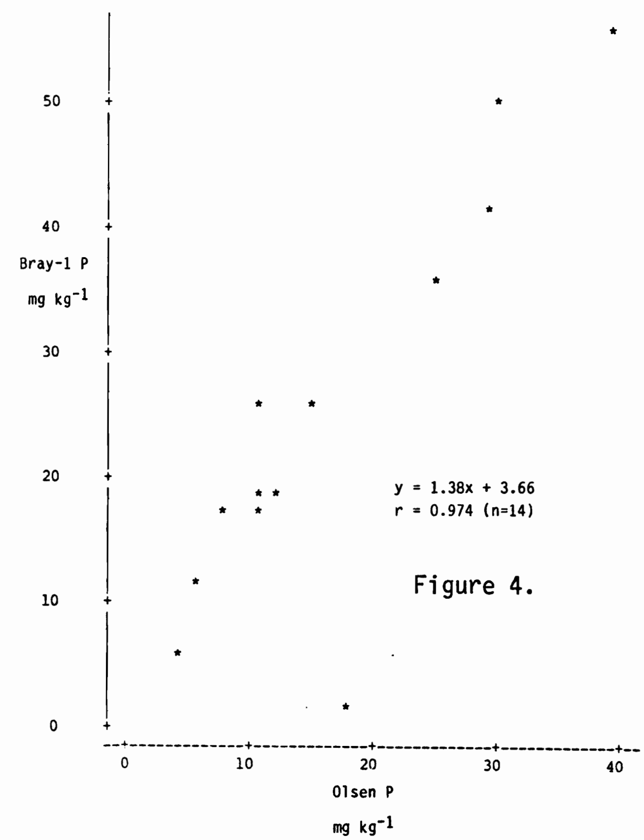

Figure 4.

Figures 1 - 4. The relationship between resin P and Olsen P, between calcium carbonate equivalent (CCE) and the effervescence test, and betweeen Bray-1 (1:10) and Olsen P for 30 alkaline soils; and the relationship between Bray-1 (1:10) and Olsen for 14 low CCE (CCE<7) soils.

PHOSPHORUS RETENTION IN CALCAREOUS SOIL

P. Nesse and J. Grava

It has been assumed that retention of added phosphorus increases with increasing amounts of free calcium carbonates, or calcium carbonate equivalent (CCE), in the soil. An objective of this research was to determine if this is true for western Minnesota soils.

Experimental Procedure. Twenty-four alkaline soils from western Minnesota and three neutral soils from south-central Minnesota were each incubated with 0 and 60 ppm of KH_2PO_4 for six weeks in 50 ml capped centrifuge tubes. Phosphorus was extracted using the Olsen method. Percent recovery was then estimated for each soil by subtracting the amount of extractable P in the check from the amount of extractable P in the 60 ppm added tube, and dividing the remainder by 60. Average recovery for the 24 alkaline soils was 34.3 percent with a minimum of 22.0 and a maximum of 46.0 percent. Recovery for the three neutral soils was 26.5, 33.2, 35.3 for an average of 31.7 percent. The range in pH for the three soils was 6.3 to 6.8. Calcium carbonate equivalent (CCE) is the same as free calcium carbonate and it was determined for all 27 soils by weight loss after addition of 6 N HCl. Average CCE for the 24 alkaline soils was 13.4 percent with a low of nearly 0 and a high of 62 percent. Thirteen of these soils had CCE greater than 7%. The range in pH for the 24 soils was 7.7-8.4. The three neutral soils had CCE of 0. Organic matter for the 24 alkaline soils ranged from 3.3 to 17.1 with an average of 6.7 percent. Organic matter for the three neutral soils was 6.8, 5.6 and 5.8 percent.

In a related study, a Calciaquoll soil and a Haplaquoll soil were sampled in each of two Red River Valley fields with the help of local Soil Survey personnel (M. Jacobsen and A. Gienke).Fargo and Hegne samples were taken about 75 feet apart from a Clay County field. A and B horizons were sampled. Both soils are poorly drained and had received similar management considerations prior to sampling. The major difference between these two soils is that Hegne is a Calciaquoll and it contains considerably more calcium carbonates than Fargo, a Haplaquoll. Perella and Colvin soils are from a Polk County field and they were sampled about 100 feet apart. A and B horizons were sampled. Both soils are poorly drained and had similar management. They are Haplaquolls and Calciaquolls, respectively. As before, the major difference between these soils is that the Colvin soil contains more calcium carbonates than Perella soils. Organic matter levels were visually estimated based on soil color for all four samples. CCE was determined by weight loss after addition of 6 N HCl to soil samples. Resin extractable phosphorus was determined after 0.5 g of soil was shaken for 24 hours with 0.4 g of Dowex 1 X 8 resin (HCO_3 form) in 30 ml of deionized water and subsequent extraction of the P from the resin by shaking with 0.5 N HCl.

Results. The relationship between calcium carbonate equivalent (CCE) and percent recovery of added P was found to be insignificant (r=-0.025) for 24 alkaline soils. Average percent recovery for the 24 alkaline soils was similar (34.3 %) to the average recovery for the three neutral soils (31.7 %). Recovery values would likely be lower for longer incubation times for both alkaline and neutral soils. There is presently no evidence to suggest that the ratio of the recovery of alkaline soils to the recovery of P in neutral soils would drastically vary with longer incubations that might better approximate field conditions.

Using Table 1, we can compare P retention in Calciaquoll soils to P retention in Haplaquolls. The amount of resin P extracted from the plow layers was greater for the two Calciaquolls than for their landscape associates. The relationship is reversed in Field No. 1 when comparing the amount of extractable P in the B horizon of the Calciaquoll, Hegne, to the B horizon of the noncalcareous Fargo. The B horizons are very low in organic matter. The situation in the B horizons of Field No. 2 is impossible to interpret due to the greater depth of the A horizon in the Perella soil.

Conclusions. The results from this study indicates that phosphorus retention does not increase with the amount of calcium carbonates present in the soil for western Minnesota surface soils. These soils typically have high organic matter. A possible explanation is that organic matter is coating the carbonates, thereby reducing the adsorptivity of phosphates to the calcite crystals.

Table 1. A comparison of resin extractable phosphorus between Haplaquolls (low CCE) and Calciaquolls (high CCE) that have similar texture and management, Red River Valley.

Soil	Depth (cm)	Horizon	Resin P (ppm)	CCE (%)	OM	Soil	Depth (cm)	Horizon	Resin P (ppm)	CCE (%)	OM
			Field Number 1, Clay County, Minnesota								
Fargo	0-23	AP	110	0	High	Hegne	0-25	AP	115	5	High
sic	23-33	Bg1	23	0	Low	sic	25-33	Bk1	13	26	Low
	33-46	Bg2	12	0	Low		33-46	Bk2	4	28	Low
			Field Number 2, Polk County, Minnesota								
Perella	0-23	AP	23	6	High	Colvin	0-23	AP	37	16	High
sicl	23-35	A12	10	1	High	sicl	23-35	Bk	3	32	Low
	35-46	Bw	3	7	Low						

SULFUR MANAGEMENT FOR CORN PRODUCTION ON IRRIGATED SANDY SOILS

G.W. Rehm, M. O'Leary, G. Cremers, B. Anderson

The importance of sulfur (S) for corn production on sandy soils has been well documented over the past 15-25 years. Both sources and rates of S have been evaluated. In this past research, however, the S fertilizers have been either broadcast and incorporated or applied in the row as a starter fertilizer to the side of and below the seed at planting.

In addition to nitrogen (N), S is also mobile in soils. Considerable research with N has been conducted to define management practices such as frequency with timing of application which should reduce the loss of N due to leaching on sandy soils. Parallel studies to define the best management practices for the use of S fertilizers on these sandy soils have not been initiated.

In Minnesota as well as in other states, rainfall patterns during the early portion of the growing season are such that the potential for loss of both N and S to leaching is high. Research shows that split applications of N will reduce the amount of N lost from these soils. Logic also suggests that split applications of S might also be more beneficial for corn production on these sandy soils. Yet, few if any, studies have been initiated to evaluate the concept of split applications of S. The objective of this study is, therefore, to determine the effect of split applications of fertilizer S on the growth and production of irrigated corn on sandy soils.

Experimental Procedure:

This study was conducted in Benton County in north-central Minnesota. The soil at the experimental site is classified as a Hubbard sandy loam. Appropriate soil properties are listed in Table 1. All treatments received a broadcast application of 250 lb. 0-0-60 per acre which was incorporated before planting.

The S source was 21-0-0-24. Treatments used are listed in Table 2. Corn was planted on May 2. All treatments received a basic starter of 100 lb. of 9-23-30 per acre.

For the treatments involving the preemergence application of S, the 21-0-0-24 was broadcast on the soil surface after planting. The broadcast application was followed immediately by an irrigation to supply .5 in. of water per acre. The 21-0-0-24 was broadcast on the soil surface for the treatments which involved the application of S at the 8-leaf and tassel stages of corn development. These broadcast applications were also followed by an irrigation of .5 in. per acre.

A total of 200 lb. N per acre was applied to all treatments as 46-0-0. The amount of N as 46-0-0 was adjusted to compensate for the N supplied as 21-0-0-24. One half of the total N needed was broadcast immediately after planting. The remainder of the needed N was applied at the 8-leaf stage. Plots were irrigated immediately after these broadcast applications.

Ear leaf samples were collected when 50% of the silks had emerged and analyzed for S. Grain was harvested in mid-October and corrected to 15.5% moisture.

Results and Discussions:

Neither the rate of S applied nor the time of application had a significant effect on grain yield (Table 2). Considering the soil test for S (2.5 ppm) a response to applied S was expected. The 1985 corn crop, however, was apparently able to get adequate S from: 1) the irrigation water, 2) the rainfall, or 3) the release of S from the mineralization of the organic matter.

The yields were not as high as hoped for but 1985 yields were restricted by temperatures which were much below normal.

Both rate of applied S and time of application had a significant effect on the S concentration in the ear leaf tissue. There was no significant interaction between these two variables so main effects will be presented in this report. The S content of the control treatment was .185% and this value was significantly lower than the S concentration which resulted from the application of fertilizer S. When averaged over all times of application, the S concentration increased to .216%, .219%, and .224% with rates of 6, 12, and 24 lb.S per acre respectively. The S concentration from the control treatment is considered to be borderline between deficient and adequate. The other values indicate an adequate supply of S for the corn crop.

The effect of time of application on the S concentration in the ear leaf tissue is summarized in Table 3. When averaged over all rates, the lowest concentration resulted from the combination of a starter and tassel application. Split application did not produce a significant increase in the S concentration in the tissue. Although the results of the plant analysis indicate that there is no advantage to a split application, this should be confirmed in yields from a responsive site before a definite conclusion can be made.

Table 1. Selected soil properties for the experimental site.

pH	5.9
P (Bray & Kurtz #1, lb./acre	69
K (1N $NH_4C_2H_3O_2$), lb./acre	264
SO_4-S, ppm	2.5
organic matter, %	2.4
soil texture	sandy loam

Table 2. Effect of rate and time of S application on corn yield and S content of ear leaf tissue.

Treatment N	Total S Applied	Method of Application	Yield	S Content
	lb./acre		bu./acre	%
1	0	---	158.2	.185
2	6	starter	152.2	.213
3	12	starter	154.5	.217
4	24	starter	156.0	.225
5	6	1/2 starter, 1/2 preemerge	151.5	.223
6	12	1/2 starter, 1/2 preemerge	153.3	.226
7	24	1/2 starter, 1/2 preemerge	150.1	.220
8	6	1/2 starter, 1/2 8 leaf stage	151.3	.221
9	12	1/2 starter, 1/2 8 leaf stage	150.3	.228
10	24	1/2 starter, 1/2 8 leaf stage	146.4	.234
11	6	1/2 starter, 1/2 tassel	155.6	.203
12	12	1/2 starter, 1/2 tassel	153.7	.212
13	24	1/2 starter, 1/2 tassel	153.1	.220
14	6	1/3 starter, 1/3 preemerge, 1/3 tassel	152.1	.213
15	12	1/3 starter, 1/3 preemerge, 1/3 tassel	150.4	.223
16	24	1/3 starter, 1/3 preemerge, 1/3 tassel	147.6	.217
17	6	all preemerge	153.4	.225
18	12	all preemerge	157.5	.209
19	24	all preemerge	149.0	.231

THE EFFECT OF SULFUR FERTILIZATION ON YIELD AND QUALITY OF CORN AND ALFALFA

George Rehm, Mike O'Leary, and Neal Martin

The importance of sulfur (S) fertilizers for crop production in Minnesota has been recognized for several years. In past research, the use of S had increased crop production only on the sandy soils. Since the soil organic matter is a major reservior of S for plant use, there is always some question about the need for S in a fertilizer program where soils are not sandy but have a low organic matter content.

It is well known that S is an important component of some amino acids in plants and thus is important in the formation of plant proteins. The percentage of protein in plant material is one measure of the quality of that material for use as an animal feed. In Minnesota, both alfalfa and corn silage are important feed sources for the livestock industry. If the quality of this forage can be improved, this enhances the value of the forage and may result in improved profit from the livestock enterprise.

Although the effect of fertilizer S on the yield of corn and alfalfa has been studied in detail, very little attention has been devoted to the measure of the effect of fertilizer S on the quality of forage crops (alfalfa and corn silage). This report summarizes the initial results of a study designed to measure the effect of fertilizer S on both the yield and quality of corn and alfalfa.

Experimental Procedures:

This study was initialed in the spring of 1984 and continued in 1985. The overall objective was to evaluate the effect of S fertilization on the yield and quality of corn and alfalfa.

For alfalfa, fertilizer S at rates of 25, 50, 75, and 100 lb./acre were broadcast on established stands and these rates were compared to a control treatment. Each year, the study was conducted at a site with a sandy texture as well as a site where the soil had a silt loam texture. For the soils with a silt loam texture, the S was applied where the alfalfa had been manured heavily as well as where the alfalfa had received no manure.

In addition to the S, adequate P, K, and B were broadcast at rates needed to achieve maximum yield. Three cuttings were harvested at the Staples location in 1984. Four cuttings were taken from the Winona and Goodhue County locations. Severe winter kill eliminated harvest from the Staples location in 1985.

Whole plant samples were collected from each plot for each cutting. These samples were analyzed for S as well as quality. The standard NIR procedure was used for quality analysis.

For corn, the study was conducted at a site with a sandy texture as well as a site with a silt loam texture each year. With corn, various rates of S (0, 10, 20, 40 lb./acre) were combined with rates of N (0, 75,150, 225 lb./acre) in a complete factorial design. At the silt loam sites, the S, N, and adequate P and K were broadcast and incorporated before planting. For the sandy sites, the S, P, K and one half of the N were broadcast and incorporated before planting. The remainder of the N was applied at the 12-leaf stage. Management practices needed for production of maximum corn yields were used at all locations.

Ear leaf samples were collected from all plots at silking. These samples were dried, ground, and analyzed for N and S. Total dry weight of the corn was measured at physiological maturity. Samples collected at this growth stage were dried, ground and analyzed for N and S as well as Crude Protein (CP), Acid Detergent Fiber (ADF), and Neutral Detergent Fiber (NDF). Standard NIR procedures were used for measurement of CP, ADF, and NDF. Grain yields were also recorded and corrected to 15.5% moisture.

Soil samples were collected from all sites prior to establishment of the study. Results for the alfalfa and corn sites are summarized in Tables 1 and 2 respectively.

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

Table 1. Soil properties (0-6 in.) for experimental sites where fertilizer S was applied to alfalfa.

Soil Property	Staples (84)	Winona (84) no manure	Winona (84) manure	Goodhue (85) no manure	Goodhue (85) manure
	Site and Year				
pH	7.0	6.7	6.6	6.7	6.5
P, lb./acre (Bray & Kurtz #1)	77	26	83	40	71
K, lb./acre (1N NH_4 $C_2H_3O_2$)	152	139	316	312	310
organic matter	med.	low	low	3.1	3.4
SO_4-S, ppm	5	7.5	8	7.5	8.5

Table 2. Soil properties (0-6 in.) for experimental sites where fertilizer S was applied to corn.

Soil Property	Staples (84)	Goodhue (84)	Staples (85)	Goodhue (85)
	Site and Year			
pH	7.1	6.6	6.5	7.0
P, lb./acre (Bray & Kurtz #1)	91	56	52	147
K, lb./acre (1N NH_4 $C_2H_3O_2$)	178	231	139	402
organic matter	med.	1.6	med.	3.6
SO_4-S, ppm	4	9	2	6

Results and Discussion:

The effects of S fertilization on yield of individual cuttings were similar to effects on total yield. Therefore, total yields are presented in this report (Table 3). Yield was significantly increased by S fertilization at the Staples site in 1984 with 25 lb.S/acre being adequate to produce maximum yield. These results are consistent with results of earlier research when S was applied to alfalfa grown on a sandy soil.

Use of fertilizer S had no significant effect on the yield of alfalfa in Winona County in 1984 and Goodhue County in 1985. It should be pointed out that a previous history of heavy manure use was not reflected in the amount of SO_4-S extracted from the soil by the calcium phosphate procedure (Table 2).

Table 3. Effect of application of fertilizer S on total yield of alfalfa.

S Applied	Staples (84)	Winona (84) no manure	Winona (84) manure	Goodhue (85) no manure	Goodhue (84) manure
	Site and Year				
lb./acre	ton dry matter/acre				
0	3.0	4.2	3.7	5.2	4.9
25	3.7	4.0	3.9	5.4	5.1
50	3.5	4.1	3.8	5.0	5.0
75	3.6	4.2	3.8	5.5	5.0
100	3.5	4.0	3.9	5.3	5.1

Samples collected from each cutting were analyzed for S. The results of this analysis are summarized in Tables 4, 5, and 6. As would be expected, the use of fertilizer S increased the S concentration in the alfalfa tissue at the Staples location (Table 4). In general, the S concentration increased with a S rate of up to 50 lb./acre. Except for the first cutting, the S concentration in alfalfa that received no S was less than .200%. A response to the use of fertilizer S would be expected in this situation.

The use of fertilizer S increased the S concentration in the alfalfa tissue at the Winona County site which received no manure (Table 5). When manure was applied, S concentration in the tissue was not affected by S fertilization. The S concentration in the control treatment, however, was above the critical level for S in alfalfa tissue and no response to fertilizer S would be expected.

Except for the second cutting at the site which was not manured, use of fertilizer S increased the S concentration in the tissue for all cuttings at the Goodhue County site in 1985 (Table 6). The S concentration of the alfalfa taken from the control treatment, however, was not near the critical level. Therefore, no response to fertilizer S would be expected. These data do show that applied S is being absorbed by the alfalfa plant.

Whole plant samples collected from each plot were also analyzed for crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) using standard NIR (Near Infra Red) analytical techniques. These three measurements provide a good estimate of the quality of the forage produced.

The use of fertilizer S did produce a significant increase in the protein content of the first cutting at Staples in 1984. Applied S had no effect on the protein content of tissue taken from the other two cuttings.

The percentage of ADF and NDF was not affected by S fertilization in 1984. It should be noted that the crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) values remained fairly close together for the major portion of the growing season.

Use of fertilizer S had no significant effect on the three quality measurements of alfalfa grown in Winona County in 1984 (Tables 8, 9, 10). Likewise, application of fertilizer S had no effect on the quality of the alfalfa produced at the Goodhue County sites in 1985 (Tables 11, 12, 13). In general, the quality of the 4th cutting was superior to the quality of hay taken from the other three cuttings.

In the 2 years of the study, corn grain yields have been measured at 4 sites (Tables 14, 15). As would be expected, yields increased with rate of applied N. The N rate of 150 lb./acre was satisfactory for highest yield at Staples in both years. Yields at the Goodhue County site in 1984 increased linearly with N rate. In 1985, a rate of 75 lb. N/acre was satisfactory for optimum production. The lower N requirement in 1985 may be attributed to the lower yield caused by drought as well as the release of N from the soil organic matter (3.6%).

Application of fertilizer S increased grain yield at Staples in both 1984 and 1985 (Table 15). A rate of 20 lb. S/acre was needed for maximum production in 1984 while highest yields were produced by the use of 40 lb. S/acre in 1985. The higher rate needed in 1985 can be attributed to heavy rains in late May and early June which may have leached applied S below the root zone. In general, 1985 yields at Staples were reduced by a cool growing season.

Use of fertilizer S had no effect on grain yield at the Goodhue County site in 1985. By contrast, maximum yields were produced by the use of 10 lb.S/acre at the 1984 Goodhue County site. The response of corn to S when grown on sandy soils is consistent with other research; the response on the silt loam soil is not. The response to S at the Goodhue County site in 1984 can be attributed to 1) high yields, 2) the low organic matter content of the soil (1.6%), and 3) heavy rains in late May and early June of 1984.

It is important to note that there was no significant interaction between N and S at all sites. The effects of fertilizer N were independent of the effects of fertilizer S.

Total dry matter production, as would be expected, was influenced by rate of applied N (Table 16). Except for the Staples site in 1985, the use of 150 lb. N/acre produced the highest yield. The 225 lb. N/acre produced the highest yield at the Staples site in 1985.

In contrast to grain yield, use of fertilizer S had no significant effect on total dry matter production measured at physiological maturity (Table 17). As was the case for grain production, there was no significant N by S interaction.

Ear leaf samples were collected from each plot at silking. These tissue samples were analyzed for N and S by standard laboratory procedures and the N/S ratio was computed. As would be expected, the N concentration in the ear leaf tissue was increased by the use of N fertilizer (Table 18). This is consistent with results of previous research.

Except for the Staples location in 1985, the S concentration in the ear leaf tissue was increased by the application of both N and S (Table 19). In general, the highest S concentration was associated with the application of 150 lb. N/acre. The use of 20 lb. S/acre appeared to be adequate in producing the highest S concentration in the tissue.

The S concentration in the ear leaf tissue varied with year and location. It is not possible to define a "critical" value for S in the ear leaf tissue from the data gathered from this study to date.

The N/S ratio was affected by N rate at 3 of the 4 locations (Table 20). Use of fertilizer S significantly reduced the ratio at 2 of the 4 locations. There is some thinking that the N/S ratio should be closely related to yield. In this study, there has been no significant relationship between grain yield and the N/S ratio in the ear leaf at silking (data not shown). Since both N and S are components of protein, it seems logical that the N/S ratio should remain relatively constant. In this study, the ratio varied over a rather wide range for any site.

Whole plant samples were collected when dry matter yields were measured at physiological maturity. These samples were dried, ground, and analyzed for CP, ADF, and NDF by the NIR techniques. The protein content was increased by the use of fertilizer N but the addition of S had no significant effect (Table 21). Except for the Goodhue County site in 1985, the protein content increased as rate of N was increased.

The percentage of ADF was significantly reduced (digestibility increased) by N at 2 of the 4 sites (Table 22). The use of fertilizer S reduced the percentage of ADF at the Goodhue County site in 1984. The importance of this observation must be weighed against similar data which will be collected from other sites in future years.

The percentage of NDF was significantly reduced (intake increased) by fertilizer N at 2 of the 4 sites (Table 23). The application of S reduced this percentage at the Goodhue County site in 1985. This is consistent with the observations for the percentage of ADF and the importance must await similar data collected from additional sites in future years.

<u>Summary</u>:

It is not possible to make concrete conclusions from field data collected in 2 years of research. Nevertheless, there are some general statements that can be made. These are:

1. Use of fertilizer S improved yield of alfalfa grown on a sandy soil but had no significant effect on yield when alfalfa is grown on fine textured soils.

2. The S concentration of the alfalfa tissue increased with rate of applied S. Where there is no response to fertilizer S, the S concentration in the tissue from the control treatment is greater than .200%.

3. Application of S had no consistent effect on the percentage of CP, ADF, and NDF in alfalfa tissue for all cuttings recorded.

4. Use of S increased grain yield of corn. The response at the Goodhue County site in 1984 is of special importance. However, S fertilization had no significant effect on total dry matter produced.

5. The concentration of N in the ear leaf tissue was affected by applied N but not by the rate of S used.

6. The S concentration in the ear leaf tissue was increased by the use of both N and S.

7. The N/S ratio in the ear leaf tissue was not consistently influenced by applied N and S. There was no apparent relationship between N/S ratio and corn yield.

8. The percentage of crude protein in corn tissue at physiological maturity was improved with N but not S fertilization.

9. Neither applied N nor S had a consistent effect on the percentage of both ADF and NDF in the tissue of corn at physiological maturity.

Table 4. Effect of rate of applied S on the S concentration in alfalfa tissue. Staples. 1984.

S Applied	Cutting 1	Cutting 2	Cutting 3
lb./acre	% S		
0	.227	.182	.193
25	.279	.268	.260
50	.310	.300	.287
75	.316	.308	.305
100	.328	.327	.297
PR>F	.01	.01	.01
BLSD (.05)	.03	.03	.03
C.V.:	7.7	6.8	7.9

Table 5. Effect of applied S on the S concentration in alfalfa tissue. Winona County, 1984.

Site	S Applied	Cutting 1	2	3	4
	lb./acre	-----	-----	% S	-----
no manure	0	.244	.266	.306	--
	25	.292	.327	.352	--
	50	.314	.311	.394	--
	75	.336	.330	.404	--
	100	.328	.318	.398	--
	PR>F	.013	.034	.001	--
	BLSD (.05)	.044	.041	.024	--
	C.V.	9.3	8.1	4.5	--
manure	0	.393	.323	.355	.387
	25	.431	.340	.374	.419
	50	.423	.342	.397	.427
	75	.411	.364	.386	.435
	100	.429	.360	.377	.412
	PR>F	.298	.171	.375	.394
	BLSD (.05)	--	--	--	--
	C.V.	5.9	5.3	7.7	7.1

Table 6. Effect of applied S on the S concentration in alfalfa tissue. Goodhue County. 1985.

Site	S Applied	Cutting 1	2	3	4
	lb./acre	-----	-----	% S	-----
no manure	0	.236	.286	.285	.355
	25	.265	.296	.295	.415
	50	.303	.308	.322	.433
	75	.307	.301	.321	.440
	100	.312	.304	.339	.446
	PR>F	.01	.50	.05	.01
	BLSD (.05)	.028	--	.043	.041
	C.V. %	6.7	5.9	8.0	6.4
manure	0	.261	.277	.278	.363
	25	.315	.301	.285	.421
	50	.342	.317	.322	.442
	75	.337	.313	.329	.429
	100	.349	.328	.313	.449
	PR>F	.01	.01	.07	.04
	BLSD (.05)	.028	.027	.047	.062
	C.V.	6.0	5.6	8.9	8.7

Table 7. Effect of S fertilization on the quality of alfalfa, Staples. 1984.

Component	S Applied	Cutting 1	Cutting 2	Cutting 3
	lb./acre	%		
Crude protein	0	20.9	19.7	20.1
Crude protein	25	21.9	20.3	20.1
Crude protein	50	21.6	20.6	20.3
Crude protein	75	21.9	20.7	20.1
Crude protein	100	21.9	20.3	20.4
	PR>F	.08	.76	.88
	BLSD (.05)	.9	--	--
	C.V. %	2.4	5.6	2.9
		%		
ADF	0	32.2	33.0	32.0
ADF	25	31.9	33.1	32.8
ADF	50	31.7	32.0	32.0
ADF	75	31.8	32.2	32.2
ADF	100	32.6	31.9	32.4
	PR>F	.59	.29	.48
	BLSD (.05)	--	--	--
	C.V. %	2.6	3.0	2.1
		%		
NDF	0	47.2	49.3	47.9
NDF	25	46.1	48.6	47.9
NDF	50	46.1	48.2	47.5
NDF	75	45.2	47.6	47.4
NDF	100	46.5	47.6	47.6
	PR>F	.42	.41	.91
	BLSD (.05)	--	--	--
	C.V. %	3.1	2.9	1.9

Table 8. Effect of S fertilization on the crude protein content of alfalfa. Winona County. 1984.

Site	S Applied	Cutting 1	Cutting 2	Cutting 3	Cutting 4
	lb./acre	%			
no manure	0	24.4	21.4	26.3	--
	25	24.2	21.6	25.9	--
	50	24.0	21.1	26.4	--
	75	24.1	21.6	25.7	--
	100	24.1	22.1	25.6	--
	PR>F	.96	.56	.55	--
	BLSD (.05)	--	--	--	--
	C.V.	3.3	3.9	3.1	--
manure	0	24.9	22.0	25.8	26.9
	25	25.7	21.6	25.5	26.8
	50	25.2	22.9	25.7	26.3
	75	25.7	21.9	26.2	26.8
	100	25.8	21.6	26.0	26.9
	PR>F	.73	.70	.94	.94
	BLSD (.05)	--	--	--	--
	C.V.	3.7	5.6	4.4	4.1

Table 9. Effect of S fertilization on the percent ADF for alfalfa. Winona County. 1984.

Site	S Applied	Cutting 1	Cutting 2	Cutting 3	Cutting 4
	lb./acre	% ADF			
no manure	0	30.4	30.6	32.3	--
	25	29.6	30.1	31.3	--
	50	30.2	31.0	31.8	--
	75	29.8	30.2	32.5	--
	100	29.3	29.4	32.2	--
	PR>F	.37	.43	.36	--
	BLSD (.05)	--	--	--	--
	C.V.	3.0	3.8	2.8	--
manure	0	28.8	30.0	29.9	26.5
	25	28.3	30.4	31.2	27.1
	50	28.8	30.6	29.6	26.7
	75	28.7	30.7	31.0	27.8
	100	29.0	30.8	30.0	26.6
	PR>F	.90	.71	.53	.21
	BLSD (.05)	--	--	--	--
	C.V.	2.9	2.6	4.3	2.4

Table 10. Effect of S fertilization on the percent NDF for alfalfa. Winona County. 1984.

Site	S Applied	Cutting 1	Cutting 2	Cutting 3	Cutting 4
	lb./acre	% NDF			
no manure	0	42.1	45.3	43.0	--
	25	42.1	45.5	42.8	--
	50	41.7	46.1	42.4	--
	75	41.2	44.7	43.9	--
	100	41.0	44.0	42.8	--
	PR>F	.77	.35	.37	--
	BLSD (.05)	--	--	--	--
	C.V.	3.6	3.2	2.4	--
manure	0	40.9	43.3	41.6	37.0
	25	40.5	44.8	42.6	37.5
	50	40.6	43.5	40.7	37.1
	75	41.2	45.1	42.3	38.3
	100	40.9	45.3	40.5	36.6
	PR>F	.99	.54	.48	.61
	BLSD (.05)	--	--	--	--
	C.V.	4.7	4.1	3.9	3.5

Table 11. Effect of S fertilization on the crude protein content of alfalfa. Goodhue County. 1985.

Site	S Applied	Cutting 1	Cutting 2	Cutting 3	Cutting 4
	lb./acre	%			
no manure	0	19.6	22.1	21.8	28.3
	25	20.1	21.0	21.9	28.8
	50	20.9	21.8	22.4	28.6
	75	20.8	21.1	22.3	29.5
	100	20.4	21.6	22.2	28.6
	PR>F	.27	.36	.40	.38
	BLSD (.05)	--	--	--	--
	C.V.	3.9	3.3	2.3	3.4
manure	0	21.0	23.1	21.1	28.2
	25	21.5	22.9	21.4	28.9
	50	21.9	22.7	21.5	29.4
	75	21.8	22.8	21.3	28.5
	100	22.0	22.9	21.1	29.1
	PR>F	.67	.99	.99	.63
	BLSD (.05)	--	--	--	--
	C.V.	2.9	4.3	3.5	4.1

Table 12. Effect of S fertilization on the percent ADF for alfalfa. Goodhue County. 1985.

Site	S Applied	Cutting 1	Cutting 2	Cutting 3	Cutting 4
	lb./acre	% ADF			
no manure	0	31.6	31.6	30.7	24.0
	25	31.8	31.9	30.3	22.7
	50	30.0	30.6	28.4	24.2
	75	30.1	32.6	29.3	22.8
	100	31.7	31.9	29.7	23.6
	PR>F	.20	.59	.27	.53
	BLSD (.05)	--	--	--	--
	C.V.	4.1	4.1	4.0	7.1
manure	0	29.9	28.8	31.1	24.5
	25	29.1	28.6	30.4	23.9
	50	29.1	29.6	30.9	23.4
	75	28.9	29.2	30.2	24.3
	100	28.3	29.3	31.5	23.6
	PR>F	.23	.86	.51	.85
	BLSD (.05)	--	--	--	--
	C.V.	4.2	4.6	3.1	5.9

Table 13. Effect of S fertilization on the percent NDF for alfalfa. Goodhue County. 1985.

Site	S Applied	Cutting 1	2	3	4
	lb./acre	% NDF			
no manure	0	42.2	40.4	39.2	32.6
	25	41.6	40.9	38.5	31.7
	50	39.4	39.6	37.0	32.7
	75	39.7	41.5	37.3	30.7
	100	40.7	41.1	38.0	32.3
	PR>F	.13	.43	.37	.75
	BLSD (.05)	--	--	--	--
	C.V.	3.7	3.6	4.0	6.2
manure	0	38.6	36.1	38.8	32.3
	25	37.4	36.2	38.7	31.0
	50	37.1	36.7	38.8	31.1
	75	37.0	37.6	39.4	31.8
	100	36.8	36.7	39.7	32.1
	PR>F	.01	.93	.91	.90
	BLSD (.05)	--	--	--	--
	C.V.	3.4	5.3	3.7	6.5

Table 14. Effect of rate of applied N on grain yield of corn.

N Applied	Site and Year: Staples (84)	Goodhue (84)	Staples (85)	Goodhue (85)
lb./acre	bu./acre			
0	78.9	118.2	45.4	108.9
75	136.4	172.2	87.8	125.5
150	150.5	177.5	121.2	127.8
225	155.3	187.5	118.9	128.2
PR>F	.01	.01	.01	.99
BLSD (.05)	10.0	6.7	10.4	6.7
C.V., %	12.1	6.5	11.1	8.3

Table 15. Effect of rate of applied S on grain yield of corn.

N Applied	Site and Year: Staples (84)	Goodhue (84)	Staples (85)	Goodhue (85)
lb./acre	bu./acre			
0	122.4	154.7	89.9	119.9
10	132.4	166.7	89.8	120.6
20	137.8	165.3	91.6	126.6
40	128.6	168.9	102.0	123.3
PR>F	.06	.01	.11	.26
BLSD (.05)	12.7	7.5	13.3	--
C.V., %	12.1	6.5	11.1	8.3

Table 16. Effect of rate of applied N on the dry matter produced by corn.

N Applied	Site and Year: Staples (84)	Goodhue (84)	Staples (85)	Goodhue (85)
lb./acre	ton D.M./acre			
0	4.24	5.28	2.38	5.16
75	5.95	6.94	4.69	4.89
150	6.48	7.46	5.14	6.26
225	6.13	7.14	5.58	6.18
PR>F	.01	.01	.01	.01
BLSD (.05)	.38	.45	.51	.29
C.V., %	10.6	10.4	11.8	7.7

Table 17. Effect of rate of applied S on the dry matter produced by corn.

S Applied	Site and Year: Staples (84)	Goodhue (84)	Staples (85)	Goodhue (85)
lb./acre	ton D.M./acre			
0	5.38	6.73	4.19	5.84
10	5.80	6.64	4.58	5.90
20	5.83	6.49	4.44	5.83
40	5.78	6.96	4.57	5.92
PR>F	.13	.31	.44	.93
BLSD (.05)	--	--	--	--
C.V., %	10.6	10.4	11.8	7.7

Table 18. Effect of rate of applied N and S on the N concentration in the ear leaf at silking.

N Applied	Site and Year: Staples (84)	Goodhue (84)	Staples (85)	Goodhue (85)
lb./acre	% N			
0	1.73	2.14	1.72	2.07
75	2.74	2.72	2.57	2.38
150	2.77	2.93	3.21	2.38
225	2.84	2.95	3.37	2.23
PR>F	.01	.01	.01	.01
BLSD (.05)	.17	.12	.46	.15
S Applied: lb./acre	% N			
0	2.38	2.66	2.61	2.18
10	2.56	2.63	2.75	2.31
20	2.59	2.68	2.70	2.26
40	2.56	2.77	2.80	2.32
PR>F	.13	.21	.86	.30
BLSD (.05)	--	--	--	--
C.V., %	10.8	7.2	17.0	9.9

Table 19. Effect of rate of applied N and S on the S concentration in the ear leaf at silking.

N Applied	Site and Year Staples (84)	Goodhue (84)	Staples (85)	Goodhue (85)
lb./acre	% S			
0	.141	.171	.162	.167
75	.191	.211	.225	.186
150	.203	.235	.250	.193
225	.202	.229	.278	.197
PR>F	.01	.01	.01	.01
BLSD (.05)	.01	.01	.02	.006
S Applied: lb./acre	% S			
0	.161	.202	.232	.180
10	.184	.203	.217	.188
20	.198	.215	.228	.186
40	.194	.226	.237	.188
PR>F	.01	.01	.32	.07
BLSD (.05)	.014	.010	--	.007
C.V., %	11.4	7.4	9.0	4.8

Table 20. Effect of rate of applied N and S on the N/S ratio in the ear leaf at silking.

N Applied	Site and Year Staples (84)	Goodhue (84)	Staples (85)	Goodhue (85)
lb./acre	N/S Ratio			
0	12.2	12.6	10.5	12.4
75	14.4	12.9	11.4	12.8
150	13.8	12.5	12.9	12.4
225	14.2	13.0	12.2	11.4
PR>F	.01	.34	.07	.01
BLSD (.05)	.7	--	2.0	.9
S Applied: lb./acre	N/S Ratio			
0	14.7	13.3	11.1	12.1
10	13.8	13.0	12.5	12.3
20	13.1	12.4	11.8	12.1
40	13.0	12.3	11.6	12.4
PR>F	.01	.02	.45	.90
BLSD (.05)	.8	.7	--	--
C.V., %	8.2	7.3	14.2	10.0

Table 21. Effect of rate of applied N and S on the percentage of crude protein in corn at physiological maturity.

N Applied	Staples (84)	Goodhue (84)	Site and Year Staples (85)	Goodhue (85)
lb./acre	% CP			
0	5.58	6.26	7.56	7.78
75	6.88	7.29	7.74	9.44
150	7.87	7.80	8.58	9.46
225	8.05	8.21	9.32	9.42
PR>F	.01	.01	.01	.01
BLSD (.05)	.37	.27	.58	.47
S Applied: lb./acre	% CP			
0	7.05	7.38	8.72	8.97
10	7.10	7.25	8.40	9.18
20	7.23	7.53	8.15	8.95
40	7.00	7.40	7.93	9.00
PR>F	.81	.34	.08	.81
BLSD (.05)	--	--	--	--
C.V., %	8.3	5.8	6.9	8.1

Table 22. Effect of rate of applied N and S on the ADF percentage in corn at physiological maturity.

N Applied	Staples (84)	Goodhue (84)	Site and Year Staples (85)	Goodhue (85)
lb./acre	% ADF			
0	31.2	28.5	30.2	25.8
75	28.3	26.5	28.5	21.5
150	27.9	27.5	27.3	23.0
225	26.7	26.1	26.3	24.8
PR>F	.01	.19	.29	.04
BLSD (.05)	1.7	--	--	3.5
S Applied: lb./acre	% ADF			
0	27.4	28.0	27.0	24.8
10	28.8	28.3	27.1	23.4
20	28.3	25.2	28.1	23.7
40	29.5	27.1	30.1	23.3
PR>F	.12	.05	.42	.76
BLSD (.05)	--	2.6	--	--
C.V., %	8.8	12.3	14.4	18.6

Table 23. Effect of rate of applied N and S on the NDF percentage in corn at physiological maturity.

N Applied	Staples (84)	Goodhue (84)	Site and Year Staples (85)	Goodhue (85)
lb./acre	---------------	--------------- % NDF	---------------	---------------
0	48.9	42.1	45.1	40.8
75	45.6	40.4	44.9	36.0
150	45.3	41.9	43.5	38.0
225	44.1	40.0	42.2	39.9
PR>F	.01	.37	.61	.07
BLSD (.05)	2.2	--	--	4.4
S Applied:				
lb./acre	---------------	--------------- % NDF	---------------	---------------
0	44.5	42.0	42.5	39.8
10	46.3	42.5	43.1	38.3
20	46.2	38.7	43.8	38.6
40	47.1	41.2	46.2	38.0
PR>F	.14	.05	.46	.80
BLSD (.05)	--	3.2	--	--
C.V., %	6.9	9.7	43.9	13.8

PLACEMENT OF NITROGEN SOLUTIONS UNDER DIFFERING TILLAGE SYSTEMS

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The use of 28% N solution (UAN) 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 UAN. These concerns are related to the potential volatilization 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 UAN under different tillage systems, and (2) with surface applications of UAN compare uniform broadcast applications to surface dribble applications under different tillage systems.

MATERIALS, METHODS, AND OBSERVATIONS

Experimental sites - Experiments were conducted in 1984 and 1985 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 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 classified as either Seaton (Typic Hapludalfs) or Mt. Carroll (Mollic Hapludalfs).

Experimental treatments - The treatment combinations at each location were a complete factorial arrangement of either four (EC) or three (SE) tillage treatments at three nitrogen (75, 150 and 300 # N/A), with three method of UAN application (broadcast, injected, or surface dribble). The 44 treatments established at the EC location consisted of four tillage systems (no till, ridge till, chisel, and moldboard plow) with all three methods of UAN application, plus two control treatments (zero N) for each tillage system. The two control treatments were included to determine the effect of the injection procedure across tillage systems. The 33 treatments established at the SE location were set up in an identical manner except that only three tillage systems were investigated. No moldboard plow treatment was included because this is no longer a recommended tillage 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 nitrogen rate and the second sub-plot being method of application. The smallest experimental sub-units were 14.7 ft. (4 rows) wide 50 ft. long.

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

Surface residue cover - Tillage practices can have a considerable impact on the amount of crop residue remaining on the soil surface. The amount of residue on the surface may likewise influence many other parameters and processes including soil temperature, soil moisture, mineralization rate, nitrification rate, potential for surface volatilization of urea as well as leaching and/or denitrification processes. Surface residue cover observed in 1984 and 1985.

1984 and 1985 cover*

Location	Tillage	In Row 1984	In Row 1985	Between Rows 1984	Between Rows 1985
Becker (EC)	Moldboard	3.5 (4.6)	1.5 (2.47)	2.5 (3.5)	1.0 (1.79)
(6/27/84)	Chisel	25.0 (13.7)	18.0 (13.3)	41.3 (17.4)	21.2 (11.7)
(5/30/85)	Ridge till	16.7 (12.4)	10.5 (6.0)	32.0 (14.5)	28.2 (11.5)
	No till	64.0 (17.9)	53.7 (20.0)	73.0 (14.6)	53.7 (12.7)
Goodhue Co. (SE)	Chisel	16.8 (11.0)	29.2 (17.8)	23.8 (11.1)	28.2 (19.1)
(6/19/84)	Ridge till	10.0 (7.9)	11.7 (8.6)	31.8 (14.3)	53.7 (6.3)
(6/4/85)	No till	77.8 (17.2)	71.7 (21.2)	65.5 (15.3)	76.0 (9.8)

* In the row = an 8 inch area centered over the row and between is the remainder. The number in parentheses is the standard deviation.

With moldboard tillage there was very little residue remaining on the soil surface in 1984 and 1985. The chisel plow treatment left 15-41% surface cover with the EC (Becker) location having slightly more residue cover. The ridge till was almost the same at both locations but there was more cover at the (SE) Goodhue location between rows in 1985 than 1984. As would be expected the no till areas had the highest residue cover ranging from 53-78% of the soil surface.

Grain yields and N utilization - Leaf samples from opposite and below the ear at mid-silking were collected on July 23 at the EC location and on July 26 at the SE location. All leaf samples were dried, ground, and analyzed for Kjeldahl N. Total dry matter production was determined on Sept. 24 and 25 at the EC location and at the SE location on Oct. 2, 3, and 7. At each location ears were separated from 40 ft. of row, field weights obtained, and subsamples collected for moisture analysis and N determination. Grain yields were adjusted to 15.5% moisture. Stover yields were obtained by removing the above ground plant material in the same 40 ft. row. Subsamples were also collected for moisture determination and N analysis.

RESULTS AND DISCUSSION - EC LOCATION - BECKER, MN

A summary of the crop yield components and N utilization components for 1984, 1985 and a two year average are presented in Tables 2 - 5. Treatment variables were evaluated utilizing analysis of variance. Treatment means are reported for individual treatments and statistically analyzed as factorial combinations in a split-split block design. Where appropriate a BLSD (0.5) was computed to compare treatment means. Analysis of variance was also computed for the two year average. Since the year term was expected to be significant with most observations, but in general meaningless for treatment comparisons, the probability levels for year terms have not been reported.

The grain yields obtained and response to nitrogen/tillage treatments were excellent in both 1984 and 1985. Yields obtained in 1985 from the better treatments (185 bu/A) and low yielding treatments (35 bu/A) were similar to those obtained in 1984. Significant leaching losses of nitrate-N was experienced in 1984, while minimal leaching was experienced in 1985. This led to treatment means and main effects that were higher in 1985 than in 1984. Although the grain yields from specific treatments were higher in 1985 than 1984, the relative differences between treatments (tillage, method of placement, and N rate) followed the same general trends as those observed in 1984.

Grain yields were significantly influenced by all main treatment effects (tillage, N rate, and method of application). Significant two-way interactions obtained in both years suggest that method and rate of N application did not provide similar responses under different tillage systems. Since the trends for 1984 and 1985 were similar, discussion will be concentrated with the two-year average.

The N-rate x tillage interaction indicated that at the lowest N-rate (75 # N/A) only modest differences were observed between tillage systems (although no till had the lowest yield). As N-rate increased differences in N response across tillage systems became more apparent. At the highest N rate (300 # N/A) no till was clearly inferior to the other tillage systems, while moldboard plow provided the highest yields. Averaged over two years at the highest N rate, moldboard plow was 53 bu/A better than no till, 18 bu/A better than ridge till, and 10 bu/A better than chisel plow.

The most efficient method of UAN placement was highly dependent on tillage system (tillage x method interaction). On moldboard plow treatment where residue cover was minimal, method of placement had no influence on yield. Method of UAN placement had similar effects on the chisel and ridge-till tillage systems. Injected treatments were 10-14 bu/A higher than dribble which were in turn 10-14 bu/A better than broadcast treatments. Injected treatments were clearly superior with no till (high residue cover). Surface dribble treatments on no till were intermediated, but 29 bu/A lower than injected while broadcast treatments were 25 bu/A lower than dribble treatments. This would suggest that as surface residue covers increase, injection of UAN would become the most efficient method of application. Although a significant N-rate x method of application interaction existed, the practical significance would suggest that as N-rate increased to higher than "adequate" levels, differences between methods of application were not as clearly defined.

Stover yields and N utilization characteristics followed the same trends as those that were observed with grain yield.

RESULTS AND DISCUSSION - SE LOCATION - GOODHUE CO.

A summary of the crop yield components, and nitrogen utilization characteristics similar to the previous experiments are presented in Tables 6-9. The experimental design and treatments were identical in both experiments except only three tillage treatments were evaluated at this location.

The yields obtained in 1985 were slightly below those that were obtained in 1984, but were good considering the extremely dry conditions that were experienced early in the growing season at this location. The dry conditions also magnified problems with plant population, weed control, and cut worms, especially on the no till treatments. Because of these confounding factors, no till treatments performed very poorly compared to other treatments and several treatments were discarded.

Although yields from the no till treatments were considerably lower than the other tillage systems, overall trends in 1985 were similar to those established in 1984. Yields from the two-year average indicated that ridge till and chisel produced similar yields while no till had significantly lower yield during both years. Optimum nitrogen rate was around 150 # N/A, but method of application interacted with N rate. This interaction indicated that at the low N rates when surface residue was present, surface applications of UAN were inferior to injected treatments. As nitrogen rates increased or as surface residue decreased, differences between methods of application narrowed.

GENERAL CONCLUSIONS

The results at this location in 1984 and 1985 followed the same general trends. These general trends would suggest that as surface residue cover increases, surface applications become less efficient. Although concentrating the surface application into a dribble application improved the efficiency over broadcasting, it was never as efficient as injection. If surface residue was not present there was little difference between methods of application.

Although the trends were the same at both locations, the magnitude of differences were substantial across locations. The coarse textured irrigated soil exhibited relatively large differences between treatments while the non-irrigated silt loam soil had relatively modest differences. Part of this may be explained on the basis that the coarse textured soil, because of the soil and irrigation, is much more responsive to N fertilizer (140-150 Bu/A) than the silt loam soil (60-70 Bu/A). This may tend to magnify differences. The corn residue (stover) at the Becker location (coarse textured soil) had a much lower concentration of N than the stover samples at the site with the silt loam soil. Although this aspect was not investigated in depth, immobilization of nitrogen by the residue at the site with the coarse-textures soil may have been a more dominant factor than at the silt loam location thus magnifying differences especially with surface applications.

Table 1. Management practices utilized at the Becker (EC) and Goodhue (SE) experimental locations.

Management Practice	EC (Becker)	Date	SE (Goodhue)	Date
Tillage	Moldboad plow & plowpacker	4/5		
	Chisel	4/29		5/7
	Ridge Till	6/24		6/29
	Culitivation	----		----
Planting Date[1]	No Till	5/7		5/7
Corn Variety	Pionner 3906		Pionner 3906	
Seeding Rates	29,580 seeds/A		28,000 seeds/A	
Row spacing	30 inches		38 inches	
Fertilizer treatments application		5/7		5/9
Starter Fertilizer	150#/A 8-10-30		14gal/A 7-21-7	
Other Fertilizer	235#/A 0-0-22 250#/A 1-14-42	4/1 4/1		
Insecticide			Counter 15g 6#/A	
Herbicide[2]	Atrazine 2#/A Dual AE 1.5 pint/A Round Up 1 qt./A Atrazine 2#/A + oil	5/3 5/3 5/3 5/30	Lasso 2.5#/A Round Up 1 qt/A Atrazine 2#/A Butril 1 pint/A	5/7 5/7 5/7 6/14
Irrigation	0.90 inches 5.90 inches 0.60 inches	June July August		

1 At the EC location the ridge till treatments were planted with a Buffalo till planter (disc trash cleaners) and a white (12 inch fluted coulter). At the SE location a Hiniker planter was used for all treatments (trash discs were raised for no till and chisel treatments).

2 Weed control was obtained at each location but giant foxtail was a problem on the no till plots at each location we had to throw some treatments out at the SE location because the weeds were so bad in 1985.

Table 2. Influence of nitrogen rates, tillage systems, and methods of 28% N application on grain yields and % dry matter of the grain for 1984 and 1985 on irrigated corn. Becker, MN 84-85.

N-Rate	Treatments Tillage System	Method Applied	Grain Yields 1984	1985	Ave.	Dry Matter Grain 1984	1985	Ave.
#/A				Bu/A			%	
Control	No Till	---------	45.5	35.6	40.6	62.9	65.0	64.0
Control-Knife	No Till	---------	44.5	35.1	39.8	60.7	64.0	62.4
Control	Ridge Till	---------	50.9	34.6	42.7	65.1	66.0	65.6
Control-Knife	Ridge Till	---------	52.4	36.2	44.3	65.2	67.0	66.1
HHLtrol	Chisel	---------	55.2	46.0	50.6	65.8	64.0	64.9
Control-Knife	Chisel	---------	59.5	41.2	50.3	68.0	62.0	65.0
Control	Moldboard	---------	47.9	36.1	42.0	63.1	63.0	63.1
Control-Knife	Moldboard	---------	55.9	47.0	51.5	63.2	62.0	62.6
75	No Till	Broadcast	41.0	47.9	44.5	61.8	63.0	62.4
75	No Till	Injected	76.1	77.8	77.0	60.2	61.0	60.6
75	No Till	Dribble	49.9	57.7	53.8	61.9	63.0	62.5
75	Ridge Till	Broadcast	57.7	69.0	63.4	68.9	65.0	67.0
75	Ridge Till	Injected	80.6	68.0	74.3	66.4	63.0	64.7
75	Ridge Till	Dribble	64.6	74.1	69.4	69.2	63.0	66.1
75	Chisel	Broadcast	65.6	90.9	78.3	66.3	63.0	64.7
75	Chisel	Injected	83.3	98.3	90.8	67.3	64.0	65.7
75	chisel	Dribble	76.0	96.5	86.3	67.3	62.0	64.7
75	Moldboard	Broadcast	65.9	81.4	73.9	67.3	63.0	65.2
75	Moldboard	Injected	61.8	75.7	68.8	65.2	62.0	63.6
75	Moldboard	Dribble	69.4	70.1	69.8	66.8	63.0	64.9
150	No Till	Broadcast	42.7	91.8	67.3	59.3	60.0	59.7
150	No Till	Injected	109.5	125.4	117.4	60.5	58.0	59.3
150	No Till	Dribble	50.7	80.1	65.4	61.1	61.1	61.1
150	Ridge Till	Broadcast	74.6	134.3	104.5	67.6	62.0	64.8
150	Ridge Till	Injected	128.5	144.6	136.6	66.3	62.0	64.2
150	Ridge Till	Dribble	83.0	126.5	104.8	67.7	62.0	64.9
150	Chisel	Broadcast	90.9	123.3	107.1	65.3	60.0	62.7
150	Chisel	Injected	142.6	144.0	143.3	64.4	60.2	62.2
150	Chisel	Dribble	101.3	135.2	118.3	67.0	61.0	64.0
150	Moldboard	Broadcast	137.2	149.9	143.6	68.1	62.0	65.1
150	Moldboard	Injected	135.7	150.6	143.2	67.0	63.0	65.0
150	Moldboard	Dribble	105.8	156.3	131.1	68.2	63.0	65.6
300	No Till	Broadcast	53.0	94.0	73.5	59.4	57.0	58.2
300	No Till	Injected	154.9	148.1	151.5	59.3	57.0	58.2
300	No Till	Dribble	137.9	139.8	138.9	60.5	58.0	59.3
300	Ridge Till	Broadcast	125.5	146.9	136.2	65.7	59.0	62.4
300	Ridge Till	Injected	176.8	158.8	167.8	64.9	60.0	62.5
300	Ridge Till	Dribble	165.4	160.1	162.8	66.0	61.0	63.5
300	Chisel	Broadcast	134.8	159.4	147.1	64.3	61.0	62.7
300	Chisel	Injected	181.8	168.2	175.0	63.7	61.0	62.4
300	Chisel	Dribble	160.2	178.1	169.2	64.4	61.0	62.7
300	Moldboard	Broadcast	155.2	178.2	166.7	66.4	62.0	64.2
300	Moldboard	Injected	170.6	183.5	175.8	65.1	62.0	63.6
300	Moldboard	Dribble	173.3	185.6	179.5	60.7	63.0	61.9

Table 3. Influence of nitrogen rates, tillage systems, and methods of 28% N application on dry matter production on irrigated corn. Becker, MN - 1984 and 1985.

	Treatments		Dry Matter Production								
	Tillage	Method	Grain			Stover			Total		
N-Rate	System	Applied	1984	1985	Ave.	1984	1985	Ave.	1984	1985	Ave.
#/A			T/A								
Control	No Till	---------	1.07	0.84	0.96	0.98	1.15	1.07	2.06	2.00	2.03
Control-Knife	No Till	---------	1.05	0.83	0.94	1.04	1.27	1.16	2.09	2.11	2.10
Control	Ridge Till	---------	1.20	0.82	1.01	0.91	1.24	1.08	2.11	2.06	2.09
Control-Knife	Ridge Till	---------	1.24	0.86	1.05	0.94	1.23	1.09	2.18	2.09	2.14
Control	Chisel	---------	1.30	1.09	1.02	1.05	1.41	1.23	2.35	2.50	2.43
Control-Knife	Chisel	---------	1.40	0.98	1.19	1.16	1.62	1.39	2.57	2.60	2.59
Control	Moldboard	---------	1.13	0.86	1.00	0.92	1.19	1.06	2.06	2.05	2.06
Control-Knife	Moldboard	---------	1.32	1.11	1.22	1.11	1.48	1.30	2.44	2.59	2.52
75	No Till	Broadcast	0.97	1.13	1.05	1.05	1.84	1.45	2.02	2.97	2.50
75	No Till	Injected	1.80	1.84	1.82	1.86	2.21	2.04	3.66	4.05	3.86
75	No Till	Dribble	1.18	1.37	1.28	1.28	1.69	1.49	2.46	3.06	2.76
75	Ridge Till	Broadcast	1.36	1.63	1.50	1.07	2.00	1.54	2.43	3.63	3.03
75	Ridge Till	Injected	1.90	1.61	1.76	1.68	1.89	1.79	3.59	3.50	3.55
75	Ridge Till	Dribble	1.53	1.75	1.64	1.15	2.07	1.61	2.68	3.82	3.25
75	Chisel	Broadcast	1.55	2.15	1.85	1.77	2.75	2.26	3.32	4.90	4.11
75	Chisel	Injected	1.97	2.33	2.15	2.11	2.47	2.29	4.08	4.79	4.44
75	chisel	Dribble	1.79	2.28	2.04	1.81	2.53	2.17	3.61	4.81	4.21
75	Moldboard	Broadcast	1.56	1.94	1.75	1.47	2.38	1.93	3.03	4.31	3.67
75	Moldboard	Injected	1.46	1.79	1.63	1.44	2.25	1.85	2.90	4.04	3.47
75	Moldboard	Dribble	1.64	1.66	1.65	1.51	2.33	1.92	3.15	3.99	3.57
150	No Till	Broadcast	1.01	2.17	1.59	1.24	2.28	1.76	2.25	4.45	3.35
150	No Till	Injected	2.59	2.97	2.78	2.27	2.61	2.44	4.86	5.58	5.22
150	No Till	Dribble	1.20	1.90	1.55	1.35	1.93	1.64	2.55	3.83	3.19
150	Ridge Till	Broadcast	1.76	3.18	2.47	1.64	3.05	2.35	3.40	6.23	4.82
150	Ridge Till	Injected	3.04	3.42	3.23	2.28	3.14	2.71	5.32	6.56	5.94
150	Ridge Till	Dribble	1.96	3.00	2.48	1.81	2.99	2.40	3.78	5.99	4.89
150	Chisel	Broadcast	2.15	2.92	2.54	2.26	2.95	2.61	4.42	5.87	5.15
150	Chisel	Injected	3.37	3.41	3.39	2.78	3.05	2.92	6.16	6.45	6.31
150	Chisel	Dribble	2.39	3.20	2.80	2.31	3.09	2.70	4.71	6.29	5.50
150	Moldboard	Broadcast	3.24	3.55	3.40	2.72	3.22	2.97	5.97	6.76	6.37
150	Moldboard	Injected	3.21	3.56	3.39	2.61	3.20	2.91	5.82	6.76	6.29
150	Moldboard	Dribble	2.50	3.70	3.10	2.27	3.13	2.70	4.78	6.83	5.81
300	No Till	Broadcast	1.25	2.22	1.74	1.81	2.55	2.18	3.06	4.77	3.92
300	No Till	Injected	3.66	3.51	3.59	2.80	2.82	2.81	6.46	6.32	6.39
300	No Till	Dribble	3.26	3.31	3.29	2.64	2.74	2.69	5.91	6.05	5.98
300	Ridge Till	Broadcast	2.96	3.48	3.22	2.48	2.77	2.63	5.45	6.25	5.85
300	Ridge Till	Injected	4.18	3.76	3.97	2.90	2.91	2.91	7.09	6.67	6.88
300	Ridge Till	Dribble	3.91	3.79	3.85	2.96	3.05	3.01	6.88	6.84	6.86
300	Chisel	Broadcast	3.19	3.77	3.48	2.69	3.21	2.95	5.88	6.98	6.43
300	Chisel	Injected	4.30	3.98	4.14	3.44	3.49	3.47	7.74	7.47	7.61
300	Chisel	Dribble	3.79	4.21	4.00	3.28	3.35	3.32	7.07	7.57	7.32
300	Moldboard	Broadcast	3.67	4.22	3.95	2.82	3.74	3.28	6.50	7.96	7.23
300	Moldboard	Injected	4.03	4.34	4.19	3.02	3.61	3.32	7.06	7.95	7.51
300	Moldboard	Dribble	4.10	4.39	4.25	3.08	3.69	3.39	7.18	8.08	7.63

Table 2. Continued

Treatments Tillage System	Grain Yields 1984	1985	Ave.	Dry Matter Grain 1984	1985	Ave.
		Bu/A			%	
Factorial Arrangement (Excludes Controls)						
Tillage						
No Till	79.5	95.8	87.6	60.5	59.0	59.7
Ridge Till	106.3	120.3	113.3	67.0	61.0	64.0
Chisel	115.2	132.6	123.9	65.1	61.0	63.0
Moldboard	119.4	136.8	128.1	66.9	62.0	64.4
P-Value (%)	99	99	99	99	99	99
BLSD (.05)				1.6		
N-Rate						
75	66.0	75.6	70.8	65.7	62.0	63.8
150	100.2	130.2	115.2	65.2	61.0	63.1
300	149.1	158.4	153.7	64.0	60.0	62.0
P-Value (%)	99	99	99	99	99	99
BLSD (.05)				0.9		
Method Applied						
Broadcast	87.0	113.9	100.4	65.0	61.0	63.0
Injected	125.2	128.6	126.9	64.2	61.0	62.6
Dribble	103.1	121.7	112.4	65.6	61.0	63.3
P-Value (%)	99	99	99	99	89	99
BLSD (.05)				0.8		
Tillage X N-Rate	99	99	99	76	99	94
Tillage X Method	99	99	99	18	25	3
N-Rate X Method	99	99	99	7	47	25
Tillage X N-Rate X Method	94	62	87	10	13	13

Table 3. Continued

Treatments Tillage System	Dry Matter Production: Grain 1984	Grain 1985	Grain Ave.	Stover 1984	Stover 1985	Stover Ave.	Total 1984	Total 1985	Total Ave.
					T/A				
Factorial Arrangement (Excludes Controls)									
Tillage									
No Till	1.88	2.26	2.07	1.81	2.29	20.5	3.69	4.56	4.12
Ridge Till	2.51	2.84	2.67	2.00	2.65	2.32	4.51	5.49	5.00
Chisel	2.72	3.13	2.92	2.49	2.98	2.73	5.22	6.12	5.67
Moldboard	2.82	3.23	3.02	2.33	3.06	2.69	5.15	6.29	5.72
P-Value (%)	99	99	99	99	99	99	99	99	99
BLSD (.05)									
N-Rate									
75	1.56	1.79	1.69	1.52	2.19	1.85	3.08	3.98	3.53
150	2.37	3.08	2.72	2.13	2.88	2.50	4.50	5.96	5.23
300	3.52	3.74	3.63	2.83	3.16	2.99	6.36	6.90	6.63
P-Value (%)	99	99	99	99	99	99	99	99	99
BLSD (.05)									
Method									
Broadcast	2.05	2.69	2.37	1.92	2.72	2.32	3.98	5.42	4.70
Injected	2.96	3.04	3.00	2.43	2.88	2.65	5.39	5.84	5.61
Dribble	2.44	2.87	2.65	2.12	2.71	2.41	4.56	5.59	5.07
P-Value (%)	99	99	99	99	59	99	99	99	99
BLSD (.05)									
Tillage X Rate	99	99	99	85	99	98	98	99	99
Tillage X Method	99	99	99	99	85	99	99	99	99
N-Rate X Method	99	98	99	99	55	98	99	93	99
Tillage X N-Rate X Method	99	62	84	17	9	7	57	31	25

Table 4. Influence of nitrogen rates, tillage systems and methods of 28% N application, on leaf, stover and grain N concentration on irrigated corn. Becker, MN - 1984 and 1985.

Treatments			N-Concentration								
	Tillage	Method	Leaf			Stover			Grain		
N-Rate	System	Applied	1984	1985	Ave.	1984	1985	Ave.	1984	1985	Ave.
#/A			%								
Control	No Till	---------	1.38	1.11	1.25	0.47	0.42	0.45	1.03	0.84	0.94
Control-Knife	No Till	---------	1.26	1.10	1.18	0.44	0.37	0.41	1.14	0.95	1.05
Control	Ridge Till	---------	1.35	1.01	1.18	0.40	0.39	0.40	1.19	0.93	1.06
Control-Knife	Ridge Till	---------	1.32	1.05	1.19	0.43	0.41	0.42	1.14	0.99	1.07
Control	Chisel	---------	1.22	1.09	1.16	0.45	0.47	0.46	1.19	0.90	1.05
Control-Knife	Chisel	---------	1.15	1.30	1.23	0.44	0.48	0.46	1.12	1.10	1.11
Control	Moldboard	---------	1.22	1.06	1.14	0.45	0.43	0.44	1.11	0.92	1.02
Control-Knife	Moldboard	---------	1.18	1.10	1.14	0.42	0.42	0.42	1.12	0.89	1.10
75	No Till	Broadcast	1.23	1.39	1.31	0.42	0.43	0.43	1.10	0.88	0.99
75	No Till	Injected	1.78	1.81	1.80	0.46	0.50	0.48	1.05	0.84	0.95
75	No Till	Dribble	1.30	1.51	1.41	0.39	0.44	0.42	1.14	0.79	0.97
75	Ridge Till	Broadcast	1.24	1.59	1.42	0.36	0.45	0.41	1.23	0.96	1.10
75	Ridge Till	Injected	1.65	1.59	1.62	0.46	0.39	0.43	1.10	0.90	1.00
75	Ridge Till	Dribble	1.17	1.68	1.43	0.46	0.47	0.47	1.27	0.96	1.12
75	Chisel	Broadcast	1.29	1.89	1.59	0.41	0.45	0.43	1.07	0.91	0.99
75	Chisel	Injected	1.54	2.06	1.80	0.40	0.47	0.44	1.17	0.87	1.02
75	Chisel	Dribble	1.25	2.01	1.63	0.42	0.46	0.44	1.15	0.93	1.04
75	Moldboard	Broadcast	1.18	1.80	1.49	0.41	0.48	0.45	1.23	1.08	1.16
75	Moldboard	Injected	1.43	1.62	1.53	0.44	0.46	0.45	1.16	0.96	1.06
75	Moldboard	Dribble	1.26	1.84	1.55	0.39	0.46	0.43	1.23	0.95	1.09
150	No Till	Broadcast	1.18	2.15	1.67	0.44	0.50	0.47	1.13	1.09	1.11
150	No Till	Injected	2.35	2.80	2.58	0.47	0.59	0.53	1.22	0.96	1.09
150	No Till	Dribble	1.31	1.65	1.48	0.44	0.46	0.45	1.07	0.87	0.97
150	Ridge Till	Broadcast	1.34	2.62	1.98	0.48	0.61	0.55	1.15	1.08	1.12
150	Ridge Till	Injected	2.51	2.73	2.62	0.48	0.59	0.54	1.25	1.11	1.18
150	Ridge Till	Dribble	1.52	2.43	1.98	0.39	0.55	0.47	1.26	0.93	1.10
150	Chisel	Broadcast	1.47	2.54	2.01	0.38	0.56	0.47	1.11	1.06	1.09
150	Chisel	Injected	2.43	2.80	2.62	0.48	0.64	0.56	1.36	1.05	1.21
150	Chisel	Dribble	1.69	2.74	2.22	0.42	0.61	0.52	1.11	1.12	1.12
150	Moldboard	Broadcast	2.04	2.58	2.31	0.47	0.57	0.52	1.19	1.17	1.18
150	Moldboard	Injected	2.26	2.74	2.50	0.47	0.60	0.54	1.28	1.19	1.24
150	Moldboard	Dribble	1.36	2.66	2.01	0.43	0.64	0.54	1.22	1.15	1.19
300	No Till	Broadcast	1.46	2.26	1.86	0.45	0.51	0.48	1.18	0.94	1.06
300	No Till	Injected	3.00	3.14	3.07	0.72	0.86	0.79	1.55	1.15	1.35
300	No Till	Dribble	2.36	3.29	2.83	0.49	0.65	0.57	1.35	1.04	1.20
300	Ridge Till	Broadcast	1.96	3.02	2.49	0.38	0.58	0.48	1.19	1.17	1.18
300	Ridge Till	Injected	2.91	2.87	2.89	0.68	0.68	0.68	1.49	1.37	1.43
300	Ridge Till	Dribble	2.90	3.03	2.97	0.62	0.68	0.65	1.42	1.28	1.35
300	Chisel	Broadcast	2.42	3.05	2.74	0.44	0.67	0.56	1.25	1.22	1.24
300	Chisel	Injected	2.93	3.30	3.12	0.53	0.77	0.65	1.36	1.31	1.34
300	Chisel	Dribble	2.81	3.01	2.91	0.50	0.78	0.64	1.41	1.20	1.31
300	Moldboard	Broadcast	2.49	3.04	2.77	0.47	0.80	0.64	1.24	1.01	1.13
300	Moldboard	Injected	2.99	3.09	3.04	0.54	0.83	0.69	1.52	0.95	1.24
300	Moldboard	Dribble	2.69	2.96	2.83	0.52	0.82	0.67	1.53	1.08	1.31

Table 5. Influence of nitrogen rates, tillage systems and methods of 28% N application, on stover and grain nitrogen removal by irrigated corn. Becker, MN - 1984 and 1985.

	Treatments		N-Removal								
	Tillage	Method	Grain			Stover			Total		
N-Rate	System	Applied	1984	1985	Ave.	1984	1985	Ave.	1984	1985	Ave.
#/A			#/A								
Control	No Till	---------	21.9	14.1	18.0	9.2	9.7	9.4	31.2	23.8	27.5
Control-Knife	No Till	---------	23.0	15.8	19.4	9.2	9.4	9.3	32.3	25.2	28.7
Control	Ridge Till	---------	28.7	15.3	22.0	7.5	9.7	8.6	36.3	25.0	30.6
Control-Knife	Ridge Till	---------	28.4	17.0	22.7	7.9	10.1	9.0	36.4	27.1	31.7
Control	Chisel	---------	31.3	19.6	22.5	9.5	13.2	11.4	40.9	32.8	36.8
Control-Knife	Chisel	---------	30.7	21.6	26.1	10.2	15.6	11.4	41.0	37.2	39.1
Control	Moldboard	---------	25.4	15.8	20.6	8.4	10.4	9.3	33.8	26.0	29.9
Control-Knife	Moldboard	---------	29.5	19.7	24.6	9.1	12.4	10.8	38.7	32.1	35.4
75	No Till	Broadcast	21.8	19.8	20.8	9.1	15.6	12.4	31.0	35.5	33.3
75	No Till	Injected	38.2	31.5	34.9	17.1	22.0	19.6	55.3	53.5	54.4
75	No Till	Dribble.	26.8	21.4	24.1	10.0	15.1	12.6	36.9	36.5	36.7
75	Ridge Till	Broadcast	33.7	31.5	32.6	7.8	18.1	13.0	41.5	49.7	45.6
75	Ridge Till	Injected	42.3	28.2	35.3	15.7	14.7	15.2	58.1	42.8	50.5
75	Ridge Till	Dribble	39.0	33.4	36.2	10.9	19.7	15.3	49.9	53.2	51.6
75	Chisel	Broadcast	32.9	38.9	35.9	14.4	24.6	19.5	47.3	63.6	55.5
75	Chisel	Injected	46.1	39.6	42.9	16.9	23.1	20.0	63.1	62.7	62.9
75	Chisel	Dribble	41.2	42.0	41.6	15.6	23.4	19.5	56.8	65.4	61.1
75	Moldboard	Broadcast	38.3	41.9	40.1	12.7	22.5	17.6	50.4	64.4	57.4
75	Moldboard	Injected	34.0	34.1	34.1	13.0	20.5	16.8	47.0	54.6	50.8
75	Moldboard	Dribble	40.6	31.6	36.1	12.0	21.8	16.9	52.6	53.4	53.0
150	No Till	Broadcast	23.1	47.5	35.3	10.9	22.8	16.9	34.1	70.3	52.2
150	No Till	Injected	63.6	57.8	60.7	21.6	31.3	26.5	85.2	89.1	87.2
150	No Till	Dribble	25.9	33.4	29.7	12.0	18.0	15.0	38.0	51.4	44.7
150	Ridge Till	Broadcast	40.6	69.4	55.0	15.7	37.2	26.5	56.3	106.7	81.5
150	Ridge Till	Injected	76.5	76.1	76.3	21.8	36.9	29.4	98.4	113.1	105.8
150	Ridge Till	Dribble	49.7	56.1	52.9	14.2	32.7	23.5	64.0	88.9	76.5
150	Chisel	Broadcast	48.2	61.4	54.8	17.1	33.0	25.1	65.3	94.5	79.9
150	Chisel	Injected	92.3	72.2	82.3	26.8	39.1	33.0	119.2	111.3	115.3
150	Chisel	Dribble	53.5	72.0	62.8	19.6	37.9	28.8	73.1	110.0	91.6
150	Moldboard	Broadcast	77.6	82.5	80.1	26.0	36.4	31.2	103.6	119.0	111.3
150	Moldboard	Injected	83.7	86.0	84.9	24.9	37.9	31.4	108.6	123.9	116.3
150	Moldboard	Dribble	60.8	85.4	73.1	19.8	39.6	29.7	80.7	125.1	102.9
300	No Till	Broadcast	29.3	41.7	35.5	16.8	26.0	21.4	46.2	67.7	57.0
300	No Till	Injected	114.0	79.9	97.0	40.5	48.2	44.4	154.6	128.2	141.4
300	No Till	Dribble	89.1	68.2	78.7	25.8	35.8	30.8	115.0	104.1	109.6
300	Ridge Till	Broadcast	71.0	82.8	76.9	19.2	32.0	25.6	90.2	114.8	102.5
300	Ridge Till	Injected	125.7	102.6	114.2	40.3	39.6	40.0	166.0	142.3	154.2
300	Ridge Till	Dribble	111.8	98.0	104.9	37.0	42.1	39.6	148.8	140.1	144.5
300	Chisel	Broadcast	80.4	91.9	86.2	23.8	42.4	33.1	104.3	134.4	119.4
300	Chisel	Injected	116.8	104.2	110.5	37.0	53.7	45.4	153.8	157.9	155.9
300	Chisel	Dribble	107.3	100.5	103.9	32.8	52.3	42.6	140.1	152.8	146.5
300	Moldboard	Broadcast	92.2	85.8	89.0	27.1	59.6	43.4	119.4	145.4	132.4
300	Moldboard	Injected	123.1	83.0	103.1	32.9	59.5	46.2	156.1	142.5	149.3
300	Moldboard	Dribble	125.8	94.6	110.2	32.7	60.3	46.5	158.5	155.0	156.8

Table 4. Continued

Treatments Tillage System	Leaf 1984	1985	Ave.	Stover 1984	1985	Ave.	Grain 1984	1985	Ave.
	N-Concentration								
	%								
Factorial Arrangement (Excludes Controls)									
Tillage									
No Till	1.77	2.22	1.99	0.47	0.54	0.50	1.20	0.95	1.07
Ridge Till	1.91	2.39	2.15	0.48	0.55	0.51	1.26	1.08	1.17
Chisel	1.98	2.60	2.29	0.44	0.60	0.52	1.22	1.07	1.14
Moldboard	1.97	2.48	2.22	0.46	0.62	0.54	1.29	1.06	1.14
P-Value (%)	99	99	99	98	99	90	99	99	99
BLSD (.05)							0.04		
N-Rate									
75	1.36	1.73	1.54	0.42	0.45	0.43	1.16	0.91	1.03
150	1.79	2.53	2.16	0.44	0.57	0.50	1.20	1.06	1.13
300	2.58	3.00	2.79	0.53	0.71	0.62	1.37	1.14	1.25
P-Value (%)	99	99	99	99	99	99	99	99	99
BLSD (.05)									
Method Applied									
Broadcast	1.61	2.32	1.96	0.43	0.55	0.49	1.17	1.04	1.10
Injected	2.31	2.54	2.42	0.51	0.61	0.56	1.29	1.05	1.17
Dribble	1.80	2.39	2.09	0.46	0.58	0.52	1.26	1.02	1.14
P-Value (%)	99	99	99	99	99	99	99	46	99
BLSD (.05)									
Tillage X N-Rate	99	82	97	49	99	68	26	99	79
Tillage X Method	99	99	99	99	99	99	43	30	48
N-Rate X Method	99	97	99	99	99	99	99	92	99
Tillage X N-Rate X Method	99	99	99	99	93	99	70	48	69

Table 5. Continued

Treatments Tillage System	Grain 1984	1985	Ave.	Stover 1984	1985	Ave.	Total 1984	1985	Ave.
	N-Removal								
	#/A								
Factorial Arrangement (Excludes Controls)									
Tillage									
No Till	48.0	45.6	46.8	18.2	26.1	22.1	66.3	70.7	68.5
Ridge Till	65.6	64.2	64.9	20.3	30.3	25.3	85.9	94.6	90.2
Chisel	68.7	69.2	68.9	22.7	36.6	29.6	91.4	105.8	98.6
Moldboard	75.1	69.4	72.2	22.3	39.8	31.0	97.5	109.3	103.4
P-Value (%)	99	99	99	99	99	99	99	99	99
BLSD (.05)									
N-Rate									
75	36.2	32.8	34.5	12.9	20.1	16.5	49.2	53.0	51.1
150	58.0	66.7	62.3	19.2	33.6	26.4	77.2	100.3	88.7
300	98.9	86.1	92.5	30.5	46.0	38.2	129.4	132.1	130.7
P-Value (%)	99	99	99	99	99	99	99	99	99
BLSD (.05)									
Method									
Broadcast	49.1	57.9	53.5	16.7	30.8	23.7	65.8	88.8	77.3
Injected	79.7	66.2	72.9	25.7	35.5	30.6	105.5	101.8	103.6
Dribble	64.3	61.4	62.8	20.2	33.2	26.7	84.5	94.7	89.6
P-Value (%)	99	99	99	99	99	99	99	99	99
BLSD (.05)									
Tillage X Rate	97	99	94	80	99	98	93	99	92
Tillage X Method	99	96	99	99	99	99	99	99	99
N-Rate X Method	99	99	99	99	99	99	99	99	99
Tillage X N-Rate X Method	62	65	78	66	44	66	58	65	72

Table 6. Influence of nitrogen rates, tillage sytems and methods of 28% N application on grain yield and % dry matter of the grain on corn. Goodhue Co. MN - 1984 and 1985.

	Treatments		Grain Yields			Dry Matter Grain		
N-Rate	Tillage System	Method Applied	1984	1985	Ave.	1984	1985	Ave.
#/A			------Bu/A--------			----------%----------		
Control	No Till	--------	82.8	82.8*	82.8	60.8	60.0*	60.8
Control-Knife	No Till	---------	84.7	84.7*	84.7	61.0	61.0*	61.0
Control	Ridge Till	---------	70.8	66.6	68.7	65.0	55.0	60.0
Control-Knife	Ridge Till	---------	73.4	68.1	70.8	63.9	57.0	60.5
Control	Chisel	---------	91.3	66.3	78.8	66.1	54.0	60.1
Control-Knife	Chisel	---------	93.2	84.9	89.1	64.0	57.0	60.5
75	No Till	Broadcast	127.8	90.2	109.0	63.1	59.0	61.1
75	No Till	Injected	145.7	111.5	128.6	63.8	58.0	60.9
75	No Till	Dribble	140.9	82.5	111.7	63.2	57.0	60.1
75	Ridge Till	Broadcast	143.6	128.1	135.9	64.6	60.0	62.3
75	Ridge Till	Injected	152.4	135.1	143.8	63.6	60.0	61.8
75	Ridge Till	Dribble	145.9	124.2	135.1	65.1	59.0	62.1
75	Chisel	Broadcast	144.1	138.8	141.5	66.0	61.0	63.5
75	Chisel	Injected	148.9	133.8	141.4	65.9	60.0	63.0
75	Chisel	Dribble	140.8	135.2	138.0	65.8	60.0	63.0
150	No Till	Broadcast	148.2	108.6	128.4	63.1	59.0	61.1
150	No Till	Injected	154.4	122.6*	138.5	62.9	55.9*	59.4
150	No Till	Dribble	159.1	115.1	137.1	63.4	58.0	60.7
150	Ridge Till	Broadcast	154.6	139.1	146.9	64.8	59.0	61.9
150	Ridge Till	Injected	168.0	153.1	160.6	64.6	60.0	62.3
150	Ridge Till	Dribble	165.3	138.6	152.0	64.4	59.0	61.7
150	Chisel	Broadcast	164.0	145.2	154.6	64.8	62.0	63.4
150	Chisel	Injected	158.8	152.2	155.5	63.8	60.0	61.9
150	Chisel	Dribble	167.0	154.0	160.5	66.4	61.0	63.7
300	No Till	Broadcast	161.1	114.8	138.0	62.6	57.0	59.8
300	No Till	Injected	158.2	108.2	133.2	62.8	58.0	60.4
300	No Till	Dribble	151.1	109.4	130.3	62.9	57.0	60.0
300	Ridge Till	Broadcast	167.1	150.9	159.0	64.1	60.0	62.1
300	Ridge Till	Injected	158.8	149.0	153.9	64.1	61.0	62.6
300	Ridge Till	Dribble	169.0	148.4	158.7	66.7	61.0	63.9
300	Chisel	Broadcast	161.3	157.2	159.3	64.7	58.0	61.4
300	Chisel	Injected	165.7	134.6	150.2	64.6	59.0	61.8
300	Chisel	Dribble	165.1	157.1	161.1	65.9	60.0	63.0

* After the number means that sum of the 1985 plots were thrown out because of low plant population or weed problems. Then either the 1984 ave. was used or a value that would best fit that treatment was assigned to it.

Table 7. Influence of nitrogen rates, tillage sytems and methods of 28% N application on grain dry matter production on corn. Goodhue Co. MN - 1984 and 1985.

Treatments			Dry Matter Production								
	Tillage	Method	Grain			Stover			Total		
N-Rate	System	Applied	1984	1985	Ave.	1984	1985	Ave.	1984	1985	Ave.
#/A			T/A								
Control	No Till	---------	1.96	1.96*	1.96	1.85	1.85*	1.85	3.81	3.81*	3.81
Control-Knife	No Till	---------	2.00	2.00*	2.00	1.87	1.87*	1.87	3.88	3.88*	3.88
Control	Ridge Till	---------	1.67	1.58	1.63	1.59	1.33	1.46	3.26	2.91	3.09
Control-Knife	Ridge Till	---------	1.73	1.61	1.67	1.63	1.35	1.49	3.37	2.96	3.17
Control	Chisel	---------	2.16	1.57	1.87	1.61	1.77	1.69	3.77	3.34	3.56
Control-Knife	Chisel	---------	2.20	2.01	2.11	1.86	1.82	1.84	4.07	3.83	3.95
75	No Till	Broadcast	3.02	2.14	2.58	2.34	20.3	2.19	5.37	4.16	4.77
75	No Till	Injected	3.44	2.64	3.04	2.68	2.51	2.60	6.13	5.15	5.64
75	No Till	Dribble	3.33	1.95	2.64	2.65	1.97	2.31	5.98	3.92	4.95
75	Ridge Till	Broadcast	3.39	30.3	3.21	2.46	2.30	2.38	5.86	5.33	5.60
75	Ridge Till	Injected	3.60	3.20	3.40	2.78	2.64	2.71	6.39	5.84	6.12
75	Ridge Till	Dribble	3.45	2.94	3.20	2.65	2.21	2.43	6.11	5.15	5.63
75	Chisel	Broadcast	3.41	3.29	3.35	2.70	2.58	2.64	6.11	5.87	5.99
75	Chisel	Injected	3.52	3.17	3.35	2.80	2.83	2.82	6.33	5.99	6.16
75	Chisel	Dribble	3.33	3.20	3.27	2.69	2.47	2.58	6.02	5.67	5.85
150	No Till	Broadcast	3.50	2.57	3.04	2.93	2.29	2.61	6.43	4.86	5.65
150	No Till	Injected	3.65	2.69*	3.17	3.03	2.21*	2.62	6.68	4.90*	5.79
150	No Till	Dribble	3.76	2.72	3.24	2.98	2.36	2.67	6.74	5.08	5.91
150	Ridge Till	Broadcast	3.65	3.29	3.47	2.63	2.57	2.60	6.29	5.86	6.08
150	Ridge Till	Injected	3.97	3.62	3.80	3.16	2.82	2.99	7.13	6.44	6.79
150	Ridge Till	Dribble	3.91	3.28	3.60	2.87	2.52	2.70	6.78	5.80	6.29
150	Chisel	Broadcast	3.88	3.44	3.66	2.96	2.91	2.94	6.84	6.43	6.59
150	Chisel	Injected	3.75	3.60	3.68	30.2	3.12	3.07	6.78	6.72	6.75
150	Chisel	Dribble	3.95	3.65	3.80	3.19	2.93	3.06	7.14	6.58	6.86
300	No Till	Broadcast	3.81	2.72	3.27	3.08	3.04	3.06	6.89	5.76	6.33
300	No Till	Injected	3.74	2.56	3.15	3.08	2.68	2.88	6.82	5.24	6.03
300	No Till	Dribble	3.57	2.59	3.08	3.08	2.50	2.79	6.66	5.09	5.88
300	Ridge Till	Broadcast	3.95	3.57	3.76	2.97	2.79	2.88	6.92	6.36	6.64
300	Ridge Till	Injected	3.75	3.53	3.64	2.97	2.66	2.82	6.73	6.19	6.46
300	Ridge Till	Dribble	3.99	3.51	3.75	2.88	2.66	2.77	6.88	6.17	5.53
300	Chisel	Broadcast	3.81	3.72	3.77	3.23	3.07	3.15	7.05	6.79	6.92
300	Chisel	Injected	3.92	3.19	3.56	2.98	2.82	2.90	6.90	6.00	6.45
300	Chisel	Dribble	3.90	3.72	3.81	2.89	2.85	2.87	6.80	6.57	6.69

Table 6. Continued

Treatments Tillage System	Grain Yields 1984	1985	Ave.	Dry Matter Grain 1984	1985	Ave.
		Bu/A		---------%---------		
Factorial Arrangement (Excludes controls)						
Tillage						
No Till	149.7	107.0	128.3	63.1	44.8	53.9
Ridge Till	158.3	140.7	149.5	64.7	44.6	54.6
Chisel	157.3	145.3	151.3	65.3	44.6	54.9
P-Value (%)	99	99	99	98	92	97
BLSD (.05)	2.7			1.5		
N-Rate						
75	143.3	119.9	131.6	64.6	46.5	55.5
150	159.9	136.5	148.2	64.2	44.4	53.4
300	161.9	136.6	149.2	64.3	45.1	54.7
P-Value (%)	99	99	99	31	4	16
BLSD (.05)	6.6					
Method						
Broadcast	152.4	130.3	141.3	64.2	45.4	54.8
Injected	156.8	133.3	145.0	64.0	45.4	54.5
Dribble	156.0	129.4	142.7	64.9	45.1	55.0
P-Value (%)	84	67	82	99	39	76
BLSD (.05)				0.6		
Tillage X N-Rate	1	67	9	39	77	70
Tillage X Method	11	98	88	58	52	55
N-Rate X Method	85	99	99	56	93	97
Tillage X N-Rate X Method	71	14	22	73	26	52

Table 7. continued

Treatments Tillage System	Dry Matter Production Grain 1984	1985	Ave.	Stover 1984	1985	Ave.	Total 1984	1985	Ave.
	-------------------------				T/A				-------------------------
Factorial Arrangement (Excludes controls)									
Tillage									
No Till	3.54	2.50	3.02	2.87	2.39	2.63	6.41	4.75	5.58
Ridge Till	3.74	3.33	3.35	2.82	2.57	2.69	6.75	5.90	6.32
Chisel	3.72	3.43	3.57	2.94	2.84	2.89	6.66	6.28	6.47
P-Value (%)	99	99	99	56	99	99	89	99	99
BLSD (.05)	0.06								
N-Rate									
75	3.39	2.83	3.11	2.64	2.39	2.51	6.03	5.23	5.63
150	3.78	3.20	3.49	2.97	2.63	2.80	6.67	5.69	6.18
300	3.83	3.23	3.53	3.02	2.78	2.90	6.85	6.01	6.43
P-Value (%)	99	99	99	99	99	99	99	99	99
BLSD (.05)	0.16						0.23		
Method									
Broadcast	3.60	3.08	3.34	2.81	2.61	2.71	6.42	5.70	6.06
Injected	3.71	3.13	3.42	2.94	2.69	2.81	6.65	5.68	6.16
Dribble	3.69	3.06	3.37	2.88	2.49	2.68	6.57	5.55	6.06
P-Value (%)	99	49	72	84	99	99	94	65	65
BLSD (.05)									
Tillage X N-Rate	1	40	4	58	99	99	10	99	87
Tillage X Method	11	96	80	80	14	57	46	85	69
N-Rate X Method	85	99	99	96	99	99	94	99	99
Tillage X N-Rate X Method	71	47	39	32	52	28	37	99	96

Table 8 Influence of nitrogen rates, tillage systems and methods of 28% N application, on leaf stover and grain N concentration by corn. Goodhue Co. MN - 1984 and 1985.

	Treatments		N-Concentration								
	Tillage	Method	Leaf			Stover			Grain		
N-Rate	System	Applied	1984	1985	Ave.	1984	1985	Ave.	1984	1985	Ave.
#/A			--------------------	--------	--------	--------	%	--------	--------	--------	--------------------
Control	No Till	---------	1.91	1.60	1.76	0.52	0.58	0.55	1.12	1.14	1.16
Control-Knife	No Till	---------	1.93	1.57	1.75	0.44	0.61	0.53	1.11	1.08	1.08
Control	Ridge Till	---------	1.70	1.32	1.51	0.41	0.56	0.49	1.10	1.10	1.10
Control-Knife	Ridge Till	---------	1.79	1.27	1.53	0.40	0.56	0.48	1.06	1.11	1.09
Control	Chisel	---------	1.85	1.42	1.64	0.46	0.49	0.48	1.06	1.08	1.07
Control-Knife	Chisel	---------	1.90	1.43	1.67	0.47	0.54	0.51	1.05	1.09	1.07
75	No Till	Broadcast	2.67	2.22	2.45	0.69	0.74	0.72	1.24	1.08	1.16
75	No Till	Injected	2.93	2.79	2.86	0.67	0.78	0.73	1.29	1.20	1.25
75	No Till	Dribble	2.60	1.98	2.29	0.60	0.71	0.66	1.28	1.30	1.29
75	Ridge Till	Broadcast	2.53	2.21	2.37	0.61	0.63	0.62	1.15	1.38	1.27
75	Ridge Till	Injected	2.89	3.05	2.97	0.52	0.78	0.65	1.32	1.23	1.28
75	Ridge Till	Dribble	2.66	2.09	2.38	0.53	0.80	0.67	1.24	1.34	1.29
75	Chisel	Broadcast	2.69	2.04	2.37	0.54	0.60	0.57	1.26	1.30	1.28
75	Chisel	Injected	2.85	2.59	2.72	0.55	0.63	0.59	1.36	1.27	1.32
75	Chisel	Dribble	2.40	1.95	2.18	0.45	0.64	0.55	1.28	1.32	1.30
150	No Till	Broadcast	3.02	2.69	2.86	0.58	0.85	0.72	1.44	1.46	1.45
150	No Till	Injected	3.03	3.04	3.03	0.85	0.97	0.92	1.46	1.24	1.35
150	No Till	Dribble	3.01	2.44	2.73	0.82	0.97	0.90	1.40	1.13	1.27
150	Ridge Till	Broadcast	2.96	2.54	2.75	0.68	0.75	0.72	1.40	1.44	1.42
150	Ridge Till	Injected	2.98	3.21	3.10	0.77	0.95	0.86	1.37	1.49	1.43
150	Ridge Till	Dribble	2.84	2.59	2.72	0.56	0.85	0.71	1.27	1.43	1.35
150	Chisel	Broadcast	2.84	2.50	2.67	0.75	0.88	0.82	1.40	1.40	1.40
150	Chisel	Injected	2.83	3.06	2.95	0.67	0.86	0.77	1.46	1.38	1.42
150	Chisel	Dribble	2.61	2.44	2.53	0.68	0.74	0.71	1.43	1.37	1.40
300	No Till	Broadcast	3.10	3.17	3.14	0.79	1.09	0.94	1.46	1.48	1.47
300	No Till	Injected	3.17	2.91	3.04	0.76	1.14	0.95	1.51	1.43	1.47
300	No Till	Dribble	3.15	2.83	2.99	0.75	0.90	0.83	1.46	1.45	1.46
300	Ridge Till	Broadcast	2.98	3.00	2.99	0.77	0.91	0.84	1.42	1.44	1.43
300	Ridge Till	Injected	2.92	2.90	2.91	0.91	0.85	0.88	1.46	1.20	1.33
300	Ridge Till	Dribble	3.05	2.95	3.00	0.78	0.79	0.79	1.44	1.30	1.37
300	Chisel	Broadcast	3.08	3.04	3.06	0.80	0.89	0.85	1.43	1.59	1.51
300	Chisel	Injected	3.01	3.07	3.04	0.64	0.96	0.80	1.45	1.61	1.53
300	Chisel	Dribble	2.77	3.00	2.89	0.76	0.83	0.80	1.44	1.47	1.46

Table 9. Influence of nitrogen rates, tillage systems and methods of 28% N application, on grain and stover nitrogen removal by corn. Goodhue Co. MN - 1984 and 1985.

Treatments			N-Removal								
	Tillage	Method	Grain			Stover			Total		
N-Rate	System	Applied	1984	1985	Ave.	1984	1985	Ave	1984	1985	Ave.
#/A			#/A								
Control	No Till	---------	43.9	43.9*	43.9	19.3	19.3*	19.3	63.2	63.2*	63.2
Control-Knife	No Till	---------	44.8	44.8*	44.8	16.6	16.6*	16.6	61.4	61.4*	61.4
Control	Ridge Till	---------	37.1	34.8	35.9	13.0	14.9	13.9	50.2	49.8	50.0
Control-Knife	Ridge Till	---------	36.8	35.7	36.2	13.3	15.1	14.2	50.2	50.4	50.3
Control	Chisel	---------	45.9	33.9	39.9	14.9	17.3	16.1	60.9	56.0	58.4
Control-Knife	Chisel	---------	46.3	43.8	45.0	17.6	19.7	18.3	64.0	63.3	58.4
75	No Till	Broadcast	75.5	46.0	60.7	33.4	30.1	31.7	109.0	76.2	92.6
75	No Till	Injected	89.3	63.0	76.1	36.2	39.3	37.7	125.5	102.3	113.9
75	No Till	Dribble	85.6	51.3	68.4	32.2	27.9	30.0	117.8	79.3	98.0
75	Ridge Till	Broadcast	78.0	84.5	81.2	30.8	28.6	29.7	108.8	113.1	110.9
75	Ridge Till	Injected	95.0	78.0	86.5	29.1	41.0	30.5	124.1	119.1	121.6
75	Ridge Till	Dribble	86.1	79.0	82.5	28.5	35.5	32.0	114.7	114.5	114.6
75	Chisel	Broadcast	86.6	85.2	85.9	30.2	31.5	30.8	116.9	116.8	116.8
75	Chisel	Injected	96.2	81.2	88.7	31.1	35.6	33.3	127.3	116.9	122.1
75	Chisel	Dribble	86.0	85.0	85.5	24.2	31.4	27.8	110.2	116.5	113.3
150	No Till	Broadcast	100.8	74.7	87.7	34.1	38.9	36.5	134.9	113.7	124.3
150	No Till	Injected	106.5	67.1*	86.8	51.2	42.9*	47.0	157.8	109.9*	133.8
150	No Till	Dribble	105.1	61.6	83.3	48.5	45.9	47.2	153.7	107.5	130.6
150	Ridge Till	Broadcast	103.0	94.9	98.9	36.0	38.5	37.2	139.0	133.4	136.2
150	Ridge Till	Injected	109.5	108.4	108.9	48.7	53.2	50.9	158.3	161.6	159.9
150	Ridge Till	Dribble	99.7	93.8	96.7	32.6	42.7	37.6	132.4	136.6	134.5
150	Chisel	Broadcast	108.9	95.6	102.2	45.3	51.3	48.3	154.2	147.0	150.6
150	Chisel	Injected	109.8	98.8	104.3	40.7	54.2	47.4	150.6	153.1	151.8
150	Chisel	Dribble	113.6	99.8	106.7	43.8	43.8	43.8	157.4	143.7	150.5
300	No Till	Broadcast	111.8	79.9	95.8	49.0	65.8	57.4	160.8	145.8	153.3
300	No Till	Injected	113.1	73.0	93.0	47.3	60.7	54.0	160.4	133.8	147.1
300	No Till	Dribble	104.4	74.5	89.4	46.9	44.9	47.2	151.3	119.5	135.4
300	Ridge Till	Broadcast	112.2	102.9	107.5	46.0	50.9	48.4	158.3	153.8	156.0
300	Ridge Till	Injected	110.2	84.7	97.4	54.7	45.6	50.1	165.0	130.4	147.7
300	Ridge Till	Dribble	115.3	92.1	103.7	45.5	41.7	43.6	160.9	133.8	147.3
300	Chisel	Broadcast	109.5	118.7	114.1	51.9	54.8	53.3	161.4	173.6	167.5
300	Chisel	Injected	114.0	102.5	108.2	38.4	53.6	46.0	152.5	156.2	154.3
300	Chisel	Dribble	113.1	109.2	111.1	44.1	47.0	45.5	157.3	156.2	156.7

Table 8. Continued

Treatments Tillage System	N-Concentration Leaf 1984	1985	Ave	Stover 1984	1985	Ave.	Grain 1984	1985	Ave.
	---------------------	-----	-----	-----	%	-----	-----	-----	-----
Factorial Arrangement (Excludes controls)									
Tillage									
No Till	2.96	2.67	2.81	0.72	0.90	0.81	1.39	1.31	1.35
Ridge Till	2.87	2.72	2.79	0.68	0.81	0.74	1.34	1.36	1.35
Chisel	2.78	2.63	2.70	0.65	0.78	0.71	1.39	1.41	1.40
P-Value (%)	96	32	82	62	99	97	96	99	99
BLSD (.05)							0.04		
N-Rate									
75	2.69	2.32	2.50	0.57	0.70	0.63	1.27	1.27	1.27
150	2.90	2.72	2.81	0.71	0.86	0.78	1.40	1.37	1.38
300	3.02	2.98	3.00	0.77	0.92	0.84	1.45	1.44	1.44
P-Value (%)	99	99	99	99	99	99	99	99	99
BLSD (.05)							0.04		
Method									
Broadcast	2.87	2.59	2.73	0.69	0.81	0.75	1.35	1.39	1.37
Injected	2.95	2.95	2.95	0.70	0.88	0.79	1.41	1.34	1.37
Dribble	2.79	2.47	2.63	0.66	0.80	0.73	1.36	1.34	1.35
P-Value (%)	99	99	99	80	99	99	99	88	60
BLSD (.05)							0.04		
Tillage X N-Rate	39	65	48	71	96	46	54	99	98
Tillage X Method	98	65	61	93	39	82	8	32	15
N-Rate X Method	99	99	99	78	92	87	82	95	98
Tillage X N-Rate X Method	15	6	6	98	73	96	40	99	85

Table 9. continued

Treatments Tillage System	N-Removal Grain 1984	1985	Ave.	Stover 1984	1985	ave.	Total 1984	1985	Ave.
	---------------------	-----	-----	-----	#/A	-----	-----	-----	-----
Factorial Arrangement (Excludes controls)									
Tillage									
No Till	99.1	65.7	82.4	42.1	44.1	43.1	141.2	109.8	125.5
Ridge Till	101.0	90.9	95.9	39.1	42.0	40.5	140.2	132.9	136.5
Chisel	104.2	97.4	100.8	38.8	44.8	41.8	143.1	142.2	142.6
P-Value (%)	98	99	99	39	50	48	22	99	99
BLSD (.05)	3.2								
N-Rate									
75	86.5	72.6	79.5	30.6	33.4	32.0	117.1	106.1	111.6
150	106.3	88.3	97.3	42.3	45.7	44.0	148.7	134.1	141.4
300	111.5	93.1	102.3	47.1	51.7	49.4	158.7	144.8	151.7
P-Value (%)	99	99	99	99	99	99	99	99	99
BLSD (.05)	5.5			4.1			8.3		
Method									
Broadcast	98.5	86.9	92.7	39.6	43.4	41.5	138.1	130.4	134.2
Injected	104.8	84.1	94.4	41.9	47.4	44.6	146.8	131.5	139.1
Dribble	101.0	82.9	91.9	38.5	40.1	39.3	139.5	123.1	131.3
P-Value (%)	99	77	67	84	99	99	99	97	99
BLSD (.05)	3.8						6.3		
Tillage X N-Rate	11	89	15	47	99	80	28	99	34
Tillage X Method	1	41	28	98	39	88	74	25	61
N-Rate X Method	87	97	97	83	99	99	71	99	99
Tillage X N-Rate X Method	65	82	63	84	77	77	60	70	54

CORN TILLAGE RESIDUE MANAGEMENT, LANCASTER, 1985

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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 Fayett-Dubuque, Seaton, and associated soils, are highly erodible, form dense crust 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 them to be more effectively incorporated into the overall farming systems of the region.

Experimental Procedures

The experimental site is located on the Lancaster Experimental Farm. Four tillage treatments are replicated four times (Table 1), the first replicate is located on Palsgrove silt loam; the other three replicates are located on Rozetta silt loam. Each treatment is split into normal and mulched subtreatments. On the no-till (slot plant) plots an additional subtreatment (bare) is established by removing all residue prior to planting; the residue is then placed on the adjacent mulched plots of the same tillage treatment. On mulched subtreatments of the moldboard, chisel and paraplow treatments, corn residue additions are made after tillage but before planting to obtain approximately 60 to 80 percent surface cover. Plots are approximately 90 to 100 feet in width and 80 feet in length. Row width was 36 inches in 1985. In 1984 corn (Pioneer 3747) was planted (at 29,000 seeds/acre) on April 25. The conventional (moldboard) treatment was plowed about April 22 and secondary tillage with a disk was done on April 23 on the conventional and chisel treatments. The fall chisel and paraplow treatments were carried out in early November of 1984. All plots were planted with a 4-row John Deere 7000 Max-Emerge planter equipped with fluted coulters on one side and "trash whipunits" on the other side which removed residue from an 8 to 9 inch area over the row.

Nitrogen (250 lb/AC as 28% solution) was applied on April 15 prior to spring tillage. The starter fertilizer at planting was 200 lbs of 6-24-24. The insecticide was counter at 10 lb/ac. Preemergence chemical weed control was Bladex at 2 1/2 qts/ac and Dual at 2 pints/ac applied May 2. On May 20 Banvel was applied at 1 pint/ac (post emergence).

Percent cover was determined from slides made on May 21. Planting depth, rate of emergence, silking date and soil moisture and bulk density measurements were made on designated portions of each plot. Hourly spring soil temperatures, leaf number, soil moisture and bulk density were measured on chisel, paraplow, and no-till treatments in Rep 3 for mulch added and bare or normal treatments. Soil temperature was measured at depths of 1, 5, 10, 15, 50, and 100 cm. Yields were determined by hand harvesting 60 foot samples (two 30-ft subsamples) from each plot in mid-October, 1985.

Ten plot frames (45 3/4 x 45 3/4 inches) were implaced soon after planting before the surface was weathered by rainfall. Infiltration measurements were made on paraplow mulch, no-till bare and mulch, and conventional normal and mulch treatments. Random roughness was measured before and after each run. Residue amounts were measured on each treatment. Tensiometer measurements were made during infiltration runs on conventional and no-till bare treatments.

Results - Corn Yields

In 1985, water stress, due to drought prior to and during pollenation, reduced corn yields; only 1.59 inches of precipitation occurred between May 28 and July 25, a period of 57 days. Total precipitation for June, July, and August was only 6.77 inches with approximately 1/2 that occurring in August (Table 2). Corn yields of individual tillage, residue and in-row residue management treatments were significantly different at the 2.5 percent level (Table 1). Yields of the two highest yielding treatments, paraplow mulch (TW) and conventional normal (C), were significantly greater than the two lowest yielding treatments no till bare (C) and (TW). Average corn yields of the four replicates were significantly different at the 1 percent level; as in 1983 and 1984 average corn yield increased as average depth of rooting increased (Table 3). Depth of rooting was measured as the depth to red clay residuum. In 1985 rep average corn yields increased 12.1 bu/ac as average depth increased from 28 to 62 inches. In 1984 and 1983 the comparable yield increases were approximately 13 and 38 bu/ac respectively. In 1981 and 1982 when water stress was minimal there was no relationship between depth to clay layer and average yield per rep. Thus the effect of rooting depth and available water holding capacity in the root zone on yield depends greatly on the climatic conditions in the individual year as well as the crop grown.

Seedbed Conditions

Average planting depth and the standard deviation of the planting depth both were significantly different. Paraplow and no-till treatments planted with trash whip attachments (TW) had a greater planting depth than those planted with the fluted coulter (C). Similarly the standard deviation was less for no-till treatments planted with the trash whip unit compared to the same treatment planted with the coulter unit. The trash whip unit was adjusted for no-till and paraplow conditions and consequently ran excessively deep in the looser soil conditions of the moldboard and chisel treatment.

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

Eq. 1: % cover TW = -3.2 + 0.50 (% cover C)

explained 89% of the variation in % cover of the TW treatments for 1984 and 1985. Percent in-row cover was closely related to grain moisture and air GDD summed to 6-leaf:

Eq. 2: % Grain moisture = 20.5 + 1.97 X 10^{-2} (% in-row cover); R^2 = 0.87

Eq. 3: Air GDD (planting to 6-leaf) = 273 + 0.47 (% in-row cover); R^2 = 0.91

Thus the effect of increasing amounts of in-row cover was to delay phenologic development. Two measures of this delay were the increased number of air GDD required to reach 6-leaf stage and increased grain moisture at harvest. In-row cover was related to population at harvest by the equation:

Eq. 4: Harvest population = 25890-29. (% cover in-row); R^2 = 0.54

In both 1984 and 1985 the trash whip units significantly increased final population compared to the coulter units on the no-till and paraplow treatments. The average increase was approximately 1200 plants/acre.

For each tillage treatment the effect of mulch treatment (C) was to increase the number of days post plant required to reach 95% emergence, to delay the data that 50% plants silked, and to increase average grain moisture. Decreases in population were significant only on the chisel and moldboard treatments (Tables 1 and 4).

The effect of in-row surface residue cover and tillage on soil temperature and on corn growth was evaluated at Lancaster in 1983, 1984, and 1985. Hourly soil temperatures were recorded for 1, 5, 10, 15, 50, and 100 cm depths under the row on the chisel normal and mulch, no-till bare and mulch and the paraplow normal and mulch treatments in 1984 and 1985. Soil temperatures were measured on paraplow and no-till mulch treatments. Soil temperatures were measured using 4-couples in parallel for 15 cm and shallower depths. Leaf stage observations were taken periodically. Eq. 3 was developed using leaf stage observations and station air temperature measurements; the results agree closely with our previous research results.

Large differences in "final" (50 to 60 minute average) infiltration rates were measured between treatments (Tables 5 and 6). All mulch treatments tested had greater "final" infiltration rates than the bare treatments except for moldboard mulch treatment (E) which had a "final" infiltration rate of only 0.52 inches/hour. Based on tensiometer and infiltration rate measurements the conductivity of the 6 to 12 inch depth on this treatment was between 0.1 to 0.2 inches/hour; the tensiometer measurements showed a positive pressure head at the 6-inch depth indicating ponding of water within the plow layer. This is the first positive evidence obtained on these plots of the presence of a flow restricting layer below normal plowing depth; other circumstantial evidence is the consistently high infiltration rates measured with mulch treatments & tillage below the plow layer (no-till mulch in 1983, Table 6) and paraplow mulch in 1984 and 1985).

Final infiltration rates for 1981-1985 are given in Table 6. The ratio of (bare/mulch) infiltration rates for the conventional treatment was 0.65 which is within the range previously measured; the infiltration rate of over 3 inches/hour for the no-till mulch treatment is much higher than previous measurements except for 1983 following distrubance by spring injection of anhydrous ammonium

The implication is that the no-till mulch treatment had no major flow restricting layer in contrast to the no-till bare where a conductivity of 0.2 inches/hour was measured for the surface 0-2 inch layer. These results again illustrate the requirement of 1) a porous surface layer with high saturated conductivity, 2) a protective mulch cover, 3) absence of any flow restricting layer within the depth involved in infiltration. Residue cover by itself is not sufficient to produce a high infiltration rate when significant restrictions to flow occur within the infiltrating profile.

Summary

Five and seven year results with continuous corn at Lancaster show nearly equal yields from conventional, chisel and ridge-till treatments; no-till (slot plant) yields were slightly lower in some years (Table 7).

To evaluate tillage-residue management practices, a simple tillage-management model was developed which quantifies the effects of the major physical factors of planting date, final plant population, net growing degree days (GDD), and estimated water stress. GDD are included only when below a threshold value required to mature the crop. The net GDD are calculated as the cumulative air temperature GDD from planting to frost minus any residue management caused delay in growth up to the 6-leaf stage. Lancaster data from 1972 through 1983 was used to develop the model, which has an R^2 of 82 percent and a standard error of approximately 12 bu/acre. For the years of 1982-83 the model accounted for 89 percent of the variation with a standard error of 10 bu/ac. The major effect of tillage on yield was through the effect of tillage on seedbed conditions and water management. Seedbed conditions were affected by seed-soil contact and depth and accuracy of seed placement which affect final plant population as well as in-row residue cover which strongly affects the rate of phenological development of corn up to the 6-leaf stage. The between row surface residue cover and soil conditions strongly affect water infiltration and runoff from the soil surface. Staricka, J.A. 1985. Tillage-crop management models for corn production in southeast Minnesota. M.S. Thesis, Univ. of MN.

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 the conventional moldboard plow tillage method.

Table 1. Effect of tillage and mulch treatments on percent cover, planting depth, emergence, silking date, population and grain yield - 1985 Lancaster.

Treatments: Tillage	Treatments: Residue	In Row Residue Mtg.	Percent Cover: In-Row	Percent Cover: Entire Area	Planting Depth: Ave mm	Planting Depth: S.D. mm	Days Post Plant To 95% Emergence	Date 50% Plants Silked July	Ave. Pop. At Harvest Plants/Ac	Ave. Grain Yield Bu/Ac	Ave. Grain Moisture %
Paraplow	Normal (N)	C	35	45	21	7.3	18.5	16.5	24,400 abcd	124.8 abcd	21.1 cde
		TW	11	33	27	7.3			25,800 abd	125.8 abc	20.9 de
	Mulch (1X+N)	C	88	86	24	6.3	22.5	18.3	23,000 d	124.3 abcd	22.1 ab
		TW	37	60	25	6.6			25,500 abc	136.7 a	22.0 abc
No Till	Bare (0)	C	8	13	23	6.2	16<	15.8	24,600 abcd	115.3 cd	20.6 de
		TW			28	5.8			23,900 bcd	110.2 d	20.3 e
	Normal (1X)	C	55	72	22	5.1	19	16.8	24,100 bcd	119.9 bcd	21.4 bcd
		TW	26	40	25	4.8			26,400 ab	126.8 abc	21.1 cde
	Mulch (2X)	C	89	92	23	7.4	21.	18.5	23,800 cd	121.0 bcd	22.2 ab
		TW	50	71	26	4.1			25,800 abc	127.7 abc	21.4 bcd
Fall	Normal (N)	C	6	9	25	6.7	16<	15.8	27,000 a	125.2 abc	20.6 de
Chisel	Mulch (1X+N)	C	89	88	28	7.0	22.	18.0	22,500 d	119.9 bcd	22.0 abc
Conv.	Normal (0)	C	1	2	26	4.6	16<	15.5	25,800 abc	133.3 ab	20.2 e
(Sp. Plow)	Mulch (1X)	C	93	89	22	7.3	24.5	17.8	22.800 d	129.2 abc	22.5 a
Significance Level					0.05	0.05			0.01	0.025	0.01

Table 2. 1985 Weather Summary, Lancaster Experiment Station.

Month	Precipitation inches Total	Departure	Growing degree days °F 1985	Departure	Temperature Avg. Max	Avg. Min	Avg.	Depart
					F			
April	1.90	-1.25	---	---	62.7	40.5	51.6	+4.9
May	4.95	+1.42	366	+67	72.7	49.3	61.0	+3.2
June	1.32	-3.23	434	-79	75.2	52.6	63.9	-3.0
July	2.11	-2.18	637	-19	84.2	58.3	71.2	-0.1
August	3.34	-1.08	504	-90	77.5	55.0	66.2	-2.7
Sept.	6.89	3.34	381	+27	69.6	52.6	61.1	+0.2
October	2.94	+0.51	---	---	58.6	39.3	48.9	-1.6
Sum April thru Oct.	23.45	-2.47	2322	-94				

First Fall Low Temperatures
Sept. 28 (32 °F)
Oct. 16 (28 °F)

Table 3. Average yields and depth to clay residuum by replicate and precipitation for 1981, thru 1985, 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*
1984	107.3	110.4	118.C	120.1	3.92	7.77	2.57**	1.37**
1985	118.5	121.1	129.6	130.6	4.95	1.32***	2.11***	3.34***
Avg. depth to clay residuum in inches	29	41	46	62				

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

Table 4. Influence of tillage method and residue management on rate of emergence.

Treatment Tillage	Residue	Days Post Plant 16	19	23	26
		-----------Percent of final emergence---------			
Paraplow	Normal	89	97	100	100
	Mulch	51	82	97	100
No Till	Bare	99	100	100	100
	Normal	85	96	100	100
	Mulch	56	90	100	100
Chisel	Normal	100	100	100	100
	Mulch	64	87	99	100
Conventional Moldboard	Normal	100	100	100	100
	Mulch	63	75	91	100

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

Tillage	Treatment Residue	1981	1982	1983	1984	1985	Ave.
		--------------inches/hour----------------					
No Till	Mulch	1.46	1.10	3.53*	0.60	3.02	(1.55)+
	[No Till Mulch / Conv. Bare]	[1.51]	[0.72]	[6.53]	[0.35]	[2.16]	(1.11)+
No Till	Bare	--	--	--	1.68	1.00	
Conventional	Bare	0.97	1.52	0.54	1.70	1.40	1.23
	Mulch	2.72	2.34	1.49	2.90	2.14**	2.32
	(Bare/Mulch)	(0.36)	(0.65)	(0.36)	(0.58)	(0.65)	(0.53)

* Soil disturbed prior to planting by anhydrous ammonia injection.
** 1-observation only.
+ Omit 1983

Table 7. Continuous corn tillage yield results to Lancaster, WI 1979-1985

Tillage	1979	1980	1981	1982	1983	1984	1985	1979-83	1979-85
	----------------------------Bu/Ac------------------------------								
Ridge Plant	162	157	157	147	100	---	---	145	---
Slot Plant	163	146	151	141	85	108	120	137	131
Chisel	160	150	167	154	95	115	125	145	138
Conventional	169	159	168	151	89	121	133	147	141
Paraplow	---	---	---	---	---	106	125	---	---

Table 5. 1985 Lancaster Infiltration rate measurement.

Tillage	Residue		Application rate in one hour inches	Water applied before runoff inches	Infiltration rate X minutes after runoff commences - in/hour											
					2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5
No Till	Bare	E	5.28	0.40	3.14	1.44	1.68	1.92	1.56	1.32	0.72	1.44	1.20	0.96	0.72	1.20
		W	5.36	0.40	2.96	1.04	1.52	1.28	2.00	1.68	0.80	1.68	1.04	1.27	1.04	1.04
	Mulch	E	5.28	0.44	3.12	2.88	2.64	3.36	3.12	2.64	3.12	3.36	3.36	3.60	3.36	3.84
		W	4.96	0.50	1.12	2.08	2.56	3.04	2.32	2.80	2.56	2.56	2.56	2.32	2.56	---
Conventional (Moldboard Plow)	N	E	4.88	1.06	0.08*	1.04*	2.00	2.00	2.00	2.00	1.78	1.28	1.52	1.28	1.52	---
		W	4.88	1.14	2.00	2.48	2.48	1.76	2.12	2.12	1.40	1.28	1.16	1.28	1.52	---
	Mulch	E	4.96	0.50	2.56	1.60	0.88	0.16	0.88	0.40	0.88	1.12	0.64	0.64	0.64	0.40
		W	4.72	1.18	3.76	1.24	1.48	---	---	---	---	1.24	2.20	2.20	2.08	---
Paraplow	Mulch	E	4.88	0.94	4.52	4.28	3.92	3.20	3.20	2.96	3.68	3.56	3.08	3.20	3.44	3.20
		W	4.72	0.45	4.60	4.48	3.88	4.00	3.76	3.28	3.28	3.28	3.52	3.28	3.16	2.92

*Data Questionable:

The Effect of Tillage and Potassium Placement on the Availability of Potassium to Corn

Pat Burford, John Moncrief, James Swan, and Brian Schrieber
Cooperator: Dale Flueger

Farmers are looking for ways to reduce production inputs. Because of this there is increased interest in conservation tillage, and along with this the need for more information on fertilizer requirements for crops grown with reduced tillage systems. Therefore, the objectives of this study are:

1. To determine the effects of tillage on K availability to corn.
2. To determine the effects of row applied K and tillage on availability and growth of corn over a range of soil test K levels resulting from broadcast K 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.

This study was initiated in 1982, but only 1985 results will be discussed, with the exception of soil test K, in which case results from 1983, and 1984 will also be presented.

METHODS AND MATERIALS

The experimental site is located on approximately three and one third acres of land in Sec. 15 of Haycreek Township of Goodhue County, Minnesota on a deep loess soil over limestone. The soil is a Typic Eutrochrept (Timula silt loam) with initial soil test ranges of 20.7 $\pm$ 5.3 ppm phosphorus (Bray-1), and 83.0 $\pm$ 18.1 ppm potassium (ammonium acetate extraction). Initial pH was 6.5 $\pm$ 0.5 with about 2.5 percent organic matter. Three T/ac of limestone were applied in 1980.

Oats and alfalfa were grown at the site in 1978, followed by two years of alfalfa. Corn as silage was grown in 1981 and corn for grain from 1982 to 1985. A 95 day single cross hybrid (Pioneer 3906) was planted at a rate of 29,900 plants/ac at a row spacing of 38 inches.

Equipment used consisted of: a chisel plow (Glencoe Soil Saver) with chisels 3.5 inches wide and spaced 13.3 inches apart with twisted shovels, a field cultivator (Bushog), and a planter (Hinicker) equipped with 2 inch fluted coulters. Planting and tillage dates are given in Table 1. Pest control at the study site is given in Table 2.

Table 1. Dates of planting and tillage.

Activity	Date
Planting	18 May 1985
Chisel plowing	11 May 1985
Soil Finisher	16 May 1985

Table 2. Insect and weed control used in 1985.

Pesticide	Rate of a.i. Applied
Terbufos (Counter)	1.3 lb/ac
Atrazine	2.5 lb/ac
Alachlor (Lasso)	2.5 lb/ac
Bucktril[1] (Bromoxynil)	.38 lb/ac

1. Applied post emergence for control of lambsquarter.

This study was designed as a randomized complete block with six replications. Tillage treatments used were, spring chisel plowing (7-9 inches deep) followed by a field cultivator and no-till. Broadcast K applications were made in the spring prior to tillage. Potassium was applied in the row at planting (0-0-7.3) every other row to determine the effects of row applied K on early growth and yield. Nitrogen and phosphorus were also applied (7-21-0) to all rows. The placement depth of these row applied fertilizers was 1 to 2 inches with no-till and 3 to 4 inches with chisel plowing. The date and application rates of the fertilizer treatments are given in Table 3. The actual application rate of K_2O in the two row applied fertilizers is in Table 4. Potassium present in the 7-21-0 was due to contamination in the fertilizer. Nitrogen as ammonium nitrate was applied to the entire plot area at a rate of 300 lb/ac to ensure that N was non limiting to crop growth.

Table 3. Fertilizer treatment application schedule.

Fertilizer Type	Date Applied	Method	Rate Applied
Potassium Chloride (KCl)	30 April 1985	Broadcast	0, 200 and 400 lb K_2O/ac
ammonium polyphosphate+ urea (7-21-0)	18 May 1985	Row	20 gal/ac (18 lb N ac, 53 lb P_2O_5/ac)
Potassium Chloride (0-0-7.3)	18 May 1985	Row	15 gal/ac (11.0 lb K_2O/ac)

Table 4. K applied in the row.

0-0-7.3 K_2O	7-21-0 K_2O
----lb/ac----	
11.0	.05

Ten core composite soil samples were taken, for the 0 to 6, and 6 to 12 inch depths. Ten core composite soil samples were also taken for the 0 to 2, 2 to 4, and 4 to 6 inch depths. Soil samples were taken in this way in 1983, 1984, and 1985 before broadcast K applications and tillage, and after broadcast K applications and tillage. Soil sampling dates are given in Table 5. All soil samples were dried at 99° C, and ground to pass a .08 inch sieve.

Table 5. Dates of soil sampling.

	------Date of Sample------ 1983	1984	1985
Prior to broadcast K applications and tillage	26 April	10 April	30 April
After broadcast K applications and tillage	16 June	2 July	11 July

Whole plant samples were taken at approximately the 6-10 leaf stage of development. Plants were cut at ground level (10 plants/plot) on 1 July 1985. Grain and stover samples were taken at harvest (4 November 1985). All plant samples were dried at 140° F and ground to pass a .04 inch sieve.

The K levels in the soil tested were determined using ammonium acetate extraction (Carson, 1980). Statistical analysis was done using the Statistical Package for the Social Sciences (Norusis, 1986). Residue was measured by the line intersect method (Laflen et al., 1981).

RESULTS AND DISCUSSION

The effects of tillage on soil cover are shown in Table 6. In the row, no-till resulted in approximately four times the level of soil cover as chisel plowing, and between the row no-till had approximately three times the soil cover of chisel plowing. Within tillage treatments soil cover was slightly greater between the row than in the row. Variability of the soil cover is due to variability of stover distribution by the combine.

Table 6. The effect of tillage on soil cover in and between the row on 1 July 1985. [1] In and between the row are defined as the 20 cm area centered over the row and the remainder,respectively.

Tillage	In Row[1]	Between Row[1]
	-----------%-------------	
No-till	55.9 (15.42)[2]	65.1 (12.56)
Chisel	13.0 (6.44)	22.9 (9.75)

[2] Values in parenthesis represent the standard deviations, N=18.

Weather conditions at the study site are summarized in Table 7 and Figure 1. Precipitation was very limited throughout May, June and July in 1985. There was a total of 1.59 inches of rain from May 23 to 4 July. July was also dry with a total rainfall of 2 inches, 1.4 of which fell on 24 July. With an average temperature of 68.4 C in July, and little moisture, pollination may have been affected.

Table 7. Monthly growing degree days and average temperatures[1]

Month	Growing Degree Days (base 50/86-°F)	Average Temp.(°F)
May	769	56.5
June	783	58.1
July	1129	68.4
August	877	60.3
September	646	53.6
October	241	39.6

[1]Data is from the Rosemount, MN weather station which is approximately 40 miles from the experimental site.

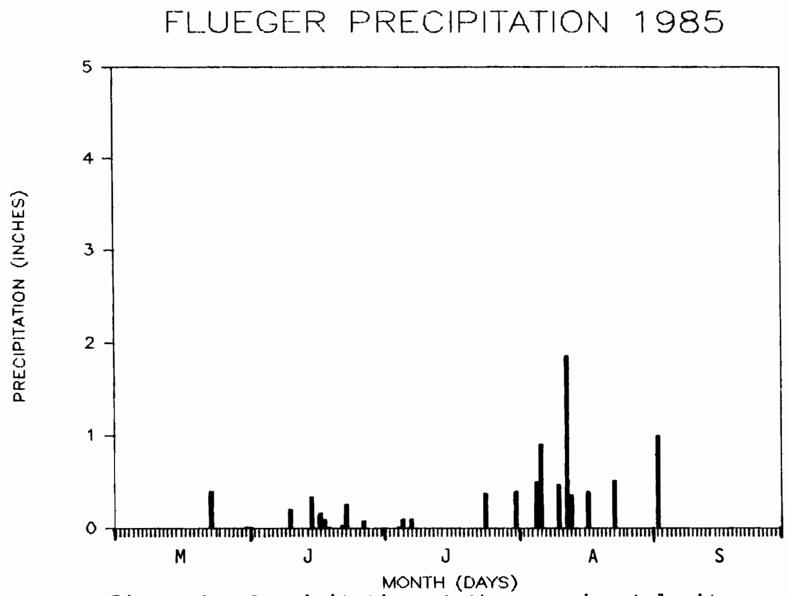

Figure 1. Precipitation at the experimental site during the 1985 growing season.

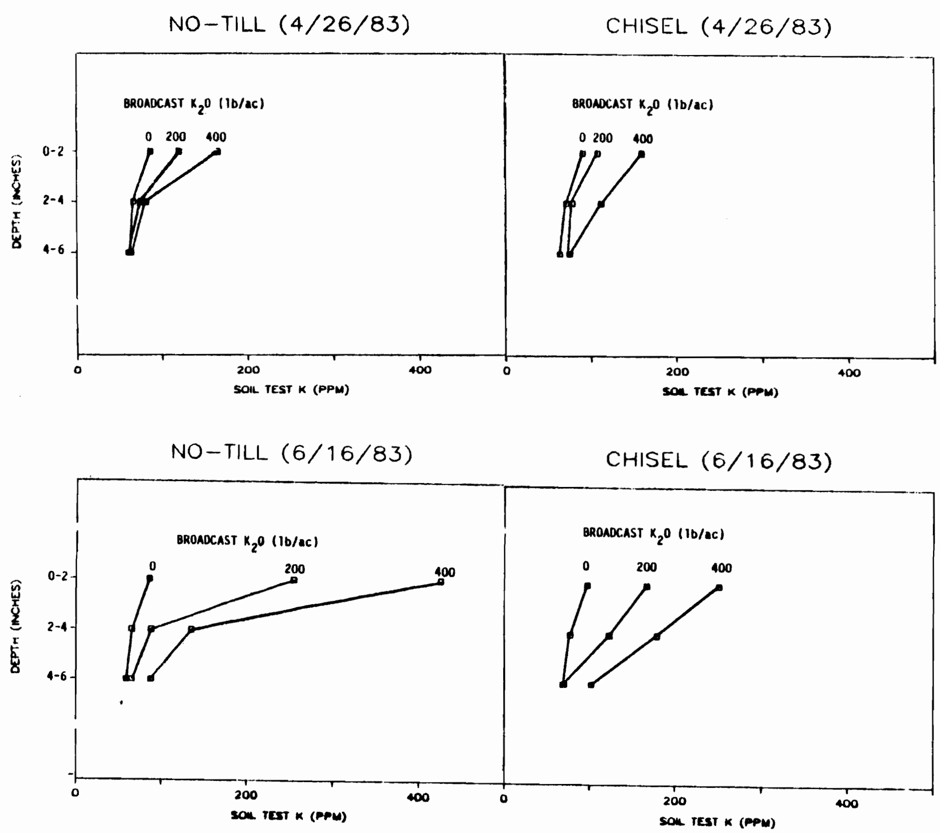

Figure 2. The effect of tillage on the distribution of soil test K before (4/26/83), and after (6/16/83) broadcast K applications, and tillage.

Tables 8 and 9 show the effects of tillage on soil moisture on 30 April 1985 and 11 July 1985, respectively. Analysis of variance was used to determine treatment differences (Table 10). Tillage significantly affected soil moisture on 30 April in the 0 to 2, and 0 to 6 inch depths with no-till having greater soil moisture than chisel plowing. The 11 July samples were significantly affected by tillage at all depths. It was much drier on 11 July than on 30 April because of the low levels of rainfall which occurred prior to sampling (only .43 inches of rain from 23 May to the July sampling date compared to spring snow thaw). The greater soil moisture with no-till than chisel plowing can be attributed to the greater soil cover with no-till than chisel plowing.

Table 8. The effect of tillage and depth on soil moisture on 4/30/85.

Depth of Sample (Inches)	Tillage	Soil Moisture (% by Wt.) mean	standard deviation
0 to 2	No-till	23.1	(2.73)
	Chisel	20.0	(3.86)
2 to 4	No-till	22.4	(1.52)
	Chisel	21.8	(1.93)
4 to 6	No-till	22.7	(1.56)
	Chisel	22.6	(2.52)
6 to 12	No-till	22.7	(.80)
	Chisel	22.2	(1.19)
0 to 6	No-till	22.9	(2.04)
	Chisel	21.6	(2.39)

Table 9. The effect of tillage and depth on soil moisture on 7/11/85.

Depth of Sample (inches)	Tillage	Soil Moisture -(% by wt)- mean	standard deviation
0 to 2	No-till	13.5	(2.34)
	Chisel	11.1	(1.16)
2 to 4	No-till	16.0	(.65)
	Chisel	15.4	(1.23)
4 to 6	No-till	16.6	(.68)
	Chisel	15.2	(1.26)
6 to 12	No-till	16.4	(1.03)
	Chisel	14.5	(3.12)
0 to 6	No-till	14.9	(.81)
	Chisel	14.0	(1.0)

Table 10. Significance of tillage effects on soil moisture.

Depth	Date of soil 4/30/85	Sampling 7/11/85
(Inches)	-Significance	level-
0 to 2	.008	.000
2 to 4	.358	.082
4 to 6	.876	.000
6 to 12	.124	.021
0 to 6	.081	.005

Figures 2,3, and 4 show the distribution of soil test K to a depth of 6 inches before and after broadcast K applications and tillage for 1983, 1984, and 1985, respectively. Tables 11, and 12 show the soil test k levels in the 0 to 6 and 6 to 12 inch depths, respectively. Analysis of variance was done to determine treatment differences, the results of which can be found in Table 13, 14, 15, 16, and 17 for the 0 to 2, 2 to 4, 4 to 6, 0 to 6 and 6 to 12 inch depth increments respectively.

There were no significant effects due to tillage on the distribution of soil test K on 26 April 1983. The rate of K affected soil test K levels to a depth of 4 inches at this time, indicating little movement or mixing (with chisel plowing) of K below this depth at this time. The 16 June 1983 (51 days after broadcast K applications) samples showed significant tillage affects in the 0 to 2, 2-4, and 4-6 inch depths. This significant tillage effect which occurred was due to the gradient of K which developed after the broadcast K applications with no-till having the steeper gradient of the two tillage treatments. No-till resulted in greater soil K in the 0 to 2 inch depth than chisel plowing. Chisel plowing resulted in greater soil K from 2 to 6 inches than the no-till treatment. The tillage by K rate interaction which existed at this time in the 0 to 2 inch depth was the result of differing tillage effects on soil test K levels with different K applications (check treatment soil test K levels were similar between tillage treatments).

In 1984 similar results to 1983 occurred, with soil K levels prior to broadcast K applications and tillage (10 April 1984) being generally unaffected by tillage (with the exception of the 0 to 2 inch depth). The rate of broadcast K significantly affected the soil K levels at all but the 6 to 12 inch depth. Eighty-three days after broadcast K applications and tillage (2 July 1983) a steep gradient in soil K was still present. Tillage affected the soil K levels significantly in the 0 to 2, and 4 to 6 inch depth. No-till resulted in greater soil K in the 0 to 2 inch depth than chisel plowing. Chisel plowing resulted in greater soil K in the 4 to 6 inch depth than no-till. It is likely that there was movement of K to the 2 to 4 inch depth, since tillage did not affect soil K levels at this time. Again rate of broadcast K significantly affected soil K levels at all but the 6 to 12 inch depth. There was again a tillage by K rate interaction in 1984.

In 1985 prior to broadcast K applications and tillage (30 April 1985) movement of K deeper in the soil profile was evident. As in 1983 there were no significant tillage effects at any depth other than the 0 to 2 inch depth. No-till had greater soil test K than the chisel plow treatment. It is interesting to note the K rate effect even in the 6 to 12 inch depth at this time indicating that at the 400 lb K_2O/ac rate of broadcast K, soil K at this depth was greater than at the 0 rate. The K rate effected soil K levels significantly at all depths at this time, indicating movement of K in the soil profile even to the 6 to 12 inch depth. Soil K levels taken 72 days after broadcast K applications (11 July 1985) were significantly affected by tillage in the 0 to 2. No-till again had greater soil K than chisel plowing in the 0 to 2 inch depth. Rate of broadcast K affected the

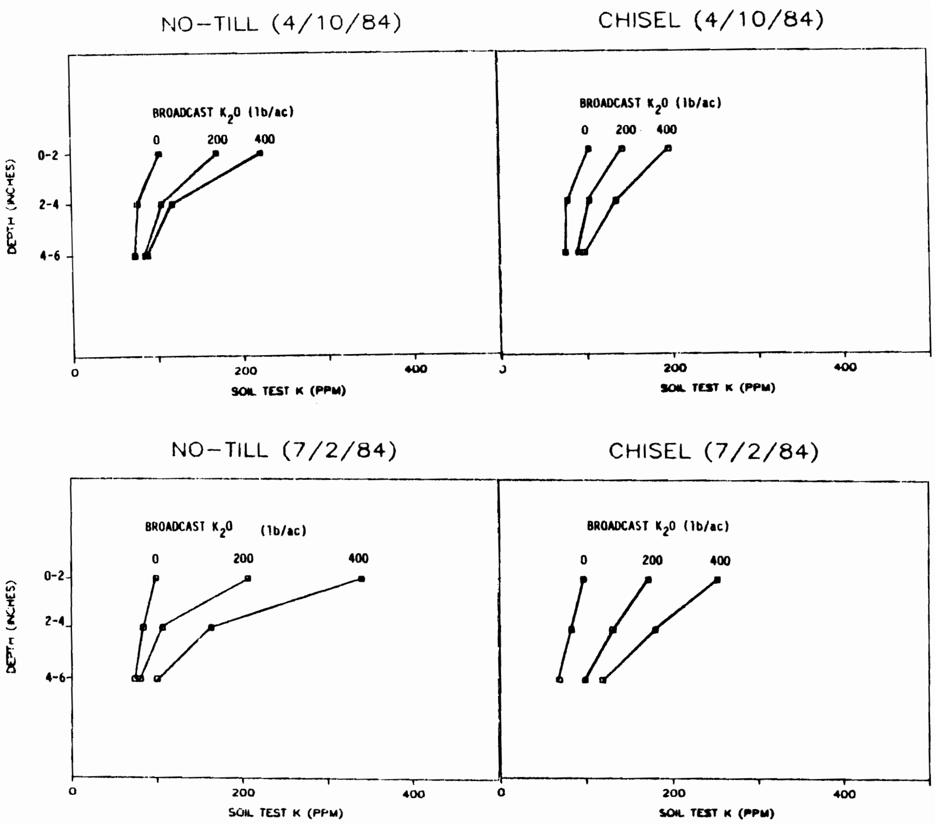

Figure 3. The effect of tillage on the distribution of soil test K before (4/10/84) and after (7/2/84) broadcast K applications, and tillage.

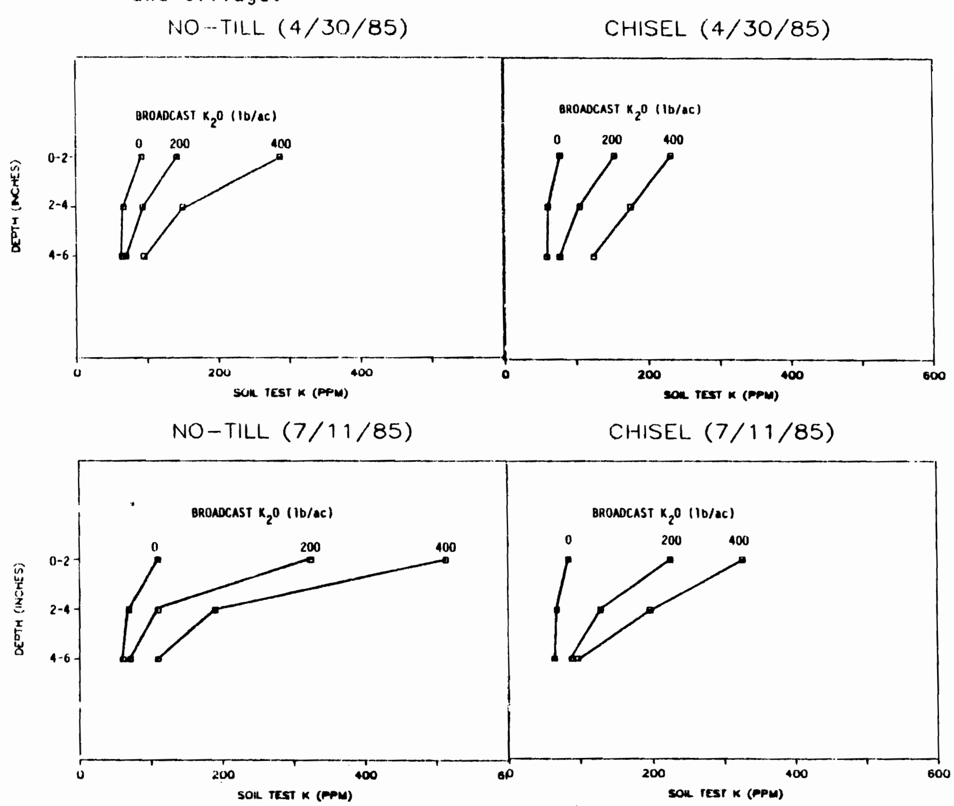

Figure 4. The effect of tillage on the distribution of soil test K before (4/30/85), and after (7/11/85) broadcast K applications, and tillage.

soil K levels in all depths. The tillage by K rate interaction in the 0 to 2 inch depth is due to the check treatment. The significant effects of replication and interactions with replication reflect, in part, the field's slope, which caused soil conditions to vary.

Analysis of variance done on the 0 to 6 inch soil test K levels showed that tillage was not a factor affecting the total amount of extractable soil K in this depth except on the 11 July 1985 sampling date. This may be a reflection of the dry soil conditions in the 1985 growing season which would slow the reactions in the soil. The greater concentration of soil K in the 0 to 2 inch depth with the no-till treatment is reflected in the higher 0 to 6 inch soil tests.

Table 11. The effect of tillage and applied K on soil test K in the 0 to 6 inch depth from 1983 to 1985.

Date of soil sample	NO-TILL			CHISEL		
	Rate of Broadcast K_2O applied annually (lb/ac)					
	0	200	400	0	200	400
	Soil Test K ppm					
4/26/83	70.5 (12.7)[1]	84.5 (16.4)	101.7 (11.0)	68.5 (15.3)	75.8 (18.8)	111.8 (29.8)
6/16/83	65.2 (13.8)	124.5 (29.1)	175.5 (6.2)	72.0 (18.0)	111.5 (30.9)	152.7 (36.3)
4/10/84	81.2 (11.1)	112.7 (21.8)	140.2 (30.9)	83.7 (12.4)	102.2 (25.3)	138.0 (28.7)
7/2/84	81.8 (13.0)	127.8 (13.6)	173.7 (40.4)	79.8 (10.0)	131.7 (18.6)	174.5 (36.3)
4/30/85	73.5 (10.6)	112.5 (11.0)	176.0 (35.2)	69.5 (12.9)	100.3 (33.0)	183.7 (39.3)
7/11/85	78.2 (12.5)	158.3 (14.9)	266.0 (56.2)	71.5 (10.9)	142.5 (30.6)	204.3 (42.9)

[1] Values in parenthesis represent the standard deviations, N=6.

Table 12. The effect of tillage and applied K on soil test in the 6 to 12 inch depth from 1983 to 1985.

Date of Soil Sample	NO-TILL			CHISEL		
	Rate of broadcast K_2O applied annually (lb/ac)					
	0	200	400	0	200	400
	Soil Test K ppm					
4/26/83	54.0 (19.6)[1]	60.9 (23.1)	55.8 (17.6)	55.8 (10.0)	53.5 (16.0)	59.5 (22.2)
6/16/83	54.7 (22.5)	62.6 (22.8)	58.2 (6.2)	54.8 (12.4)	55.3 (15.2)	59.5 (24.8)
4/10/84	70.2 (14.5)	72.8 (26.1)	74.2 (8.1)	72.5 (12.1)	78.0 (10.0)	72.7 (22.9)
7/2/84	76.8 (13.8)	81.0 (17.3)	82.7 (15.4)	80.3 (14.9)	87.0 (18.4)	82.3 (19.7)
4/30/85	62.3 (13.8)	72.7 (24.7)	71.8 (8.1)	61.0 (12.3)	68.3 (11.6)	75.7 (9.5)
7/11/85	58.8 (16.7)	78.2 (18.0)	91.5 (7.2)	63.2 (13.0)	67.7 (12.9)	71.5 (21.0)

[1] Values in parenthesis represent the standard deviations, N=6.

Table 13. Analysis of variance results for soil test K in the 0 to 2 inch depth from 1983 to 1984.

	4/26/83	6/16/83	4/10/84	7/2/84	4/30/85	7/11/85
Main[1] Effects						
Tillage	.683	.002	.099	.007	.043	.000
K rate	.000	.000	.000	.000	.000	.000
Rep	.008	.647	.163	.175	.039	.104
Interactions						
T x K	.267	.009	.207	.047	.329	.017
T x R	.094	.527	.083	.235	.371	.662
K x R	.337	.988	.903	.838	.236	.619

[1]Main effects are defined as follows: Tillage (T) is no-till and chisel plowing, K rate (K) is the broadcast K treatment of 0, 200, and 400 lb/ac of K_2O, and rep (R) is the six replications in the study.

Table 14. Analysis of variance results for soil test K in the 2 to 4 inch depth from 1983 to 1984.

	4/26/83	6/16/83	4/10/84	7/2/84	4/30/85	7/11/85
Main [1] Effects						
Tillage	.135	.016	.285	.236	.381	.536
K rate	.020	.000	.000	.000	.000	.000
Rep	.188	.088	.008	.186	.298	.074
Interactions						
T x K	.188	.506	.230	.700	.440	.938
T x R	.290	.845	.073	.055	.166	.228
K x R	.637	.933	.510	.794	.631	.504

[1]Main effects are defined as follows: Tillage (T) is no-till and chisel plowing, K rate (K) is the broadcast K treatment of 0, 200, and 400 lb/ac of K_2O, and rep (R) is the six replications in the study.

Table 15. Analysis of variance results for soil test K in the 4 to 6 inch depth from 1983 to 1984.

	4/26/83	6/16/83	4/10/84	7/2/84	4/30/85	7/11/85
Main[1] Effects						
Tillage	.160	.013	.158	.101	.310	.974
K rate	.659	.000	.008	.001	.001	.002
Rep	.024	.001	.024	.670	.205	.024
Interactions						
T x K	.637	.228	.419	.250	.252	.499
T x R	.812	.125	.302	.613	.500	.478
K x R	.232	.175	.168	.834	.842	.600

[1]Main effects are defined as follows: Tillage (T) is no-till and chisel plowing, K rate (K) is the broadcast K treatment of 0, 200, and 400 lb/ac of K_2O, and rep (R) is the six replications in the study.

Table 16. Analysis of variance results for soil test K in the 0 to 6 inch depth from 1983 to 1984.

	4/26/83	6/16/83	4/10/84	7/2/84	4/30/85	7/11/85
Main[1] Effects						
Tillage	.951	.220	.613	.867	.794	.012
K rate	.000	.000	.001	.000	.000	.000
Rep	.001	.013	.117	.896	.228	.299
Interactions						
T x K	.180	.377	.747	.978	.848	.207
T x R	.102	.182	.302	.271	.311	.110
K x R	.813	.820	.966	.999	.825	.838

[1]Main effects are defined as follows: Tillage (T) is no-till and chisel plowing, K rate (K) is the broadcast K treatment of 0, 200, and 400 lb/ac of K_2O, and rep (R) is the six replications in the study.

Table 17. Analysis of variance results for soil test K in the 6 to 12 inch depth from 1983 to 1984.

	4/26/83	6/16/83	4/10/84	7/2/84	4/30/85	7/11/85
Main[1] Effects						
Tillage	.983	.833	.718	.678	.619	.097
K rate	.902	.789	.805	.755	.065	.017
Rep	.059	.010	.038	.323	.011	.044
Interactions						
T x K	.841	.846	.952	.925	.684	.176
T x R	.937	.734	.737	.865	.759	.833
K x R	.567	.977	.690	.894	.545	.869

[1]Main effects are defined as follows: Tillage (T) is no-till and chisel plowing, K rate (K) is the broadcast K treatment of 0, 200, and 400 lb/ac of K_2O, and rep (R) is the six replications in the study.

Figure 5 shows the effects of tillage, soil test K levels and row applied K on the early growth of corn on 1 July 1985. Non significant regressions are accompanied by NS. Table 18 gives the regression equations used to calculate the lines which represent the least squares fit of the data. Early growth was not affected significantly by soil test K levels with the no-till treatment. With the chisel plow treatment soil test K affected early growth significantly when row applied K was not used. Early growth at high and low soil K levels was suppressed. Row applied K increased the variability in early growth and eliminated significance with soil K. The chisel plow treatment resulted in greater early growth than the no-till plants. This is due to the temperature effects of soil cover (Gupta et al. 1984). Cooler soil temperatures with the no-till treatment slowed emergence, and early growth.

Figure 6 shows the responses of grain yields to soil test K levels, row applied K and tillage. The lines represent the least squares fit of the data. Regression equations can be found in Table 19. Grain yields were significantly affected by soil test K levels. Row applied K increased yields approximately 30 bu/ac with the chisel plow treatment at a soil test K level of 70 ppm of K. With the no-till treatment the response to row applied K at this soil test was about 10 bu/ac. This may be the result of the depth the row applied K was applied (1 to 2 inches with no-till compared to 3 to 4 inches with chisel plowing) since, the soil moisture (Table 9) was greater with chisel plowing in the 2 to 4 inch depth than with no-till in the 0 to 2 inch depth, the row applied K may have been more available for corn utilization.

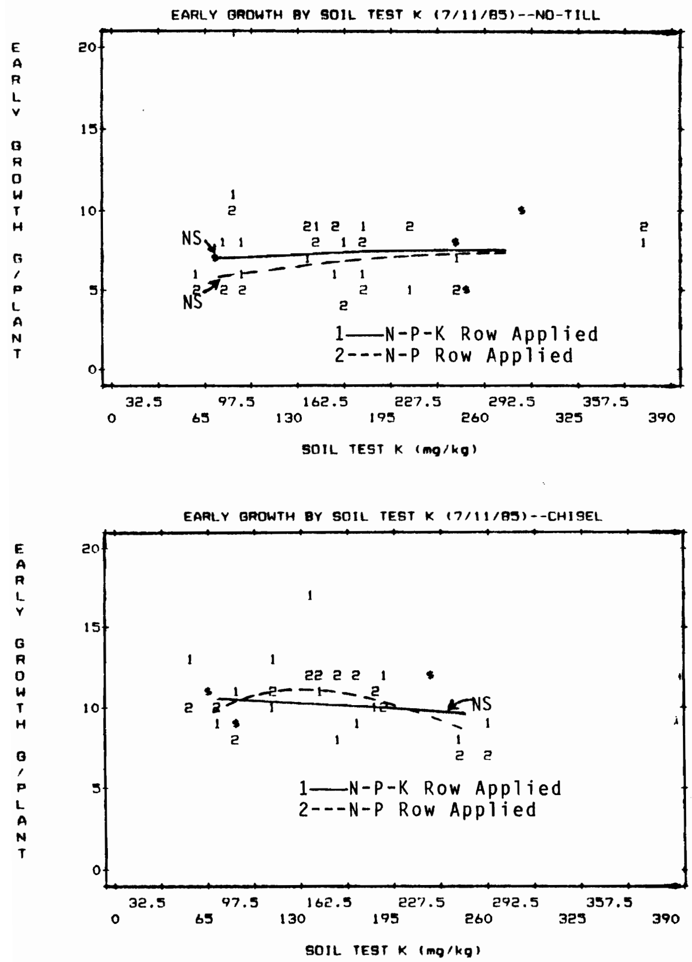

Figure 5. The effect of tillage, row applied K, and soil test K on early growth (7/1/85).

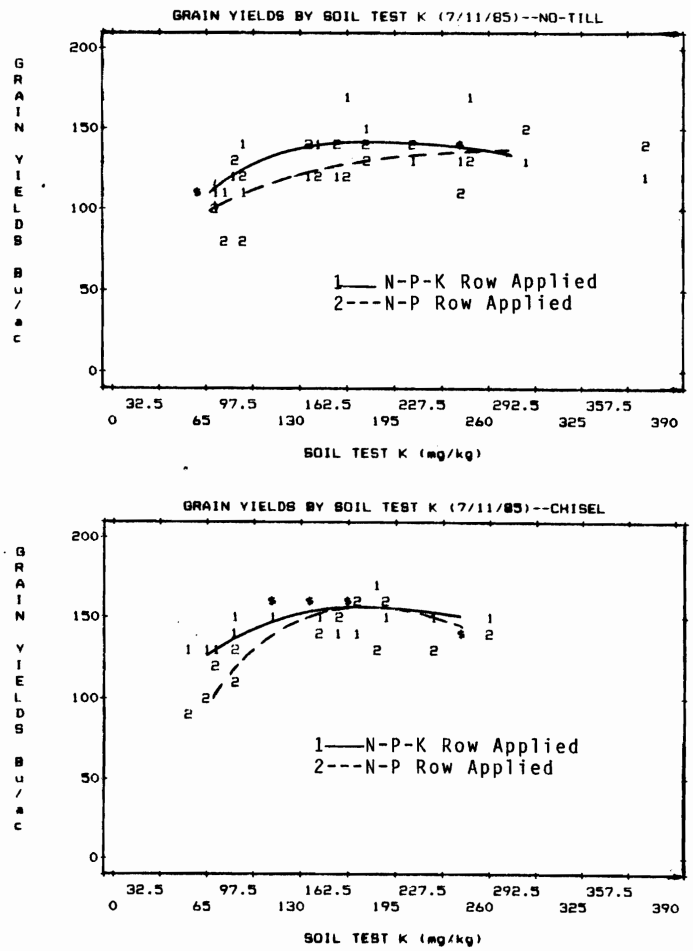

Figure 6. The effect of tillage, row applied K, and soil test K on grain yields.

Table 18. Coefficients of equations used to describe the response of early growth to soil test K levels.

Equation used: $Y=e^a K^b$
Y = Early Growth (g/plant)
K = Soil test K (ppm)

Row Applied Fertilizer	Equation exponents		R^2	p	Stn. Error of Est.
No-till	a	b			
N-P	.94178	.19098	.107	.19	.305
N-P-K	1.8046	.03653	.009	.71	.215
Chisel					
N-P	-8.4988	(4.6193 - .48797)	.316	.07	.161
N-P-K	2.6642	-.06870	.029	.52	.201

Table 19. Coefficients of equations used to describe the response of grain yields to soil test K levels.

Equation used: $Y=e^a K^b$
Y = grain yields (Bu/ac)
K = Soil test K (ppm)

Row Applied Fertilizer	Equation exponents		R^2	p	Stn. Error of Est.
No-till	a	b			
N-P	1.3591	(1.1818 - .09727 lnK)	.432	.01	.122
N-P-K	-2.0579	(2.6953 - .25880 lnK)	.531	.00	.010
Chisel					
N-P	-9.50615	(5.7084 - .56024 lnK)	.747	.00	.015
N-P-K	-.38059	(2.1482 - .21308 lnK)	.614	.00	.003

Summary

There was four, and three times the soil cover with no-till than chisel plowing in and between the row, respectively.

Soil moisture was greater with no-till in the surface 2 inches than chisel plowing on 4/30/85. On 7/11/85 soil moisture was greater with no-till than chisel plowing at all depths down to 12 inches. The late season sample was preceded by dry weather conditions.

The distribution of soil K was affected significantly by tillage, and rate of broadcast K applications. No-till had significantly greater soil test K than chisel plowing in the 0 to 2 inch depth all three years of this study after broadcast K applications and tillage. The chisel plow treatment had greater soil test K than the no-till treatment in the 2 to 4 and 4 to 6 inch depths after broadcast K applications in 1983. In 1984 there was significantly greater soil K with chisel plowing in the 4 to 6 inch depth. After broadcast K applications in 1985 the only significant tillage effect was in the 0 to 2 inch depth, indicating movement of K even in the no-till treatment to the 6 inch depth.

Chisel plowing had greater early growth than no-till. This is due to cooler spring temperatures with no-till than chisel plowing caused by greater soil cover. Row applied K did not significantly affect early growth.

Grain yields responded significantly to soil test K levels, and to row applied K up to approximately 150 ppm of soil K. Corn grown with chisel plowing responded to row applied K (11 lbs/ac) by increased grain yields of 30 bu/ac at a 70 ppm soil test K. At this soil test the response was 10 bu/ac with no tillage.

CONSERVATION TILLAGE DEMONSTRATION IN SE MINNESOTA-1985

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Conservation tillage (as an opportunity to check erosion and reduce production inputs) continues to be adopted by innovative farmers. According to the 1984 survey by the SCS there is about 20% of the corn, soybeans and small grain grown with conservation tillage (CTIC, 1984). What is needed are site specific recommendations which offer a relatively low risk approach under local conditions. In an effort to help disseminate research findings and fine tune them to local conditions a series of statewide tillage demonstrations are being established. In 1985 this effort was focused in southeastern Minnesota primarily due to the lack of Experiment Station data for these soils and the erosive nature of the soil in this area. Following is a summary of some of the findings for the 1985 growing season.

Stand

Although there were several exceptions, for the most part corn planted "no till" after corn resulted in substantial stand reductions. Conversely if other tillage strategies with this crop sequence or corn following low residue crops was opted for there were no stand problems. It appears that the following three causal factors were responsible: 1.) poor seed to soil contact due to residue pushed into the seed furrow during planting, followed by dry conditions; 2.) possible germination inhibition due to crop residue exudates (alleopathy) and; 3.) cutworm activity at some sites. The stand reduction associated with the "no till" approach (the only in row tillage was done by a fluted coulter) is rare on these well drained soils in this part of the state. Two of the four sites with corn grown after corn (for grain) had substantial stand reduction with this treatment (data only shown for the Dodge county site in table 13). More favorable rains eliminated this problem at the other two sites. To eliminate this risk, it is advisable to use clearing discs or sweeps to keep the row area clean when planting corn in heavy corn residue.

When corn was planted after soybeans there was no effect of tillage on stand. This is shown in tables 6, 9, and 18 for Fillmore, Steele, and Wabasha counties respectively.

Primary tillage and cultivation

At the Fillmore County site half the plots were cultivated (16 rows, 100ft. long). Researchers in Ohio and Indiana have shown an advantage to cultivation on silt loam soils. The soil at this site is a Tama, silt loam. Benefits from cultivation on these soils are due to: 1.) weed control; 2.) improved infiltration and retarded runoff from roughness and; 3.) improved aeration (after crusting conditions are present followed wet period). The effect of cultivation and tillage on corn yields and weed pressure are shown in tables 3 and 4 respectively.

There were significant main effects and an interaction of tillage and cultivation on grain yields at this site. The moldboard and no till treatments resulted in a significant cultivation response. There was no effect of cultivation on yields with chisel plowing or discing. Weed pressure generally decreased with less primary tillage and in the presence of cultivation although the interaction was not significant with this variable. The dominant weed at this site was velvet leaf followed by giant foxtail. The response to cultivation was likely due to a combination of weed control and improved water infiltration under no till and moldboard conditions with the latter factor being the dominant influence. This is supported by the lack of response with the chisel treatment although weed pressure differences due cultivation were similar.

Cultivation but not primary tillage had a small but significant effect on grain moisture at Fillmore County (table 7.). No one has offered a plausible hypothesis for this at this time.

The effect of tillage on corn grain yields for Steel and Wabasha was similar (tables 9. and 19 respectively.). There was no effect of tillage strategy on corn yields at these two sites. Soils at these sites were a Le Sueur, clay loam and Fayette, silt loam respectively. Corn was grown following soybeans. At Dodge County there was a large difference in grain yield due to tillage favoring the moldboard plow treatment (table 13.). The soil at this site is a Skyberg, silt loam. This soil formed in a thin mantle of silt loam cap over dense glacial till which serves to create poor internal drainage. The crop sequence at this site is continuous corn. These three sites illustrate the importance of the interaction of soil texture, drainage, and level of crop residue. It is important to realize that this is an establishment year for Steele and Dodge Counties so the ridge till and no till treatments are the same with the exception of a ridging operation.

Lodging

The effect of tillage (both primary and cultivation) affected corn lodging at the Fillmore but not the Steele County site (tables 5. and 10. respectively). Even though lodging due to severe winds was as high as 63% (Fillmore County) it did not result in harvest losses and was not correlated to grain yields.

Cutworm and Rootworm Activity

Tillage was related to cutworm activity (table 1.) for Fillmore, Wabasha, and Steele Counties (all corn after soybeans). The cutworm activity at Fillmore and Wabasha counties resulted in an application of an insecticide. It was not deemed necessary (economic threshold was not reached) to treat the corn at the Steele, or Dodge, County sites. Even though tillage had a significant effect on cut plants at sites where corn followed soybeans it did not relate to final plant population. At Fillmore County there was no effect of tillage on final stand (table 6.). At the Steele County site there was an effect of tillage on final stand but it was not the same earlier trend on cut plants (table 9.). Tillage strategies that resulted in more residue had more cut plants early. Final stands were lower with the moldboard plow treatment.

Dodge County had plots split with insecticide source treatments (Counter, Furadan, and Lorsban). This site had corn planted after corn. The results of this comparison is shown in table 14. Insecticide source approached significance (.115) with corn yields favoring the Furadan but did not effect grain moisture or final stand. The increased effectiveness of Furadan over the other two insecticides at this site is probably the result of the dry conditions favoring it's higher mobility.

Soybeans

The effects of tillage and weed control strategy on soybean yields at the Wabasha county site is shown in table 20. The major weed at this site was lambsquarter. A burndown of 2,4-D ester (.5 lbs/A) plus Poast (.19 lbs/A) was used on the post emergence treatment. The preemergence treatment was preceded by an application of Roundup (2 lbs/A).

There is significant main effects and a tillage by herbicide interaction. Herbicide option is of little consequence with a ridge till system due to the weed control provided by cultivation with this treatment. There is a sizeable advantage with the narrow rows (8 inches) over the 38 inch rows with the ridge till treatment, however. The lower yields with the post emerge treatment under the subsoil and no till treatment is due to giant foxtail pressure. Lambsquarter exerted the most pressure with the chisel plow treatment. Since this tillage treatment received a spring field cultivation it did not receive the burndown. The field cultivation was not completely effective in controlling emerged lambsquarter.

This is the reason for the lower yield with the preemerge treatment with this tillage strategy. It's obvious that under 1985 conditions if weeds are controlled there is a sizeable advantage to 8 inch rows over 38.

Cutworms

Table 1. The effect of tillage and previous crop on cutworm damage to corn in southeast MN., 1985.

Tillage	Cut corn plants			
	Steele1	Fillmore1	Wabasha1	Dodge2
	%			
No till	1.33ab	7.83a	2.33a	.33a
Ridge till	1.73a	----	1.92a	.11a
Spring Disc	----	2.37b	----	----
Subsoil	0.00c	----	1.58ab	----
Chisel	0.00c	1.23b	0.58b	----
Moldboard	0.27bc	1.30b	----	0.00a
Significance3	.01	.01	.07	.26

1. Preceding crop was soybeans.
2. Preceding crop was corn.
3. Means followed by the same letters within a column are not statistically different (Duncans Multiple Range Test - .05). The significance values at the bottom of each column are the result of an analysis of variance.

Fillmore County

Table 2. Cultural practices at Fillmore County, MN., 1985.

Soil Type Tama silt loam (Typic Argiudoll)

Soil Test 11/15/84 pH - 6.6 P - 69 lbs/A K - 416 lbs/A

Fertilizer
Nitrogen - 110 lbs N/A as anhydrous ammonia on 5/22/85
Starter - 125 lbs/A of 16-41-8 (2"x2" placement)

Tillage - All plots were split with a cultivation treatment (conventional cultivator) on 6/10/85.

No till
Spring Disc on 5/6/85
Spring Chisel on 4/19/85
Spring Moldboard on 4/19/85

Planted on 5/6/85 with a John Deere Maximerge 4 row (38") planter equipped with John Deere row cleaners at 28,300 plants/A. Soybeans were the previous crop.

Corn hybrid - Pioneer 3732

Weed Control - Cyanazine (Bladex) at 2 lbs/A + Alachlor (Lasso) at 2 lbs/A preemerge on 5/13/85. A post emergence application of Dicamba (Banvel) at 1/3 pt/A on 5/18/85.

Insecticide - Ambush was applied to control cutworms on 6/12/85.

Harvested on 10/15/85 with a four row combine.

Table 3. The effect of tillage and cultivation on grain yields at Fillmore County, 1985.

	Cultivation (.004)[1]			
	yes		no	
Tillage(.001)[1]	Mean	Standard Deviation	Mean	Standard Deviation
	Bu/a			
No till	168	6.0	158	8.4
Disc	175	7.8	171	7.0
Chisel	171	5.3	174	4.9
Moldboard	177	4.8	170	3.9

1. the number in parenthesis following the treatment is the level of significance (the tillage x cultivation interaction is .021).

Table 4. The effect of tillage and cultivation on weed pressure at Fillmore County on July 23, 1985.

	Cultivation (.003)[1]	
Tillage (.009)[1]	Yes	No
No till	1.0	2.7
Disc	1.0	1.7
Chisel	1.7	3.3
Moldboard	1.7	3.3

1. The number in parenthesis following the treatment is the level of significance.

Table 5. The effect of tillage and cultivation on percent lodging at Fillmore County, September 14, 1985.

	Cultivation (.025)[1]	
Tillage (.005)[1]	Yes	No
	%	
No till	10.0	3.3
Disc	20.0	6.7
Chisel	45.0	30.0
Moldboard	63.0	33.3

1. The number in parenthesis following the treatment is the level of significance.

Table 6. The effect of tillage on plant population at Fillmore County, May 21, 1985.

Tillage	Mean	Standard Deviation
	plants/a x 10^3	
No till	25.7	1.5
Disc	26.3	1.4
Chisel	26.5	1.4
Moldboard	26.0	1.4
Significance	NS (.745)	

Table 7. The effect of tillage on grain moisture at Fillmore County, 1985.

Tillage (.207)	Cultivation (.067)1	
	Yes	No
No till	30.9	30.9
Disc	30.9	30.6
Chisel	30.9	29.7
Moldboard	30.6	30.2

1. The number in parenthesis following the treatment is the level of significance.

Steele County

Table 8. Cultural practices at Steele county, MN., 1985.

Soil type   Le Seuer clay loam 2-4% slope Aquic Argiudoll (well tiled)

Soil test 9/25/84   pH - 6.4 P - 46 lbs/A K - 208 lbs/A

Fertilizer
- Nitrogen - 134 lbs N/A as anhydrous ammonia on 5/30/84
- Starter fertilizer - 10 gal/A of 7-21-7 (with the seed)
- Potassium - 150 lbs K_2O/A as KCl fall applied

Tillage - all plots were cultivated on 6/6/84

No till		
Ridge till	6/21/85	ridges formed
Chisel	10/25/84	field cultivated on 4/29/85
Moldboard	10/25/84	" " " "
Sub soil	10/25/84	" " " "

Minimum till plow bottom was used (12" deep)

Planted on 4/29/85 with a conventional John Deere Maximerge 8 row (30") planter at 28,000 plants/A. The previous crop was soybeans.

Corn Hybrid - Pioneer 3737

Weed Control - Alachlor (Lasso) at 4 lbs/A + Cyanazine (Bladex) at 2 lbs/A preemerge. All plots were cultivated on 6/6/85.
Excellent weed control was obtained in all tillage systems.

Harvested - 10/17/85 with a 4 row combine

Table 9. The effect of tillage on grain yields at Steele County, 1985.

Tillage	Yield Bu/a	% Moisture	Plant Population plants/acre x 10^3
No till	162	25.1	27.0
Ridge till	167	25.2	27.2
Chisel	167	24.7	28.8
Moldboard	169	25.7	24.5
Sub Soil	171	25.7	27.0
Significance	NS (.604)	NS (.622)	(.091)

Table 10. The effect of tillage on percent lodged plants at Steele County, October 12, 1985.

Tillage	%
No till	5
Ridge till	22
Chisel	23
Moldboard	22
Sub Soil	27
Significance	NS (.601)

Table 11. The effect of tillage on soil cover and emergence at Steele County, 1985.

Tillage	% Cover April 30	May 10 Emerged Plants/a x 10^3
No till	48.3	23.5
Ridge till	45.3	24.8
Chisel	5.0	19.7
Moldboard	0.0	21.5
Sub Soil	1.7	19.2
Significance	(.000)	NS(.175)

Dodge County

Table 12. Cultural practices for Dodge County, MN., 1985.

Soil type Skyberg silt loam (Udollic Ochraqualf)

Soil test pH - 5.9 P - 38 lbs/A K - 342 lbs/A
11/16/84

Fertilizer
Nitrogen - 170 lbs/A as anhydrous ammonia spring preplant
Starter - 8 gal/A of 7-21-7 (with the seed)

Tillage - All plots were cultivated on 6/4/85
No till
Ridge till 6/24/85 ridged formed
Fall Moldboard field cultivation on 5/2/85

Planted on 5/3/85 with a Series one Hiniker conservation tillage planter 6 row (30") at 31,000 plants/A. The previous crop was corn.

Corn Hybrid - Pioneer 3732

Weed Control - Cyanazine (Bladex 80w) at 2 lbs/A applied at spike stage on 5/15/85.

Harvested - 10/18/85 by hand (20 foot of row)

Table 13. The effect of tillage on grain yields and moisture at Dodge County, 1985 (averaged over insecticide treatments).

Tillage[1]	Bu/a	% moisture	Population Plants/acre x 103
No till	118	38.3	30.2
Ridge till	123	38.4	30.6
Moldboard	150	33.6	31.3
Significance	.003	.000	NS (.793)

1. This is an establishment year so the ridge till and no till differ in a ridging operation only.

Table 14. The effect of tillage and insecticide on grain yields and moisture, and plant population at Dodge County, 1985.

	Tillage[1]								
	No till			Ridge till			Moldboard		
	Insecticide[2]								
Variable	C	F	L	C	F	L	C	F	L
Yield Bu/a[3]	121	130	105	118	131	119	143	158	150
% moisture[4]	37.4	37.1	40.2	38.7	37.7	38.8	34.1	33.5	33.1
Population[5] Plants/a x 10^3	29.7	29.0	33.3	30.3	31.3	30.0	30.7	33.3	30.0

1. This is an establishment year so the ridge till and no till differ by a ridging operation only.
2. Insecticide treatments are: C=Counter, F=Furadan, and L=Lorsban.
3. Tillage and insecticide are significant at .003 and .115 respectively.
4. Tillage and insecticide are significant at .000 and .212 respectively.
5. Tillage and insecticide are significant at .793 and .680 respectively.

Wabasha County

Table 15. Cultural practices at wabasha county MN., 1985.

Soil Type   Fayette silt loam (Typic hapludalf)

Soil Test   pH - 6.6   P - 70 lbs/A   K - 275 lbs/A
4/9/84

Fertilizer
   Nitrogen - 140 lbs/A as anhydrous ammonia on 6/19/85.
   Starter fertilizer - 25 gal/A 7-21-7 (2"x2" placement)

Tillage
   No till
   Ridge till - Corn-7/8/85   Soybeans-8/1/85
   Chisel on 11/7/84
   Subsoil on 11/14/84
   Paraplow was used (14" deep)
   Cultivation - all plots except no till on 7/2/85.

Corn planted on 5/13/85 with a Hiniker Series 1 conservation tillage 2 row (38") planter at 29,900 plants/A.

Corn Hybrid - Pioneer 3737

Soybeans planted on 5/14/85 with a Tye no till drill (8" spacing) at 225,000 plants/A. Ridge till soybeans were planted with a Hiniker Series 1 conservation tillage 2 row (38") planter at 350,000 plants/A.

Soybean variety - Pioneer 1677

Weed control
- Burndown - corn plots - Glyphosate (Roundup)at 2 lbs/A
- (5/13/85) soybean plots
  - preemerge treatment - Glyphosate at 2 lbs/A
  - post emerge treatment - 2,4-D ester at .5 lbs/A + Poast at .1 lbs/A + Crop oil at 1 qt./A
- Corn - Metolachlor (Dual 8E) at 2 lbs./A + Cyanazine (Bladex)at 1.5 lbs/A on 5/17/85.
- Soybeans:

  Preemerge treatment - Metolachlor (Dual 8E) at 2 lb/A + Metribuzin (Sencor) at .25 lbs/A + Chloramben (Amiben) at 2 lbs/A on 5/17/85

  Post emerge treatment - Bentazon (Basagran) at 1 lb./A + Crop oil at 1 qt./A on 6/12/85

Insecticide - 3 pts/A of Lorsban 4E with 21 gal/A water on 6/4/85

Table 16. The effect of tillage and preceding crop on residue distribution with a ridge till tillage system on June 6, 1985 at Wabasha County.

Position of Measurement	Preceding Crop: Corn mean	Corn stdev	Soybeans mean	Soybeans stdev
	%			
In row	18.3	10.3	9.8	6.4
Between row	65.3	8.0	39.8	15.4
Weighted Avg.[1]	55.5	7.2	33.5	12.6
Perpendicular[1]	51.5	5.8	35.3	10.3

1. A paired t test was used to test the difference in the weighted average of the "in" and "between" the row measurements and a measurement perpendicular to the row. The p values were .102 and .578 for the corn and soybean residue respectively (n=16).

Table 17. The effect of tillage and preceding crop on soil cover by crop residue on June 6, 1985 at Wabasha County (measured perpendicular to the row).[1]

Tillage (.000)	Preceding Crop (.000): Corn mean	Corn stdev	Soybeans mean	Soybeans stdev
	%			
No till	63.8	10.2	53.8	12.7
Paraplow	57.3	10.2	37.0	8.3
Ridge till	51.5	5.8	35.3	10.2
Chisel	27.5	8.7	7.3	3.6

1. Tillage and preceding crop were highly significant. In addition to this there was a tillage x preceding crop interaction (.089).

Table 18. The effect of tillage on population on June 6, 1985 at Wabasha County.

	Crop			
	Corn		Soybeans	
Tillage	mean	stdev	mean	stdev
	-----plants/acre x103-----			
No till	23.8	2.17	143	56.4
Paraplow	24.4	3.43	142	61.2
Ridge till	23.7	4.13	248	72.7
Chisel	25.7	3.24	128	55.3
Significance	NS(.286)		(.000)	

Table 19. The effect of tillage on corn grain yields, and moisture at Wabasha County, 1985.

Tillage	Yield Bu/a	%moisture
No till	108	22.7
Ridge till	102	22.3
Chisel	109	23.1
Sub Soil	106	22.6
Significance	NS(.442)	(.075)

Table 20. The effect of tillage and weed control strategy on soybean yields at Wabasha County, 1985.[1]

	Tillage			
Weed control	No till	Ridge till	Chisel	Sub Soil
	------------------Bu/a------------------			
Preemerge	43.2	28.1	26.5	43.4
Post emerge	34.7	25.7	33.9	34.0

[1]Tillage is significant at .000, weed control at .007, and a tillage x weed control interaction at .000.

Table 21. The effect of tillage and previous crop on soil nitrates on 4/18/85 at Wabasha County.

	Previous Crop							
	Corn				Soybeans			
Depth (ft.)	0-1	1-2	2-4	total	0-1	1-2	2-4	total
	----------------------lbs NO_3-N/A----------------------							
Tillage								
No till	68	39	55	161	84	53	48	185
Sub Soil	73	56	61	190	82	57	48	187
Ridge	59	44	89	192	63	50	48	162
Chisel	71	47	43	161	96	57	51	204
			Average	176			Average	184

Summary

1. It is advisable to keep the row area clean when planting corn after corn no till.

2. Tillage had no effect on yield when corn was grown after soybeans at two of three sites. No till corn after corn, resulted in lower yields than chisel or

moldboard plowing in two of two sites.

3. Cultivation improved corn yield with no till and moldboard plowing.

4. Increased tillage resulted in more weed pressure at two sites (velvet leaf and lambsquarter).

5. There was a large response to narrow row soybeans. No till and subsoil treatments with preemerge herbicide resulted in the highest yield. Post emergence herbicide strategy in other years has proved to be as effective. In 1985 only broadleaf control was used resulting in foxtail pressure.

6. Cutworms were related to tillage and previous crop (no till following soybeans). This resulted in a necessary application of an insecticide at one out of three sites for no till corn following soybeans.

7. At all sites there was no measurable effect of cutworms on final stand or grain yields including the treated site.

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The effect of tillage and manure application frequency on corn growth.

Patricia Burford, John Moncrief, James Swan, and Brian Schrieber
Cooperator: Dale Flueger

In todays farming systems, economics is of primary importance. Farmers must use all resources available in order to control rising costs of inputs. Manure is one resource that should not be underestimated. No longer should manure be considered a waste problem rather: a valuable asset to farmers with access to it.

The nitrogen applied in manure is not all available for plant use the year it is applied. A decay series has been developed for types of manure in which approximately fifty percent of the N present is in the form of urea or uric acid. Approximately 75% of the N present in the manure was determined to be available the year of application with 15, 10, and 5% of the remaining N being available each subsequent year. This suggests that nutrients may be available for crop utilization in years other than the application year, which could be of significant benefit to farmers who want to the make most efficient use of the nutrients available in the manure.

The objectives of this study were to:

1) determine the effects of tillage and frequency of manure application on the growth and yields of corn, and
2) to determine tillage effects on the ability of manure to supply adequate potassium and nitrogen for corn growth by measuring yields and uptake levels.

METHODS AND MATERIALS

The experimental site was located on approximately one and one-third hectares of land in Sec. 15 of Haycreek Township in Goodhue County, Minnesota on a deep loess soil over limestone. The soil is a Typic Eutrochrept (Timula silt loam) with initial soil test ranges of 20.7 ± 5.3 ppm of phosphorus (Bray-1), and 83.0 ± ppm of potassium, a pH of 6.5 ± 2.5, and organic matter levels of approximately 2.5%. Dolomitic limestone was applied in 1980 at a rate of 2.9 T/ac. Prior to the initiation of the study, oats and alfalfa were grown in 1979, followed by alfalfa until 1982. Corn as silage was grown in 1981, and corn as grain from 1982 to 1984. Although, this study was initiated in 1982 only 1983 to 1985 results will be discussed since 1982 did not contain the entire set of treatments to be analyzed.

Pesticides used on the study area are given in Table 1. Equipment used during this study consisted of the following:
1. chisel plow (Glencoe Soil Saver) with chisels 3.5 inches wide, and spaced 13 inches apart with twisted shovels, 2. a field cultivator (Bushog), 3. two planters (John Deere maxemerge in 1982, and Hiniker in 1983, 1984, and 1985), 4. and a manure injector (Calumet). The injector consisted of a tractor drawn tandem axil tank with a 3000 gallon capacity. A rotary pump driven by the power take off delivered the slurry through injection hoses and also agitated the slurry to insure its uniformity. Manure injection bands were 38 inches apart and placement depth was approximately 8 to 10inches (depending on soil conditions at the time of injection).

Corn was planted at a rate of 29 thousand plants/ac in rows spaced 38 inches apart. Table 2 is a list of the hybrids used and their planting dates.

This study was designed as a randomized complete block with three replications. Manure was injected as a slurry annually, biennially, or triennially prior to tillage. In addition, plots were split with 0 and 200 lb/ac of broadcast K_2O. The check treatment received only broadcast K applications at a rate of 200 lb/ac of K_2O. In addition a fertilizer treatment was established as a comparison to the manure treatments. This fertilizer treatment received 300 lb/ac of broadcast N each year in the form of ammonium nitrate, and split applications of 200 and 400 lb/ac of broadcast K_2O. The rates of broadcast K used with the fertilizer treatment were selected to correspond closely with the rates of K supplied by the annual manure injection treatments with 0 and 200 lb/ac of broadcast K_2O. Small amounts of N and P were supplied in the row at planting to all treatments. Table 3 gives the dates of fertilizer applications and manure

Table 1. Pesticide applications at the study site.

Pesticide	Rate of active ingredient	Year
Terbufos (Counter)	1.3 lb/ac	1984, 1985
Fonofos (Dyphonate)	2.5 lb/ac	1983
Atrazine/Alachlor (Atrazine/Lasso)	2.5 lb/ac	1983, 1984, and 1985
[1]Bucktril (Bromoxynil)	.38 lb/ac	1985

[1]Applied post emergence for control of lambsquarter.

Table 2. Dates of tillage, soil sampling, and planting.

Activity	Date
Chisel plowing	18 May 1983 15 May 1984 11 May 1985
Planting[1]	23 May 1983 20 May 1984 18 May 1985
Soil Sampling	
0 to 12 inches[2]	26 April 1983 4 July 1984 11 July 1985
0 to 2 and[3] 2 to 5 feet	16 April 1984 25 April 1985

1A 95 day single cross hybrid was used (Pioneer 3906).
2These soil samples were taken to determine the levels of soil test K, P and pH.
3These soil samples were taken for soil nitrate and soil moisture determinations.

Table 3. Nutrients supplied by liquid dairy manure and the rates of application from 1982 to 1985.

DATE	TOTAL N	NH_4-N	P_2O_5	K_2O	RATE APPLIED
	(lb/ac)				(gal/ac)
4 May 1982	375	190	111	217	12,700
16 May 1983	232	195	125	224	9,100
17 Nov 1983	310	158	136	263	10,700
3 May 1985	261	122	111	217	9,200

injections. Zinc, and sulfur were applied to all treatments to eliminate any possible effects shortages of these nutrients may cause, and were applied at rates of 1 and 38 lb/ac of Zn and S, respectively.

Tillage treatments used were spring chisel plowing (7 to 9 inches deep) followed by a field cultivation (2 to 5 inches deep), and no-till. The injection of manure can also be considered a form of tillage. Dates of tillage can be found in Table 2.

Soil samples were taken 0 to 12 inches deep after manure injection, broadcast K applications and chisel plowing. Ten samples per plot were taken, composited, and subsampled. Soil samples were taken to a depth of 5 feet on 12 April 1984, and 25 April 1985 to determine soil nitrate levels. These deep samples were incremented 0 to 2 and 2 to 5 feet. All soil samples were dried at 95°F, and ground to pass a .08 inch sieve. Dates of these samplings are also given in Table 2.

At harvest grain and stover samples were taken, dried at 140°F, and ground to pass a .04 inch sieve. Stover was chopped and returned to the soil surface.

Surface residue was measured by the line intersect method. The K levels in the soil were determined by ammonium acetate extraction, phosphorus was determined by the Bray-1 method and pH was determined using 1:1 soil to water ratio. Total Kjeldahl nitrogen was done to determine soil nitrate levels.

RESULTS AND DISCUSSION

Table 3 shows that the ammonia N present in this manure is approximately 50 percent of the total N present, therefore, the decay series developed by other researchers may apply to this study with modifications being made for climate, and soil type.

Table 4 shows the effects of tillage, and method of fertilization on soil cover measured on 1 July 1985. Analysis of variance results are given in Table 5. Method of fertilization and tillage were both significant in their effects on soil cover, due to the reduction of soil cover with manure injection and/or when chisel plowing was done. The effects of manure injection on reducing soil cover are most evident when looking at the treatments where manure was not injected (check, fertilizer, and in non application years for biennial manure treatments) and comparing these to those with manure injected in 1985. No-till resulted in greater soil cover than chisel plowing in and between the row when manure was not injected in 1985. In the injection year there were smaller differences in soil cover due to tillage and in some cases levels were similar between tillage treatments. Variability in soil cover is due to poor distribution of stover by the combine (note standard deviations) making specific numerical differences difficult to determine. Greater soil cover has been shown to have effects on soil temperature, soil moisture, and nitrification rates. This may be useful information when determining how tillage affects N.

Table 6 shows some of the monthly climatic data near the study site, and figure 1 gives the distribution of precipitation from 1983 to 1985. This weather data helps to explain some of the treatment effects to be discussed.

The effects of tillage, manure application frequency, and depth on soil nitrate levels on 16 April 1984 and 25 April 1985 are shown in Tables 7, and 8, respectively. Table 9 gives the combined analysis of variance results for 1984-1985, and Table 10 the individual 1984, 1985 analysis of variance results. Since manure was injected either in the fall shortly before frost, or in the spring, nitrate levels in the soil were most likely not influenced in the year of manure application. Soil nitrates reflect release of N from the previous year. Annual manure applications resulted in the greatest levels of soil nitrates. Soil nitrates with the check treatment were not affected by tillage either year. The 0 to 2 foot depth had greater accumulations of soil nitrates than the 2 to 5 foot depth within any given manure application treatment. There were significant tillage by frequency of manure application interactions both years of measurement. In 1984 there were greater accumulations of nitrates in the 0 to 2 foot depth with the chisel plow treatment than with no-till when manure was applied annually, and the with biennial manure applications in the year of application. There were similar levels of nitrates between tillage treatments the year after application of manure at this depth. The tillage by depth interaction reflected the greater nitrate levels which were present with chisel plowing than no-till in the 0 to 2 foot depth in the year manure was applied, and greater soil nitrate levels with no-till than chisel plowing in the 2 to 5 foot depth in the year no manure was applied

Table 4. The effect of tillage, and source of nutrients and frequency of applications on soil cover in and between the row on 1 July 1985. In and between the row are defined as the 5 inch area centered over the row and the remainder, respectively.

Method and Frequency Fertilization	Broadcast K_2O	IN THE ROW		BETWEEN THE ROW	
	lb/ac	NO-TILL	CHISEL	NO-TILL	CHISEL
		----------(Percent Cover)----------			
CHECK	200	23.3 (20.53)[1]	6.0 (2.00)	62.0 (12.00)	15.3 (4.16)
FERTILIZER (ANNUAL)					
AMMONIUM NITRATE	200	54.7 (14.01)	9.7 (5.13)	62.7 (15.68)	22.0 (9.72)
AMMONIUM NITRATE	400	56.0 (17.30)	16.0 (8.94)	68.0 (10.81)	24.3 (14.05)
MANURE					
ANNUAL	0	18.0 (8.29)	19.3 (4.16)	23.7 (8.33)	18.7 (3.06)
ANNUAL	200	15.7 (12.86)	24.0 (11.14)	20.0 (11.31)	22.7 (2.31)
1982, 1984	0	48.0 (16.37)	16.8 (15.14)	74.0 (9.16)	13.3 (7.57)
1982, 1984	200	49.3 (18.90)	18.0 (16.37)	58.0 (32.19)	14.0 (7.21)
1983, 1985	0	33.3 (3.06)	17.3 (4.16)	24.7 (23.69)	22.0 (0)
1983, 1985	200	9.3 (6.11)	8.7 (2.31)	14.7 (13.32)	17.3 (9.24)

[1] Values in parenthesis represent the standard deviations, N=6.

Table 5. Significance levels of analysis of variance for soil cover in 1985.

MAIN EFFECTS	SIGNIFICANCE LEVELS IN ROW	BETWEEN ROW
FERTILIZATION METHOD	.000	.000
TILLAGE	.000	.000
K-RATE	.780	.559
2-WAY INTERACTIONS		
F X T	.000	.000
F X K	.166	.391
T X K	.151	.389
3-WAY INTERACTIONS		
F X T X K	.598	.656

[1]Main effects are defined as follows: Frequency of manure applications (F) refers to annual and biennial manure applications, as well as the fertilizer treatment (300 lb N/ac), Tillage (T) refers to no-till and chisel plowing, K-rate is the rate of broadcast K used.

Table 6. Monthly climatalogical data for the 1983 to 1985 growing seasons[1].

MONTH	TEMP °F	GDD (Base 50°/86°F) MONTHLY	CUMMULATIVE
	(1983)		
April	41.2	81	81
May	60.8	241	322
June	67.1	522	844
July	75.6	742	1626
August	74.1	715	2341
September	61.5	394	2735
	(1984)		
April	46.8	131	131
May	56.3	308	439
June	69.3	569	1008
July	71.1	646	1654
August	72.5	686	2340
September	58.1	328	2668
	(1985)		
April	52.8	248	248
May	62.2	427	675
June	64.6	448	1123
July	72.9	677	1800
August	65.5	481	2281
September	59.9	369	2650

[1]Data was obtained from Rosemount experiment station which is approximately 40 miles from the study site.

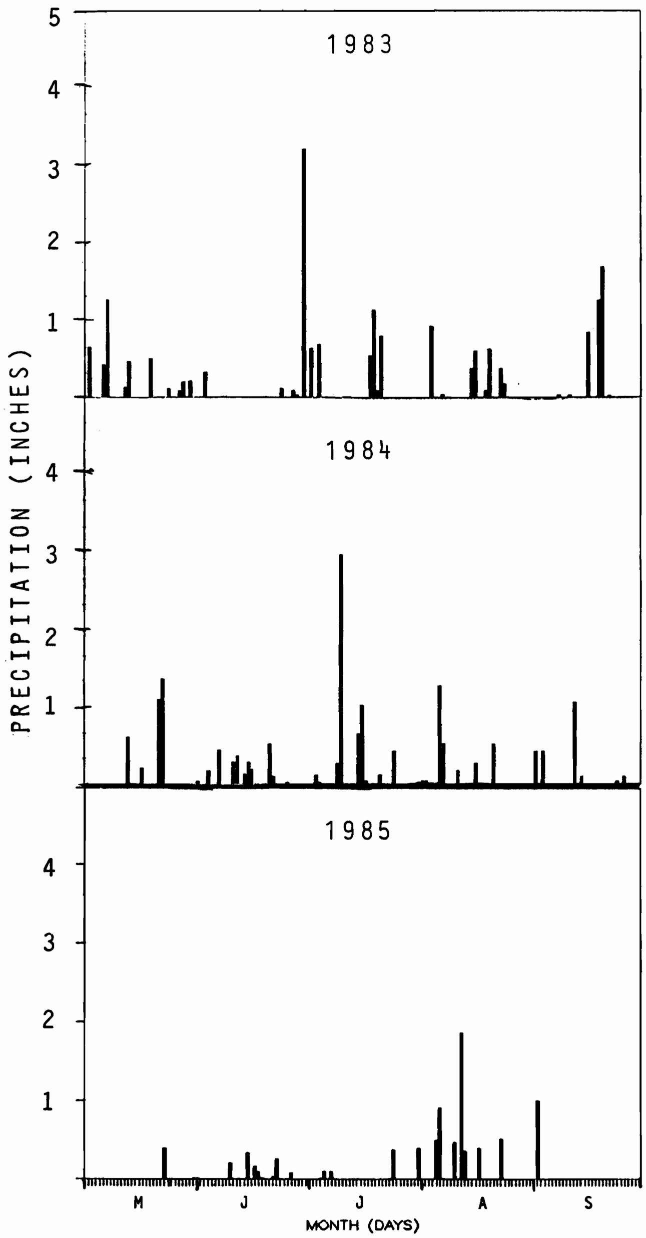

Figure 1. Distribution of precipitation at the study site.

Table 7. The effect of tillage and frequency of manure applications on soil nitrates taken on 16 April 1984.

Frequency of Manure Applications	Depth (feet)	No-till	Chisel
		-----(lb NO_3/ac)-----	
Check (None)	0-2	22.9 (10.23)[1]	25.5 (4.69)
	2-5	6.8 (5.31)	6.1 (2.24)
Annual	0-2	42.0 (13.79)	64.0 (18.59)
	2-5	33.2 (12.98)	24.8 (16.48)
1982, 1984	0-2	34.0 (6.15)	41.0 (18.01)
	2-5	19.4 (7.06)	12.2 (16.48
1983, 1985	0-2	35.0 (15.06)	38.2 (7.15)
	2-5	22.1 (2.29)	13.3 (5.53)

[1] Values in parenthesis represent the standard deviations, N=3.

Table 8. The effect of tillage and frequency of manure applications on soil nitrates on 25 April 1985.

Frequency of Manure Applications	Depth (feet)	No-till	Chisel
		------(lb NO_3/ac)------	
Check	0-2	46.7 (7.04)[1]	42.9 (8.02)
	2-5	24.6 (3.42)	24.9 (10.25)
Annually	0-2	64.5 (16.91)	80.7 (19.56)
	2-5	48.7 (16.59)	78.0 (15.76)
1982, 1984	0-2	53.2 (10.65)	59.3 (11.66)
	2-5	37.4 (3.78)	44.3 (9.39)
1983, 1985	0-2	54.7 (26.53)	48.0 (13.89)
	2-5	40.5 (27.16)	27.3 (6.27)

[1] Values in parenthesis represent the standard deviations, N=3.

Table 9. Significance levels of combined for 1984 and 1985 analysis of variance for soil nitrates.

	SIGNIFICANCE LEVELS
MAIN EFFECTS[1]	
FREQUENCY	.000
TILLAGE	.031
DEPTH	.000
YEAR	.000
2-WAY INTERACTIONS	
F X T	.002
F X D	.681
F X Y	.437
T X D	.226
T X Y	.290
D X Y	.406
3-WAY INTERACTIONS	
F X T X D	.829
F X T X Y	.222
F X D X Y	.967
T X D X Y	.076

[1]Main effects are defined as follows: Frequency (F) refers to annual and biennial manure applications, Tillage (T) refers to no-till and chisel plowing, Depth (D) refers to the two depth increments soil nitrates were measured (0 to 2 and 2 to 5 feet), and Year (Y) refers to 1984, and 1985. The check treatment was not included in this analysis.

Table 10. Significance levels of analysis of variance for soil nitrates in 1984 and 1985.

	SIGNIFICANCE LEVELS	
	1984	1985
MAIN EFFECTS[1]		
FREQUENCY	.000	.000
TILLAGE	.244	.113
DEPTH	.000	.001
2-WAY INTERACTIONS		
F X T	.062	.024
F X D	.825	.780
T X D	.004	.601

[1]Main effects are defined as follows: Frequency (F) refers to annual and biennial manure applications, Tillage (T) refers to no-till and chisel plowing, and Depth (D) refers to the two depth increments soil nitrates were measured (0 to 2 and 2 to 5 feet), The check treatment was not included in this analysis.

(biennial-1983). These greater nitrate levels in the 2 to 5 foot depth with no-till compared to chisel plowing may be the result of greater leaching of N with no-till than chisel plowing. In 1985 there were greater nitrate levels present with chisel plowing with annual manure applications at both depths, and a similar trend with biennial manure applications the year after application of manure (1984).

Soil moisture (Table 11) of the deep samples in 1985 was not significantly affected by manure application frequency, tillage, or depth of the sampling (Table 12). Since, these samples were taken in April, little difference would be expected between tillage or manure treatments.

Soil test K levels are given in Table 13 for 1983, 1984 and 1985, with analysis of variance results given in Tables 14, and 15 for individual years, and combined years, respectively. Tillage effects on the banded nature of manure injected K, resulted in variability in soil test K levels. With no-till the manure band was avoided when taking soil samples to prevent high K readings due to the concentrated K in these bands. With the chisel plow treatment the manure band was diffuse and undefineable, therefore, soil K levels were higher with this treatment. Potassium source, and K-rate were both significant in their effects on soil test K levels, and the levels of K in the soil are directly related to the amount of K supplied with the manure and with the broadcast K treatments. Soil K increased with all treatments over the three years. With the fertilizer treatment there was a trend for soil K levels to be greater with no-till than chisel plowing. With manure applications, the opposite trend was observed. This was due sampling effect mentioned previously.

The effects of tillage and manure treatment on grain yields from 1983 to 1985 are given in Table 16. The analysis of variance results for individual years are given in Table 17. Analysis of variance results for all years combined are given in Table 18. Source and frequency of nutrients, and tillage significantly affected grain yields in all three years. Generally, within a tillage treatment annual, biennial (in the year of manure application), and the fertilizer treatment resulted in similar grain yields. Generally, chisel plowing had greater yields than no-till. Differences between tillage treatments were lower in the year of manure application or when chemically fertilized. In 1984, chisel plowing resulted in greater grain yields than no-till when there was one year since manure application. There was a similar trend in 1983. The check treatment also had greater yields with chisel plowing than no-till, indicative of the greater mineralization of N occurring with soil conditions associated with chisel plowing. The rate of broadcast K applied did not affect grain yields significantly. Yields were significantly different between years with 1984 having the greatest yields.

The effects of tillage, and source and frequency of application of nutrients on stover yields are given in Table 18 for the three year period. Analysis of variance results are given in Tables 19, and 17 for individual and combined analysis of the three years, respectively. Tillage did not significantly affect the stover yields in 1983 or 1985. Yields in 1984 were generally greater when compared with the other two years. Stover yields were greater with chisel plowing than with no-till in 1984 with treatments other than the fertilizer treatment. Yields were greatest with fertilizer and annual manure applications when compared to the other treatments. Over all years tillage significantly affected stover yields. Chisel plowing resulted in greater yields in non manure application years than no-till.

SUMMARY

Soil cover was significantly greater with no-till than chisel plowing. Injection of dairy manure reduced the differences between tillage treatments for soil cover since, injection acted as a form of tillage.

Soil moisture was not affected by tillage, depth of measurement or frequency of manure applications when measured on 25 April 1985.

Potassium levels in the soil increased with all sources of K, and frequencies of application. Soil K levels were somewhat greater with no-till than chisel plowing with the fertilizer treatment. With manure applications, however, chisel plowing resulted in greater soil test K than with no-till because the manure was more evenly distributed in the soil after tillage, and was not defineable as in the no-till treatment where the injection band was avoided when taking soil samples.

Table 11. The effects of tillage and frequency of manure applications on soil moisture on 25 April 1985 in the 0 to 5 foot depth.

Frequency of Manure Application	Depth (feet)	No-till	Chisel
		-----(% by wt.)-----	
Check	0-2	22.5 (1.75)[1]	21.4 (1.60)
	2-5	22.1 (2.16)	20.8 (2.20)
Annual	0-2	23.7 (1.01)	22.8 (1.42)
	2-5	22.9 (3.28)	23.3 (1.59)
1982, 1984	0-2	23.2 (1.02)	22.8 (1.46)
	2-5	22.9 (2.98)	22.4 (2.90)
1983, 1985	0-2	22.4 (.91)	22.7 (1.08)
	2-5	22.8 (3.09)	22.8 (.68)

[1] Values in parenthesis represent the standard deviations, N=3.

Table 12. Significance levels of analysis of variance for soil moisture taken 1985.

	SIGNIFICANCE LEVELS
MAIN EFFECTS[1]	
FREQUENCY	.598
TILLAGE	.663
DEPTH	.655
2-WAY INTERACTIONS	
F X T	.893
F X D	.828
T X D	.678
3-WAY INTERACTIONS	
F X T X D	.741

[1]Main effects are defined as follows: Frequency (F) refers to annual and biennial manure applications, Tillage (T) refers to no-till and chisel plowing, Depth (D) refers to the two depth increments soil nitrates were measured (0 to 2 and 2 to 5 feet), and Year (Y) refers to 1984, and 1985. The check treatment was not included in this analysis.

Table 13. The effect of tillage, manure, and KCl application on soil test K levels in the 0 to 12 inch depth from 1983 to 1985.

Source and Frequency of Applications	Broadcast K_2O	16 June '83		2 July '84		11 July '85	
		SOIL TEST K					
	lb/ac	(PPM)[1]					
		No-till	Chisel	No-till	Chisel	No-till	Chisel
CHECK	200	95 (22.2)[2]	92 (40.7)	126 (21.9)	144 (35.9)	114 (22.9)	101 (14.6)
Fertilizer (annual)							
KCl[3]	200	115 (35.4)	112 (30.9)	128 (13.6)	132 (18.6)	158 (14.9)	143 (30.6)
KCl	400	176 (30.0)	153 (36.4)	174 (40.4)	175 (36.3)	266 (56.2)	204 (42.9)
Manure							
ANNUAL	0	100 (34.4)	143 (45.0)	128 (17.4)	162 (5.7)	121 (25.2)	148 (9.5)
ANNUAL	200	170 (41.8)	152 (30.3)	169 (32.6)	201 (17.8)	171 (31.6)	197 (23.6)
1982, 1984	0	73 (21.4)	98 (27.0)	106 (30.7)	130 (32.3)	90 (18.1)	100 (22.9)
1982, 1984	200	108 (18.6)	110 (41.1)	150 (29.5)	166 (41.7)	125 (21.2)	155 (43.6)
1983, 1985	0	74 (11.5)	105 (39.6)	98 (11.6)	106 (42.1)	97 (11.0)	87 (44.3)
1983, 1985	200	95 (38.1)	109 (19.0)	128 (27.6)	133 (26.6)	111 (17.4)	115 (23.1)

1 PPM can be converted to lb/ac by multiplying by 2.
2 Values in parenthesis represent the standard deviations, N=3.
3 These rates of broadcast K were used with the fertilizer treatment because they corresponded closely with rates of K supplied with the annual manure application treatments in the manure.

Table 14. Significance levels of analysis of variance for soil test K levels from 1983 to 1985.

	SIGNIFICANCE LEVELS		
	1983	1984	1985
MAIN EFFECTS[1]			
SOURCE OF K	.000	.000	.000
TILLAGE	.380	.032	.449
K-RATE	.000	.000	.000
2-WAY INTERACTIONS			
S X T	.280	.251	.001
S X K	.221	.810	.007
T X K	.052	.628	.372
3-WAY INTERACTIONS			
S X T X K	.696	.949	.188

[1]Main effects are defined as follows: Source of K (S) refers to manure or KCl supplied K, Tillage (T) refers to no-till and chisel plowing, and K-rate (K) is the rate of broadcast K used. The check treatment was not used in this analysis.

Table 15. Significance levels of combined analysis of variance for soil test K, 1983, 1984, and 1985.

	SIGNIFICANCE LEVELS
MAIN EFFECTS[1]	
FREQUENCY AND SOURCE	.000
TILLAGE	.164
K-RATE	.000
YEAR	.000
2-WAY INTERACTIONS	
F X T	.000
F X K	.002
F X Y	.000
T X K	.032
T X Y	.155
K X Y	.071
3-WAY INTERACTIONS	
F X T X K	.672
F X T X Y	.322
F X K X Y	.445
T X K X Y	.343

[1]Main effects are defined as follows: Frequency and Source (F) refers to annual and biennial manure applications, as well as the fertilizer treatment (300 lb N/ac), Tillage (T) refers to no-till and chisel plowing, and K-rate is the rate of broadcast K used.
The check treatment was not included in this analysis.

Table 16. The effect of tillage, and source and frequency of application of nutrients on grain yields in 1983, 1984, and 1985.

Source and Frequency of Nutrients	Broadcast K_2O lb/ac	GRAIN YIELDS 1983 (Bu/ac) No-till	1983 Chisel	1984 No-till	1984 Chisel	1985 No-till	1985 Chisel
CHECK	200	54.9 (12.11)[1]	90.8 (22.70)	66.2 (9.46)	85.1 (31.22)	62.4 (2.46)	77.6 (5.87)
Fertilizer (annual)							
AMMONIUM NITRATE	200	119.2 (6.24)	126.8 (13.05)	158.9 (9.08)	164.6 (14.19)	134.3 (9.27)	155.1 (9.46)
AMMONIUM NITRATE	400	123.0 (8.89)	134.3 (5.30)	153.3 (9.08)	157.0 (17.03)	136.2 (11.73)	145.7 (11.16)
Manure							
ANNUAL	0	126.8 (12.30)	134.3 (20.06)	143.8 (11.16)	162.7 (20.06)	147.6 (16.46)	149.5 (14.38)
ANNUAL	200	130.5 (6.43)	130.5 (8.51)	145.7 (12.11)	166.5 (17.60)	141.9 (8.51)	153.3 (20.43)
1982, 1984	0	104.1 (8.89)	124.9 (14.9)	155.1 (10.03)	153.3 (12.11)	115.4 (6.43)	121.1 (10.28)
1982, 1984	200	111.6 (7.95)	119.2 (7.19)	157.0 (6.43)	166.5 (39.16)	102.2 (14.19)	113.5 (16.84)
1983, 1985	0	124.9 (5.11)	113.5 (8.14)	98.4 (12.49)	138.1 (24.79)	132.4 (11.16)	145.7 (13.24)
1983, 1985	200	102.2 (20.24)	109.7 (9.46)	104.1 (31.79)	130.5 (23.46)	145.7 (6.24)	153.3 (13.05)

1 Values in parenthesis represent the standard deviations, N=3.

Table 17. Significance levels of analysis of variance for grain yields from 1983 to 1985.

	SIGNIFICANCE LEVELS 1983	1984	1985
MAIN EFFECTS1			
FREQUENCY AND SOURCE	.000	.000	.000
TILLAGE	.020	.000	.001
K-RATE	.583	.732	.462
2-WAY INTERACTIONS			
F X T	.204	.017	.647
F X K	.152	.415	.142
T X K	.913	.793	.708
3-WAY INTERACTIONS			
F X T X K	.140	.668	.489

1Main effects are defined as follows: Frequency and Source (F) refers to annual and biennial manure applications, as well as the fertilizer treatment (300 lb N/ac), Tillage (T) refers to no-till and chisel plowing, and K-rate (K) is the rate of broadcast K used. The check treatment was not included in this analysis.

Table 18. The effect of tillage and manure application on stover yields in 1983, 1984, and 1985.

Source and Frequency of Nutrients	Broadcast K_2O	STOVER YIELDS 1983		1984		1985	
	lb/ac	(T/ac)					
		No-till	Chisel	No-till	Chisel	No-till	Chisel
CHECK	200	1.8 (.14)[1]	2.2 (.46)	1.6 (.26)	2.1 (.17)	1.5 (.33)	1.7 (.16)
Fertilizer (annual)							
AMMONIUM NITRATE	200	2.9 (.22)	2.8 (.23)	3.6 (.17)	3.6 (.25)	2.5 (.27)	2.7 (.37)
AMMONIUM NITRATE	400	3.0 (.44)	3.2 (.49)	3.5 (.21)	3.4 (.17)	2.4 (.55)	2.6 (.33)
Manure							
ANNUAL	0	3.0 (.44)	3.6 (.58)	2.9 (.38)	3.5 (.50)	2.4 (.45)	2.3 (.45)
ANNUAL	200	3.3 (.21)	3.3 (.25)	3.0 (.42)	3.6 (.51)	2.4 (.39)	2.5 (.35)
1982, 1984	0	2.5 (.14)	2.7 (.34)	3.3 (.51)	3.1 (.17)	1.9 (.37)	2.0 (.52)
1982, 1984	200	2.6 (.28)	2.7 (.23)	3.1 (.21)	3.3 (.67)	1.9 (.43)	2.1 (.74)
1983, 1985	0	3.1 (.10)	2.8 (.12)	2.1 (.36)	2.6 (.41)	2.2 (.71)	2.1 (.43)
1983, 1985	200	2.7 (.48)	2.7 (.26)	2.4 (.81)	2.8 (.49)	2.4 (.34)	2.4 (.48)

parenthesis represent the standard deviations, N=3.

Table 19. Significance levels of analysis of variance for stover yields from 1983 to 1985.

	SIGNIFICANCE LEVELS		
	1983	1984	1985
MAIN EFFECTS[1]			
FREQUENCY AND SOURCE	.000	.000	.000
TILLAGE	.219	.001	.213
K-RATE	.212	.537	.636
2-WAY INTERACTIONS			
F X T	.206	.002	.643
F X K	.114	.399	.350
T X K	.825	.966	.533
3-WAY INTERACTIONS			
F X T X K	.084	.606	.957

[1]Main effects are defined as follows: Frequency and source (F) refers to annual and biennial manure applications, as well as the fertilizer treatment (300 lb N/ac), Tillage (T) refers to no-till and chisel plowing, and K-rate (K) is the rate of broadcast K used.
The check treatment was not included in this analysis.

Table 20. Significance levels of combined analysis of variance for 1983, 1984 and 1985 grain and stover yields.

	SIGNIFICANCE LEVELS	
	GRAIN	STOVER
MAIN EFFECTS[1]		
FREQUENCY AND SOURCE	.000	.000
TILLAGE	.000	.001
K-RATE	.502	.258
YEAR	.000	.000
2-WAY INTERACTIONS		
F X T	.057	.020
F X K	.730	.679
F X Y	.000	.000
T X K	.871	.948
T X Y	.104	.298
K X Y	.782	.738
3-WAY INTERACTIONS		
F X T X K	.405	.438
F X K X Y	.036	.088
T X K X Y	.894	.770

[1]Main effects are defined as follows: Frequency and source (F) refers to annual and biennial manure applications, as well as the fertilizer treatment (300 lb N/ac), Tillage (T) refers to no-till and chisel plowing, K-rate (K) is the rate of broadcast K used, and Year (Y) refers to 1983, 1984, and 1985.
The check treatment was not included in this analysis.

Grain yields were generally greater with chisel plowing than no-till. When in a manure injection year these differences were minimized, and in some instances yields were similar. Chisel plowing in some way increased the amount of N mineralized compared to no-till. This was indicated by the greater yields which occurred in 1984 with chisel plowing than no-till when manure was applied biennially (the year after application), and with the check treatment all three years. Stover yields had similar trends.

Broadcast K did not affect grain or stover yields, and was adequate without additional applications when manure was applied annually or biennially.

THE EFFECT OF TILLAGE, N RATE, AND NITRIFICATION INHIBITOR ON CORN RESPONSE

J.F. Moncrief, G.L. Malzer, G.W. Rehm, J. Chaplin, and M. O'Leary

In order to maintain yields, minimize production inputs, and reduce fertilizer N entry to groundwater, N management is of critical concern when tillage reductions are extreme. This is a summary of the third year of a study to investigate the effects of tillage in a continuous corn culture on N availability on a loamy sand soil under irrigation and a silt loam soil under dryland conditions.

This experiment is being conducted at two sites: the Sand Plains Experiment Station, Becker, MN and on a cooperators farm near Goodhue, MN. The Becker site is located in East Central (EC) Minnesota on a soil formed in deep glacial outwash. This soil is a Udorthentic Haploboroll (Hubbard, loamy sand). The other site is located in southeastern Minnesota (SE) on a soil formed in deep loess cap over limestone. The soil at this site is a Mollic Hapludalf (Mt. Carroll, silt loam) and Typic Hapludalf (Seaton, silt loam).

Methods

At the EC site a Buffalo planter equipped with clearing discs was used to plant the ridge till treatment. A White planter with 2" fluted coulters was used on all other tillage treatments. A Hiniker series 1 Econo till planter was used for all tillage treatments. The cleaning discs were raised for the no till and chisel treatments. Cultural practices utilized in this study are summarized in Table 1.

Anhydrous ammonia was used as the nitrogen source. A sidedressed treatment was used at the SE site in addition to the spring treatment at both sites. Nitrogen was applied at three rates with and without a nitrification inhibitor (N Serve) at both sites.

Results and Discussion

The soil cover after planting is shown in Table 2. There was more cover for a given tillage treatment at the SE site. The row area of the ridge till treatment had about 1/5 and 1/3 the soil cover of the row middles at the SE and EC sites respectively. The no till, chisel, and moldboard plow treatments had a similar cover in and between the row.

Yield and N uptake

Tillage has been shown to affect release of soil N. For this reason grain and stover yields and N uptake were measured on plots with no N applied with and without tillage by the anhydrous ammonia applicator (Table 3). There appears to be a trend favoring higher levels of yield and N uptake with the knifed plots but it is not statistically significant.

The grain and stover yields nd N uptake for the Bekcer site (EC) are shown in Table 4. At the highest rate of N the ridge till, chisel, and moldboard systems had similar grain yields. There was a significant tillage by N rate by inhibitor interaction. This is graphically shown in Figure 1. All tillage systems responded to the inhibitor but not at the same N rates. The ridge till treatment showed the classical inhibitor response diminishing with increasing N rate. There was little response with the moldboard system at any rate. The no till and chisel systems resulted in a large response at the 150 lb/A rate but little or none at the high and low rate. A similar trend occurred with N uptake.

The grain and stover yields and N uptake for the SE site are shown in Table 5. The N response was much less at this site. There was a significant tillage by time of application by inhibitor interaction at this site. This is illustrated in Figure 2. Spring or sidedress N resulted in similar yields with or without a nitrification inhibitor when corn was grown with ridge till tillage. When corn was grown with chisel plowing spring N had an advantage over sidedress and was independent of the inhibitor treatment. When sidedress N was used there was a dramatic drop in yield with the inhibitor treatment. This is the result of reduced nitrification due to the drought condition in 1985 which was less severe with the conserved moisture associated with the ridge till system.

Table 1. Management practices utilized at the Becker (EC) and Goodhue (SE) experimental locations.

Management Practice	EC (Becker)	Date	SE (Goodhue)	Date
Tillage	Moldboad plow & plowpacker	4/5		
	Chisel	4/29		5/7
	Ridge Till	6/24		6/29
	Culitivation	----		----
Planting Date[1]	No Till	5/7		5/7
Corn Variety	Pionner 3906		Pionner 3906	
Seeding Rates	29,580 seeds/A		28,000 seeds/A	
Row spacing	30 inches		38 inches	
Fertilizer treatments application		5/7		5/9
Starter Fertilizer	150 lbs/A 8-10-30		14gal/A 7-21-7	
Other Fertilizer	235 lbs/A 0-0-22 250 lbs/A 0-14-42	4/1 4/1		
Insecticide			Counter 15g 6#/A	
Herbicide[2]	Atrazine 2 lbs/A Dual 8E 1.5 pint/A Round Up 1 qt./A Atrazine+oil 2 lbs/A	5/3 5/3 5/3 5/30	Lasso 2.5 lbs/A Round Up 1 qt/A Atrazine 2 lbs/A Buctril 1 pint/A	5/7 5/7 5/7 6/14
Irrigation	0.90 inches 5.90 inches 0.60 inches	June July August		

1 At the EC location the ridge till treatments were planted with a Buffalo till planter (disc trash cleaners) and a white (12 inch fluted coulter). At the SE location a Hiniker planter was used for all treatments (trash discs were raised for no till and chisel treatments).

2 Weed control was generally good at each location but giant foxtail was a problem on the no till plots at the SE location.

Table 2. The effect of tillage on soil cover by crop residue on 6/4/85.

	SE MN				EC MN			
	In Row		Between		In Row		Between	
Tillage	mean	sdev	mean	sdev	mean	sdev	mean	sdev
No till	71.7	21.2	76.0	9.8	53.8	20.1	53.8	12.7
Ridge till	11.7	8.6	53.7	6.3	10.5	6.0	28.3	11.5
Chisel	29.2	17.8	28.2	19.1	18.0	13.3	21.3	11.7
Moldboard					1.5	2.5	1.0	1.8

Table 3. The effect of the tillage associated with anhydrous application on yields and N uptake (No N applied).

	Yields				N uptake			
Location	Grain Bu/A		Stover T/A		Grain		Stover	
East Central	Knife	No Knife	Knife	No Knife	Knife	No Knife	Knife	No Knife
Moldboard	47	39	1.5	1.4	20	19	12	11
Chisel	41	49	1.6	1.4	22	19	15	13
Ridge Till	36	34	1.2	1.1	17	14	10	9
No Till	35	31	1.3	1.1	16	13	9	9
South East								
Spring ( )								
Chisel	59	85	1.8	1.8	30	44	17	20
Ridge Till	67	59	1.3	1.3	35	31	15	15
Sidedress ( )								
Chisel	86	85	1.8	1.8	45	44	18	20*
Ridge Till	73	59	1.4	1.3	38	31	15	15

*Significant as the result of a paired to test at - .10, n = 4.

Table 4. The effect of tillage, N rate, and nitrification inhibitor on corn yield and N uptake at Becker, MN, 1985.

Tillage	N Rate lbs/A	Inhibitor	Yield Grain Bu/A	Yield Stover T/A	N uptake lbs/A Grain	N uptake lbs/A Stover
No Till	75	-	106	2.22	47	22
"	"	+	104	2.45	37	26
"	150	-	107	2.40	62	29
"	"	+	143	2.84	88	41
"	300	-	141	3.00	87	56
"	"	+	151	3.09	104	64
Ridge Till	75	-	92	2.24	40	19
"	"	+	120	2.04	63	20
"	150	-	133	2.66	60	32
"	"	+	152	2.90	78	43
"	300	-	167	3.11	106	50
"	"	+	169	3.20	118	51
Chisel	75	-	121	2.68	57	27
"	"	+	115	2.40	50	27
"	150	-	148	3.14	87	42
"	"	+	171	3.41	108	48
"	300	-	169	3.54	122	55
"	"	+	168	3.49	104	61
Moldboard	75	-	75	2.13	29	18
"	"	+	92	2.48	39	23
"	150	-	157	3.22	76	38
"	"	+	163	3.37	98	43
"	300	-	186	3.78	103	65
"	"	+	187	3.73	115	64

Main Effects

Tillage	Yield Grain Bu/A	Yield Stover T/A	N uptake lbs/A Grain	N uptake lbs/A Stover
No Till	125	2.67	71	40
Ridge Till	139	2.69	78	36
Chisel	147	3.11	88	43
Moldboard	144	3.12	77	42
P Value	99	99	95	90
N rate lbs/A				
75	101	2.33	45	23
150	147	2.99	82	39
300	167	3.37	107	58
P value	99	99	99	99
Inhibitor				
-	134	2.84	73	38
+	144	2.95	83	43
P value	99	97	99	99
Interactions	----------------------P value %--------------------			
Till X Rate	93	68	88	21
Till X Inhibitor	90	95	94	89
Rate X Inhibitor	99	62	96	92
Till X Rate X Inhibitor	93	67	97	28

Table 5. The effect of tillage, N rate, time of application and nitrification inhibitor on corn yield and N uptake at Goodhue Co., MN, 1984.

Tillage	N Rate lbs/A	Time of Application	Inhibitor	Yield Grain Bu/A	Yield Stover T/A	N uptake lbs/A Grain	N uptake lbs/A Stover
Ridge Till	75	Spring	-	138	2.55	87	44
"	"	"	+	151	2.70	102	44
"	"	SD	-	149	2.35	99	37
"	"	"	+	137	2.33	80	37
"	150	Spring	-	150	2.82	103	45
"	"	"	+	140	2.44	95	50
"	"	SD	-	136	2.47	89	33
"	"	"	+	152	2.73	98	45
"	300	Spring	-	149	2.86	95	50
"	"	"	+	159	2.75	116	49
"	"	SD	-	152	2.64	93	40
"	"	"	+	146	2.54	101	40
Chisel	75	Spring	-	144	3.02	94	47
"	"	"	+	126	2.55	85	41
"	"	SD	-	160	2.78	106	42
"	"	"	+	152	2.65	109	36
"	150	Spring	-	141	3.05	93	53
"	"	"	+	120	2.89	83	56
"	"	SD	-	172	3.20	118	46
"	"	"	+	170	3.14	106	53
"	300	Spring	-	153	3.03	107	49
"	"	"	+	137	2.95	110	57
"	"	SD	-	162	2.91	122	52
"	"	"	+	168	3.15	127	51

Main Effects

Tillage	Yield Grain Bu/A	Yield Stover T/A	N uptake lbs/A Grain	N uptake lbs/A Stover
Ridge Till	147	2.60	97	42
Chisel	150	2.94	105	49
P Value	78	97	94	89
N Rate				
75	145	2.62	95	41
150	148	2.84	98	47
300	153	2.85	109	48
P Value	93	99	99	99
Time of Application				
Spring	142	2.80	97	48
Sidedress	155	2.74	104	43
P Value	99	77	99	99
Inhibitor				
-	150	2.81	101	45
+	147	2.74	101	46
P Value	89	83	16	61
Interactions	----------------------P Value %-----------------			
Till X Rate	18	72	73	87
Till X Time	99	98	99	76
Till X Inhibitor	99	56	87	34
Rate X Time	91	90	37	02
Rate X Inhibitor	26	31	95	88
Time X Inhibitor	83	96	45	26
Till X Rate X Time	82	01	14	19
Till X Rate X Inhibitor	26	91	32	54
Till X Time X Inhibitor	98	37	87	53
Rate X Time X Inhibitor	97	52	74	58
Till X Rate X Time X Inhibitor	90	92	96	21

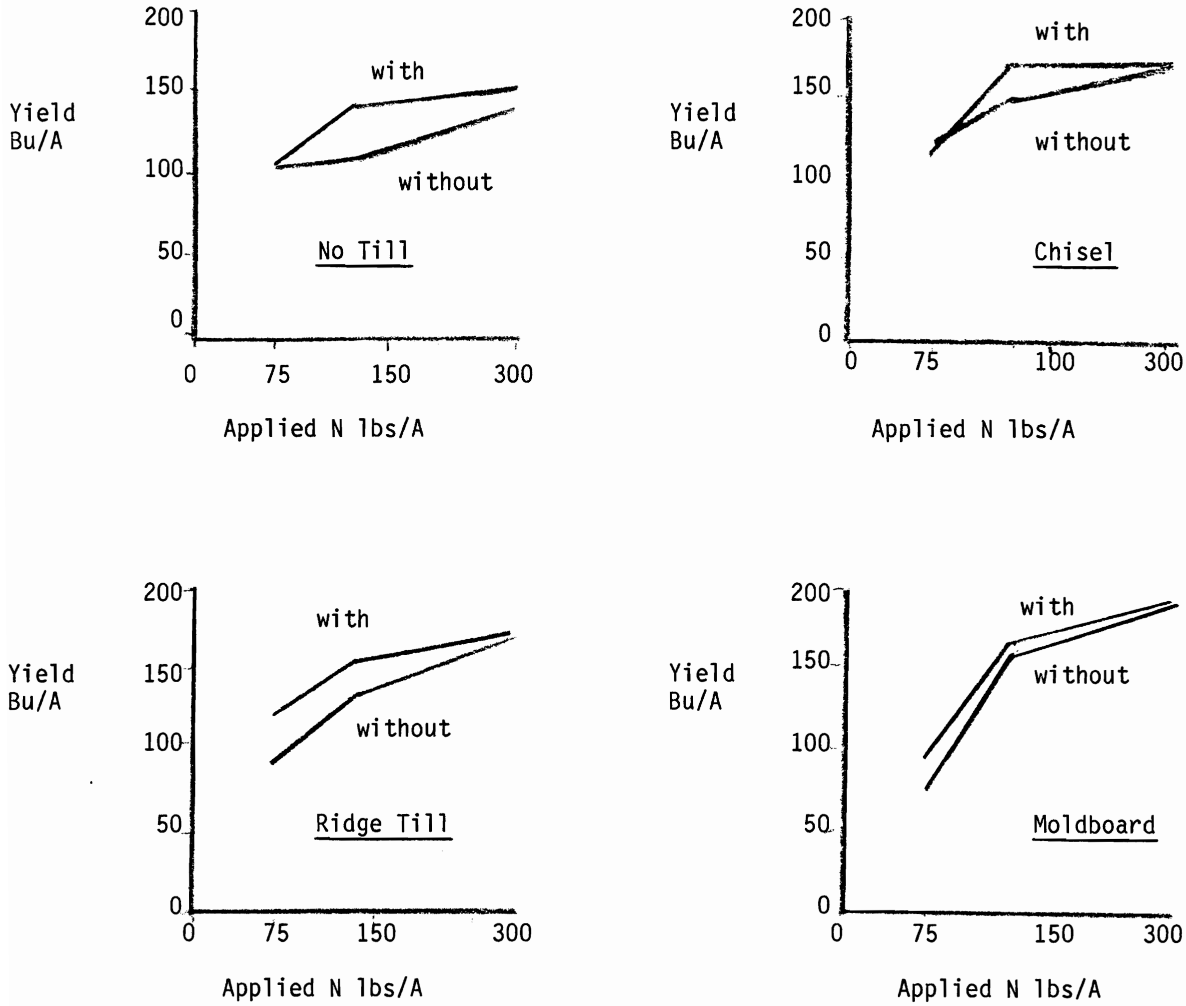

Figure 1. The effect of tillage, N rate, and nitrification inhibitor on grain yields at Becker, MN 1985.

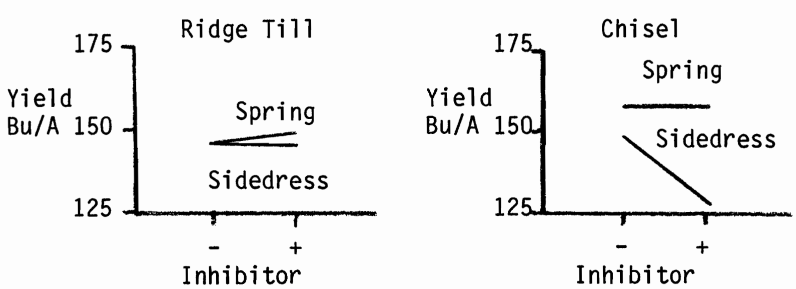

Figure 2. The effect of tillage, time of N application, and nitrification inhibitor over all rates of N at CE MN. 1985.

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