Soil Series 116

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

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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.

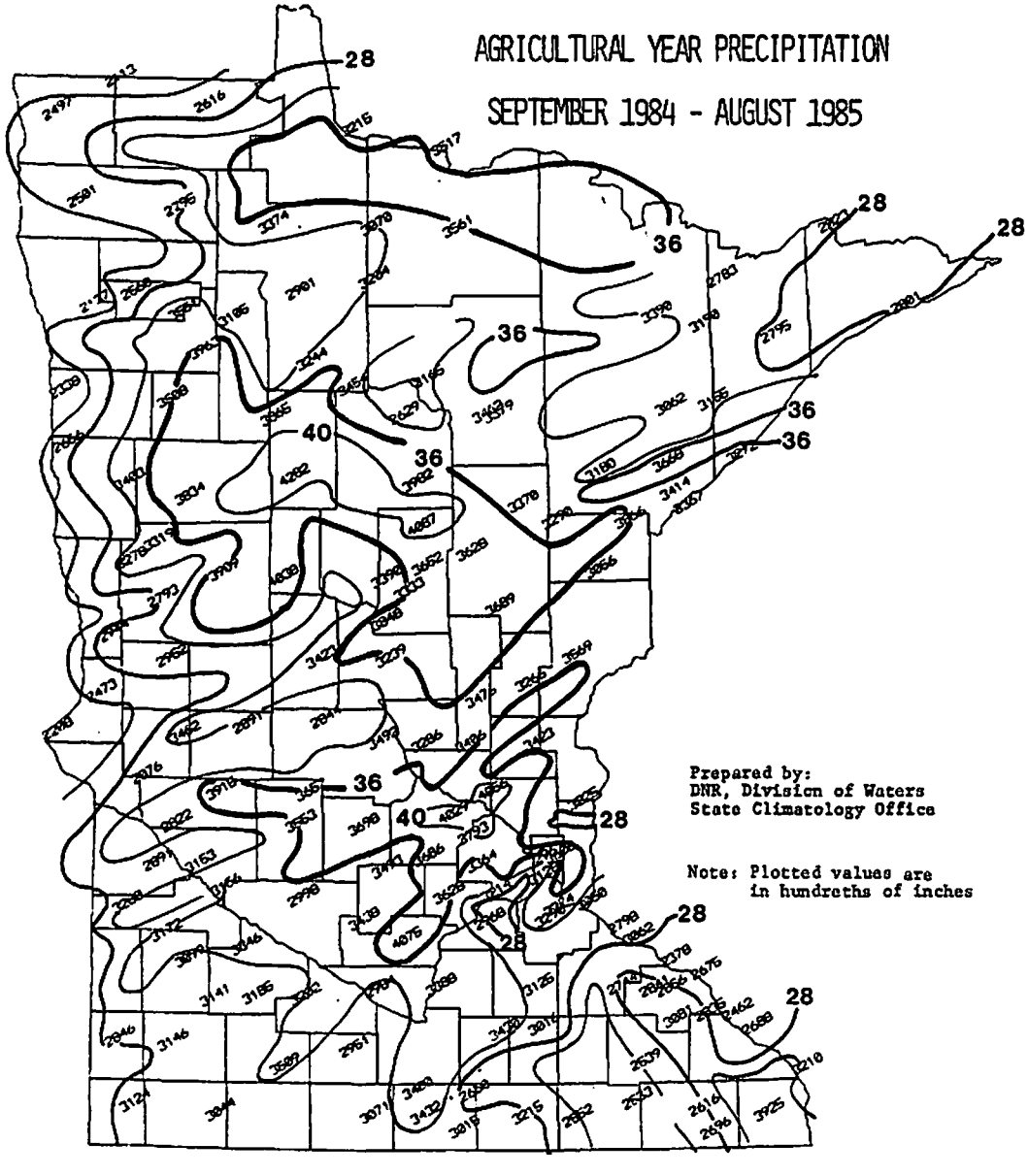


Fig. 1. Total agricultural year (September, 1984 - August, 1985) precipitation in inches.

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 exterding 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.

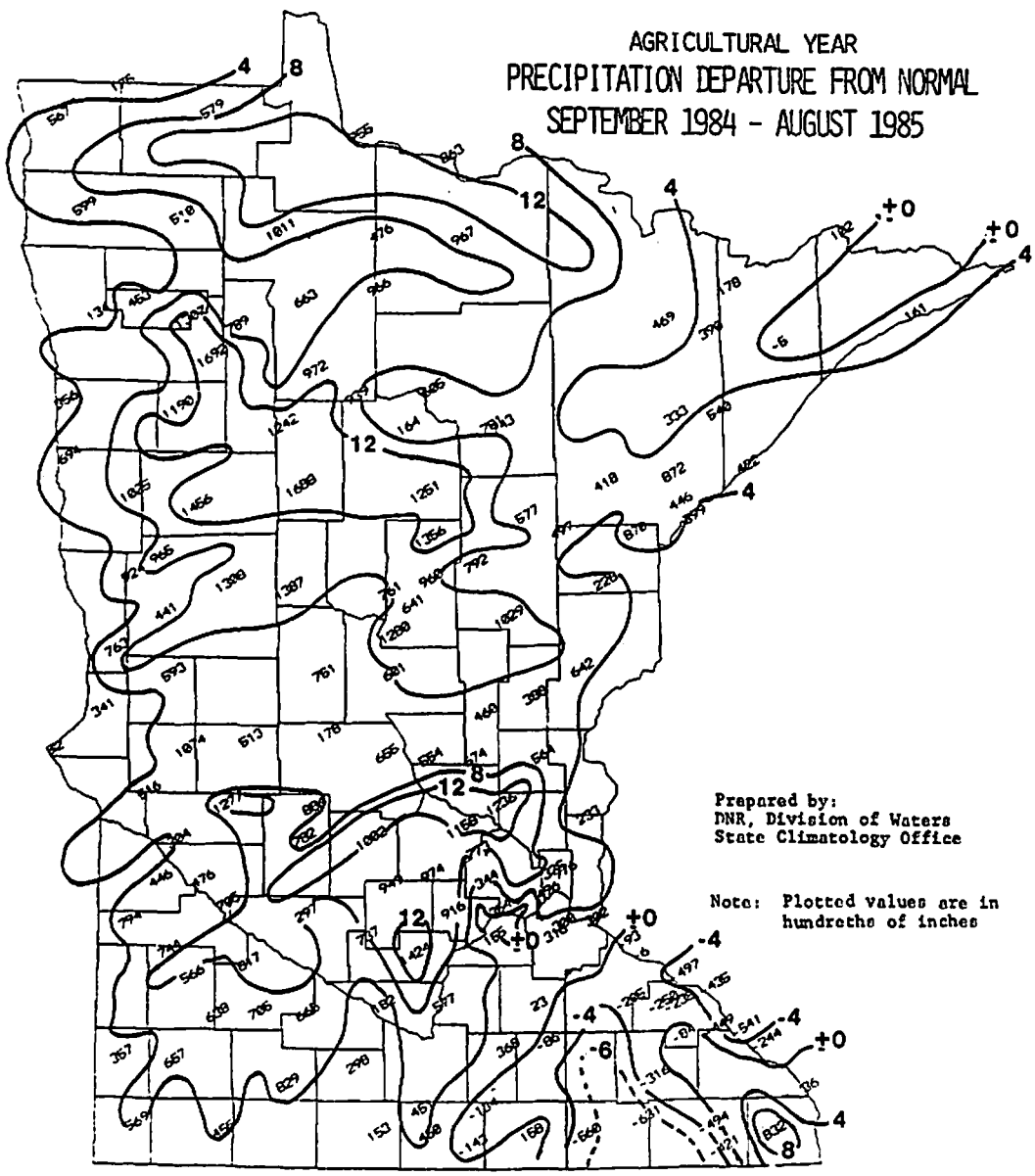


Fig. 2. Precipitation departure from normal in inches for the September, 1984 - August, 1985 agricultural year.

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.

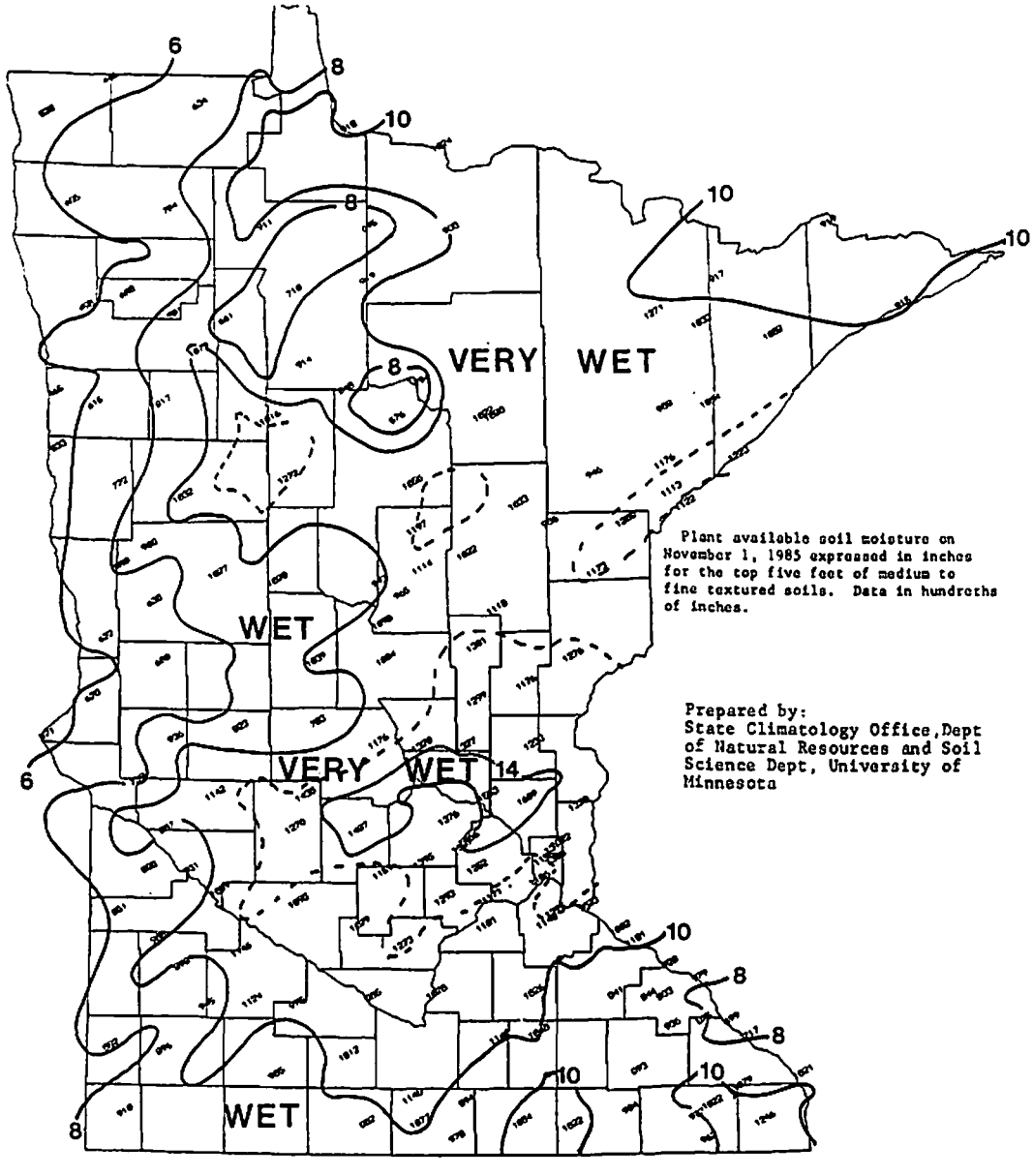


Fig. 3. Total plant available soil moisture on Nov. 1, 1985, expressed in inches, within the top 5 feet of medium to fine textures soils.

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.

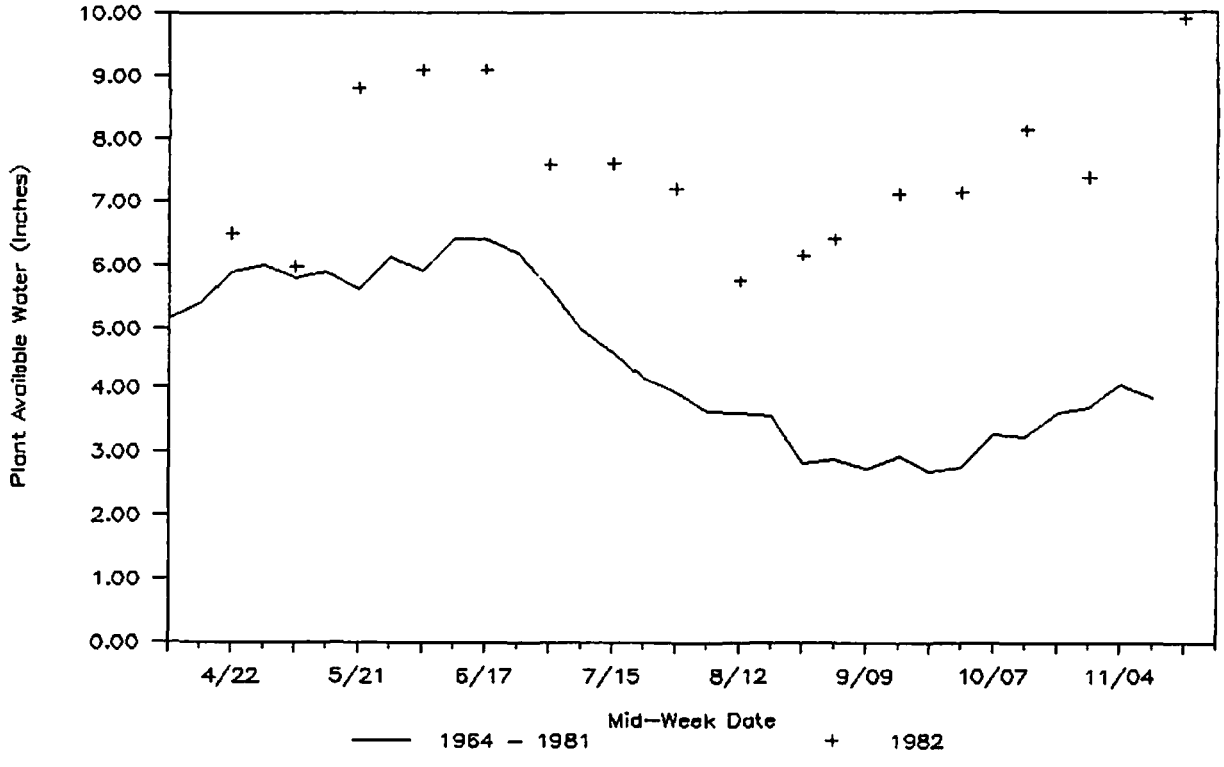


Fig. 4. Total plant available soil moisture under corn in 5 feet of soil during the 1982 season compared to the 1964-1981 average, Lamberton, Minnesota.

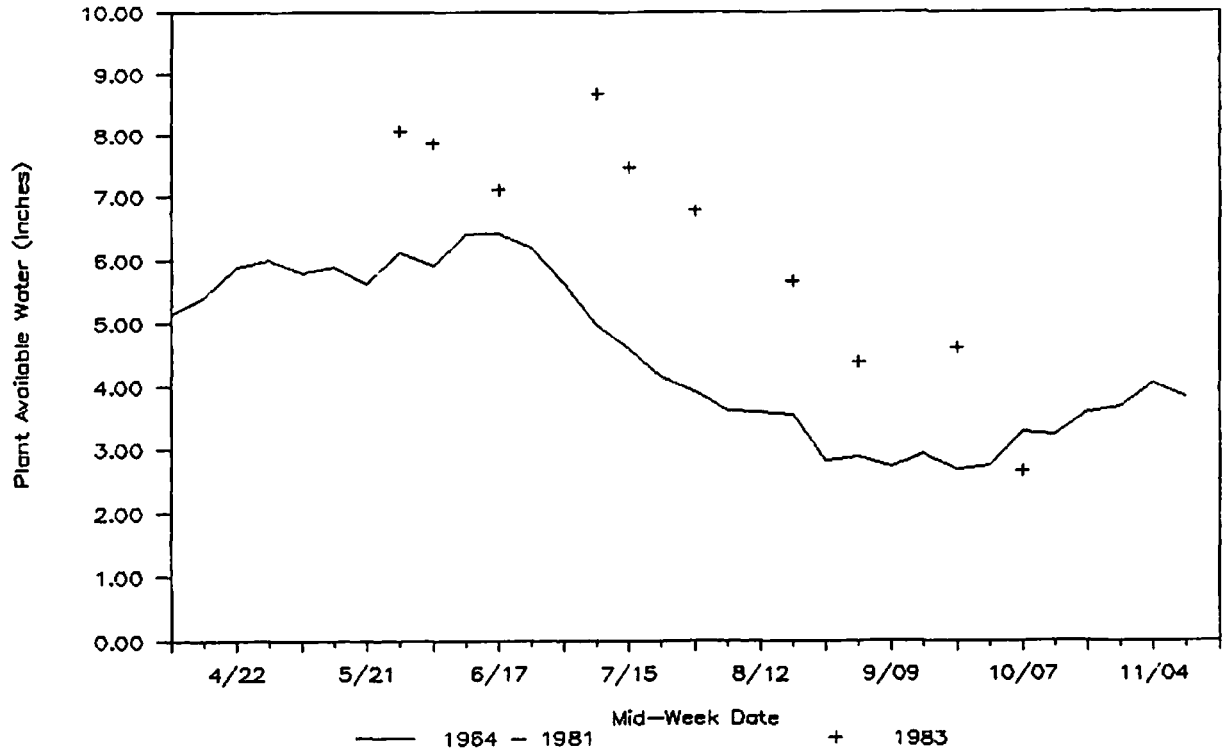


Fig. 5. Total plant available soil moisture under corn in 5 feet of soil during the 1983 season compared to the 1964-1981 average, Lamberton, Minnesota.

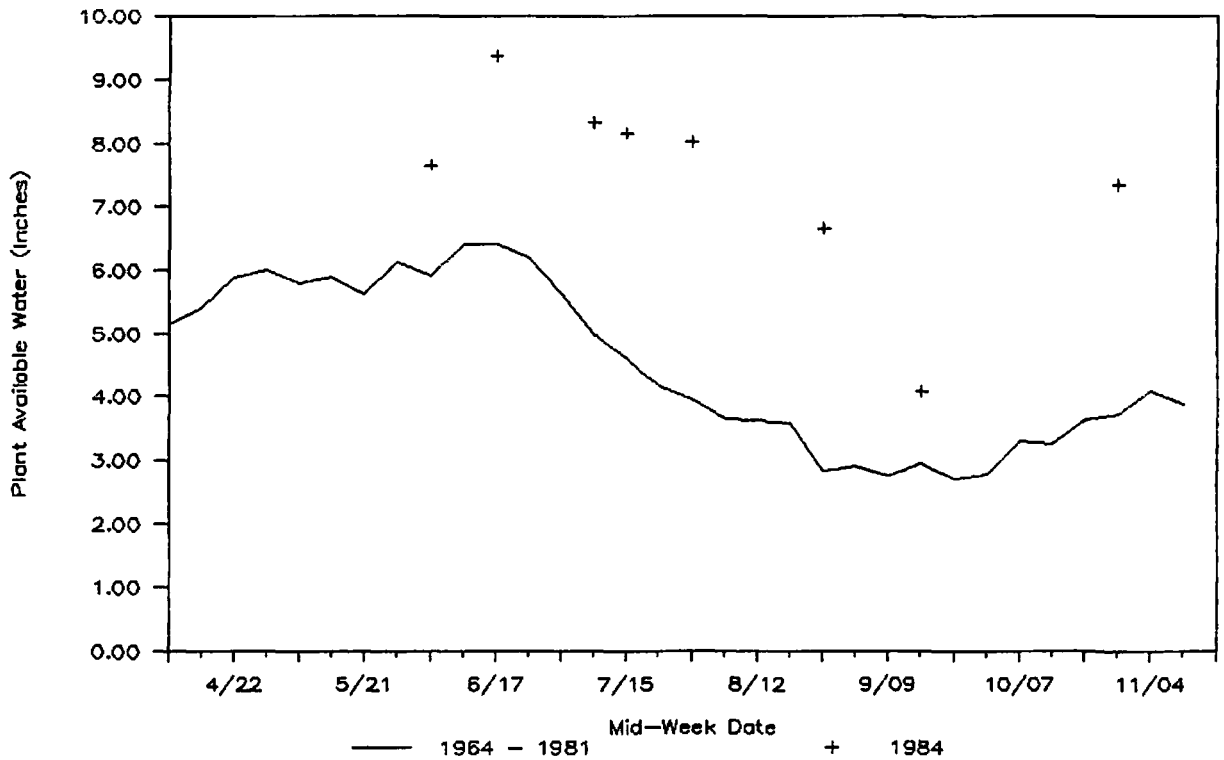


Fig. 6. Total plant available soil moisture under corn in 5 feet of soil during the 1984 season compared to the 1964-1981 average, Lamberton, Minnesota.

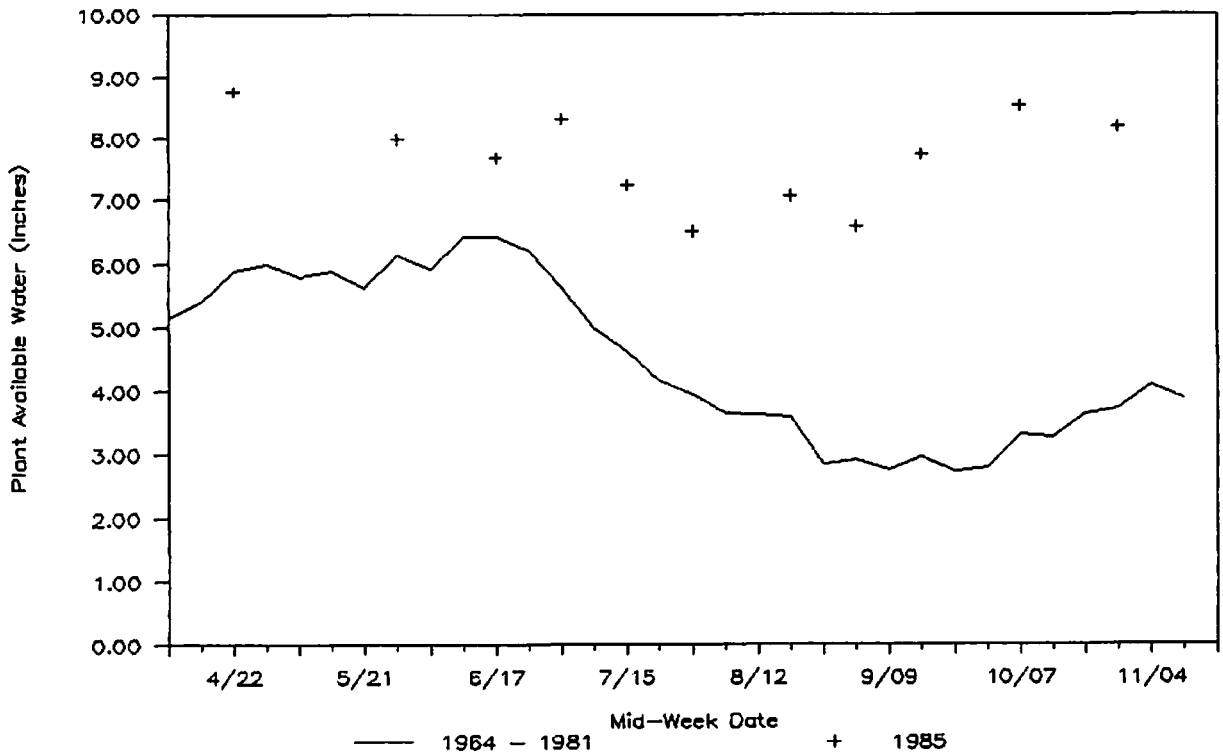


Fig. 7. Total plant available soil moisture under corn in 5 feet of soil during the 1985 season compared to the 1964-1981 average, Lamberton, Minnesota.

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.

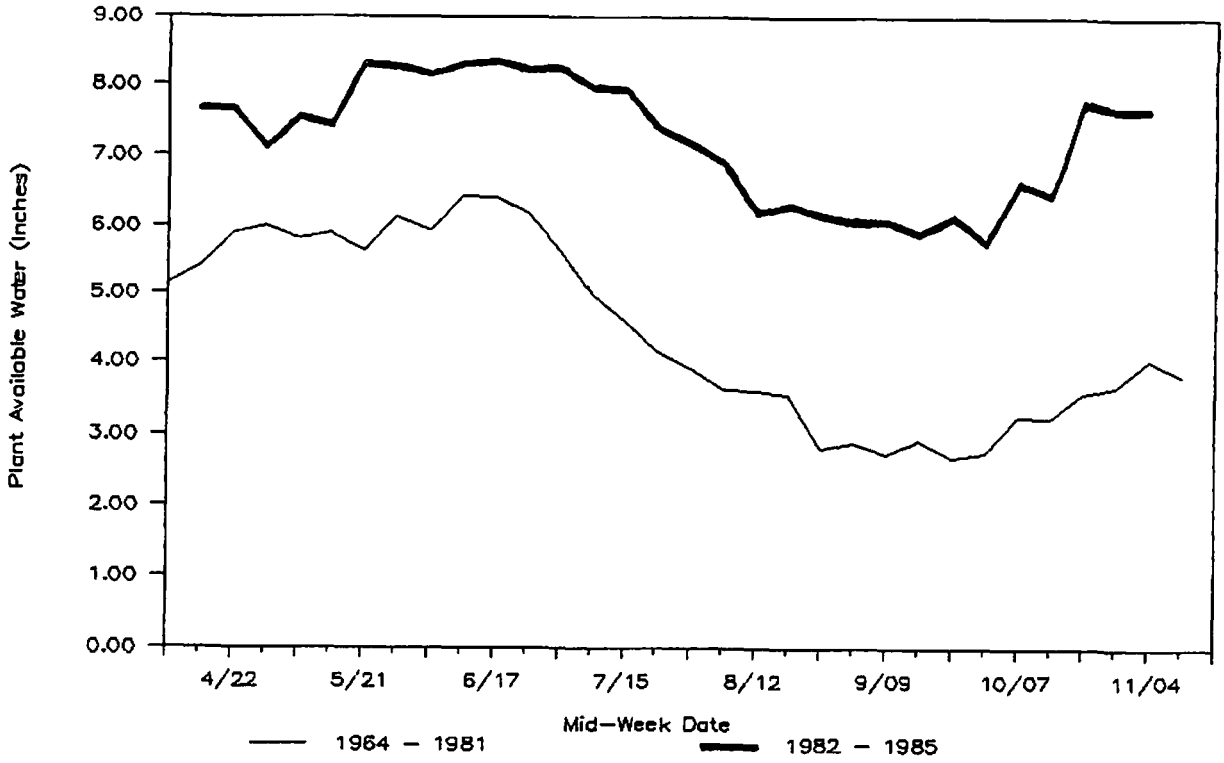


Fig. 8. Comparison between the average total plant available soil moisture under corn in 5 feet of soil during the 1982-1985 seasons and the 1964-1981 seasons, Lamberton, Minnesota.

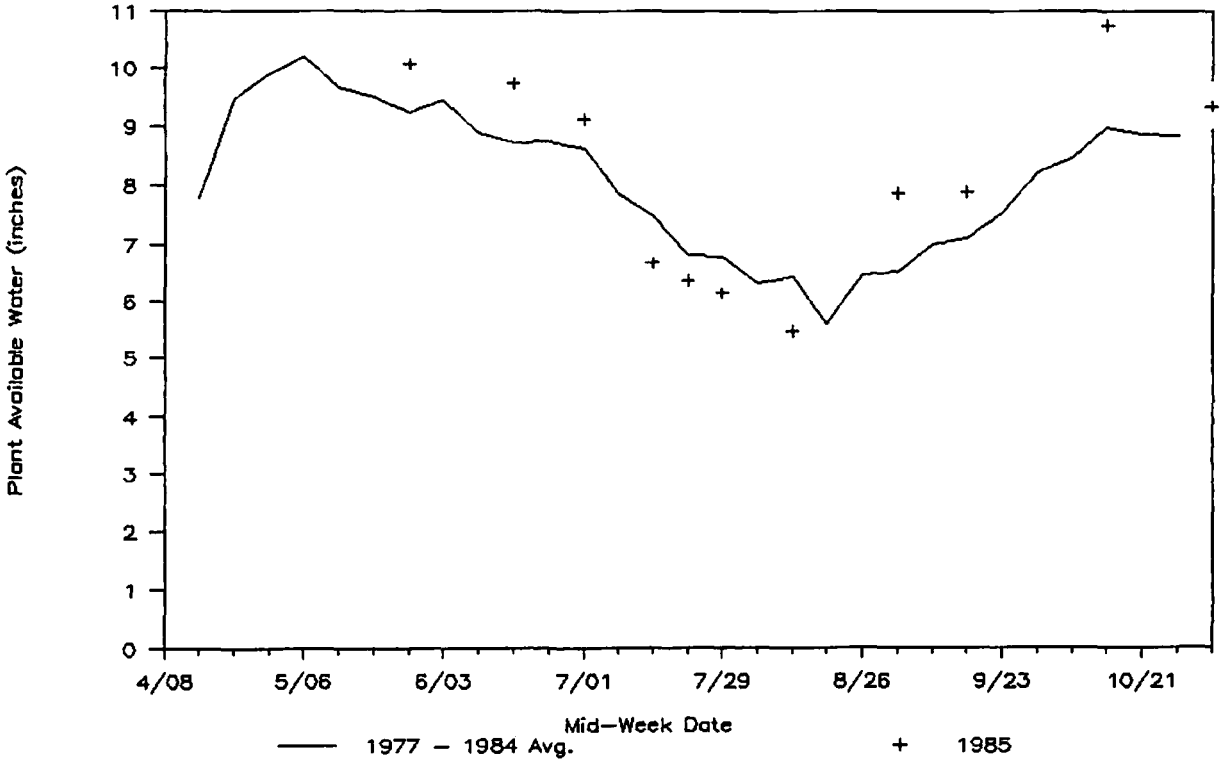


Fig. 9. Total plant available soil moisture under corn in 5 feet of soil during the 1985 season compared to the 1977-1984 average, Waseca, Minnesota.

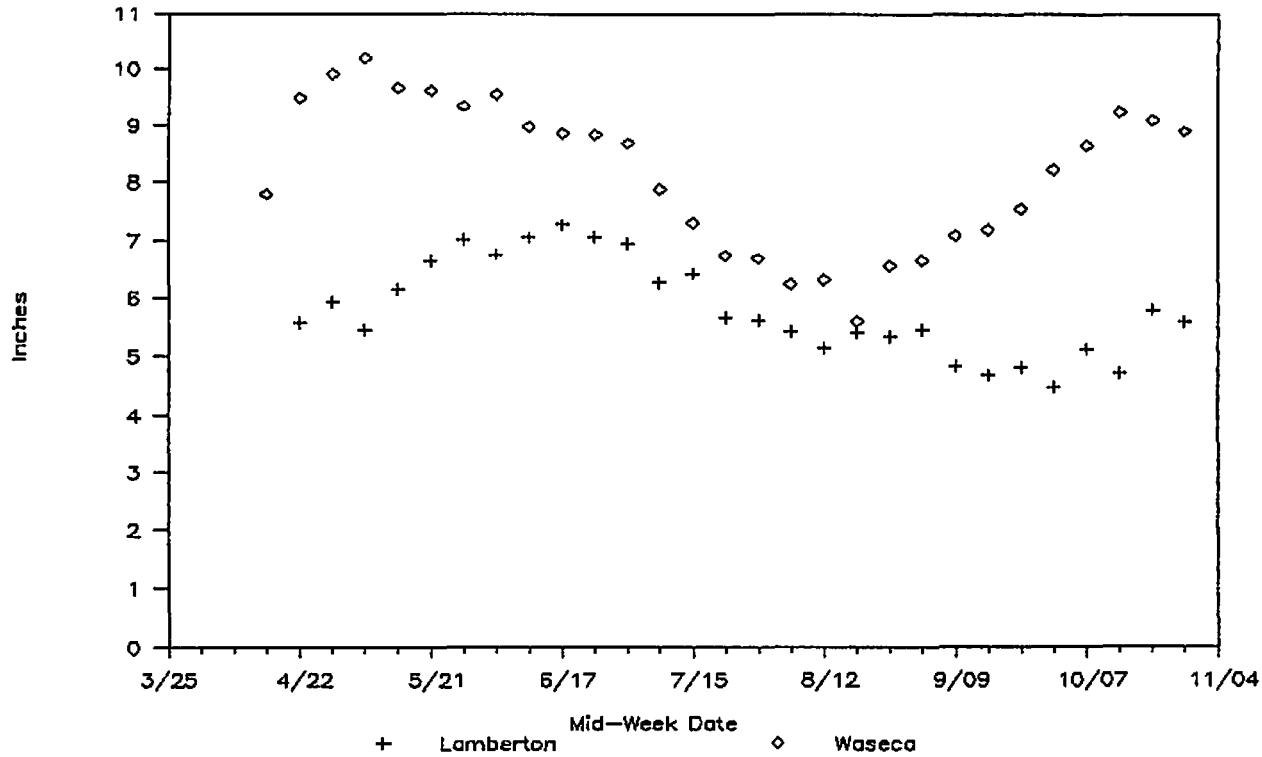


Fig. 10. Comparison between the average plant available soil moisture under corn at Lamberton and at Waseca, 1977-1985.

## 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.

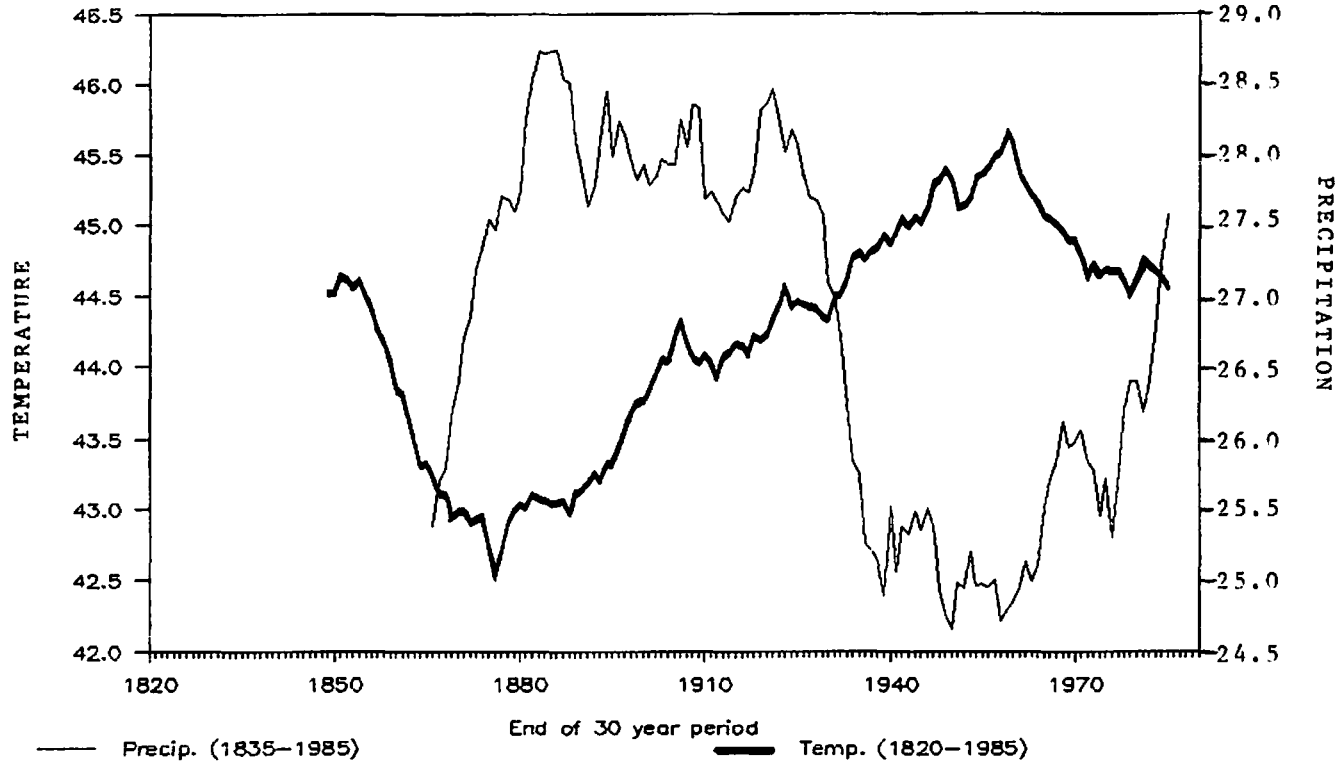


Fig. 11. Comparison of the long-term 30-year average annual temperatures and annual total precipitation at Minneapolis-St. Paul. The 30-year average value is plotted at the end of each 30-year period. The temperature record is from 1820-1985 and the precipitation record is from 1837-1985.

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.

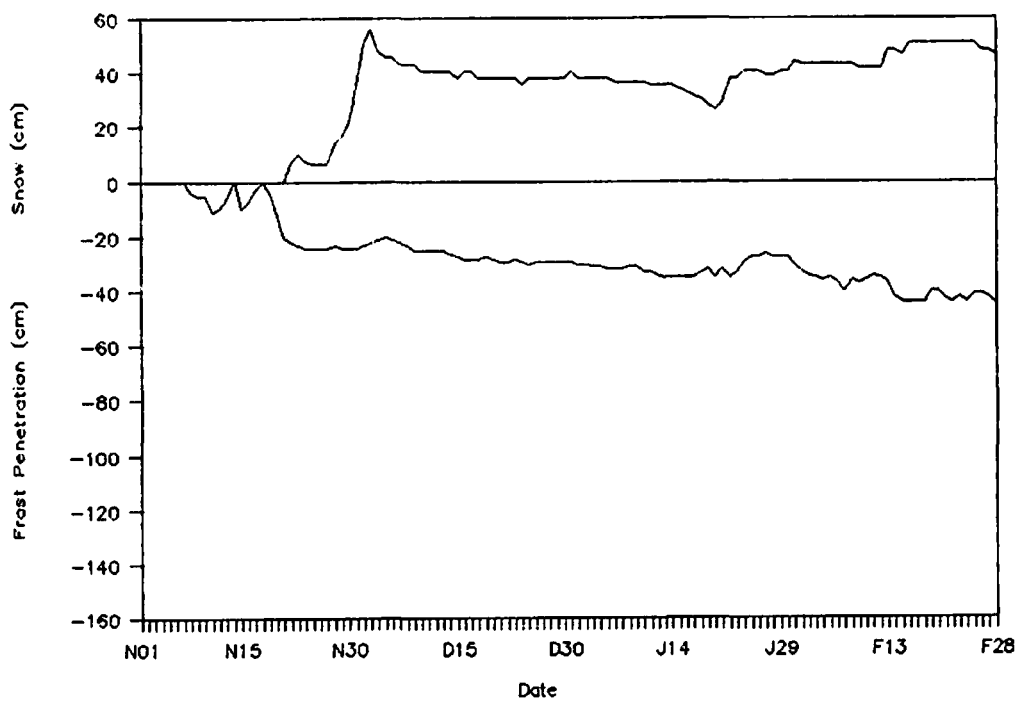


Fig. 12. Soil freezing depth and depth of snow cover in centimeters (10 cm = 4 inches) during the 1985-1986 winter at the University of Minnesota, St. Paul campus. The period is from Nov. 1 to Feb. 28.

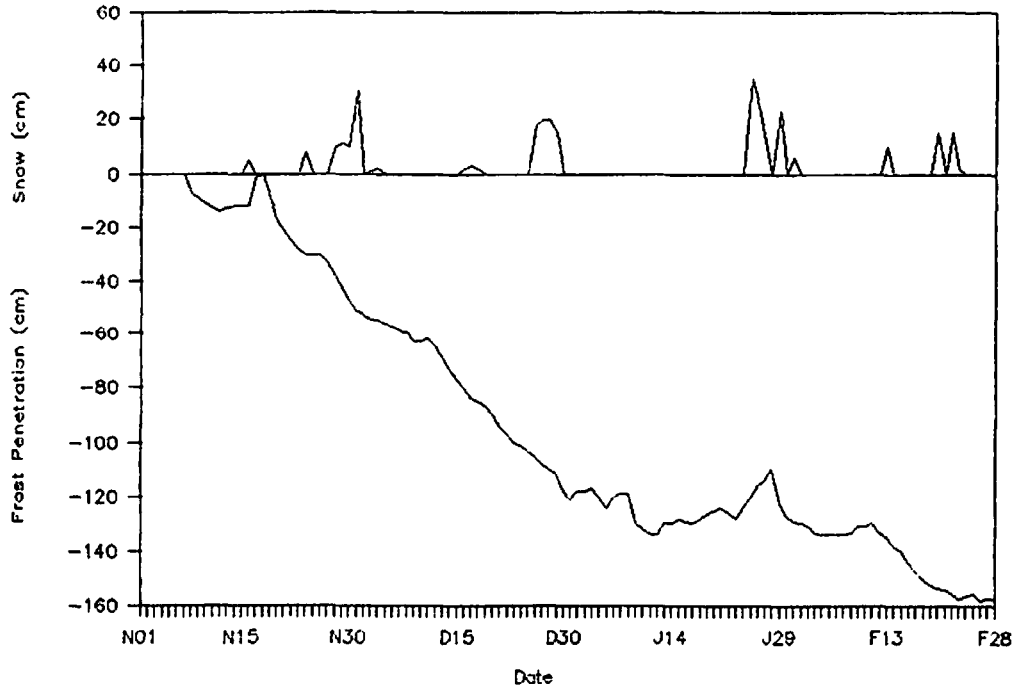


Fig. 13. Soil freezing depth in centimeters (10 cm = 4 inches) under a plot kept free of snow (except as indicated) during the 1985-1986 winter at the University of Minnesota St. Paul campus. The period is from Nov. 1-Feb. 28.

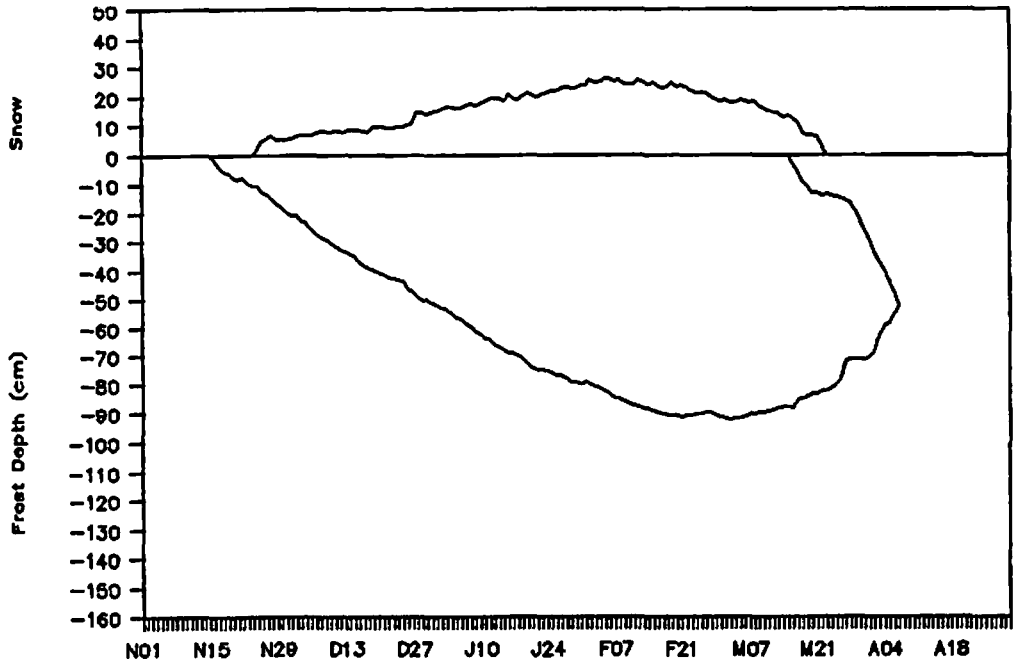


Fig. 14. Average soil freezing depth and average depth of snow cover in centimeters (10 cm = 4 inches) at the University of Minnesota St. Paul campus for 21 winters, 1964-1965 through 1983-1984.

# 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 | | 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 | % | lb/ton | Impurities Na | K | Amino N | 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 | | | |
| Method | Rate lb/ac | P | K | Ca | Zn | P | K | Ca | Zn |
| | | - - - % - - - | | | 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.

| Method | P Rate lb/ac | Grain Yield Bu/ac | Grain Test Weight lb/bu | Forage Yield lb/ac | Forage Uptake P lb/ac | Forage Uptake Zn 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 Yield | Grain Test Weight | Forage Yield | Forage P | Forage 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.

| Method | P Rate lb P/ac | Grain Yield Bu/ac | Grain Test Weight lb/bu | Forage Yield lb/ac | Forage Uptake P lb/ac | Forage Uptake Zn 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 Yield | Grain Test Weight | Forage Yield | Forage P | Forage 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 No. | Application Date | | | | | |
|---|---|---|---|---|---|---|
| | 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 No. | Elemental Analyses | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 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 | | |
| 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. | Year 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. | $NaHCO_3$-P Fall of Year | | | | | | Exchangeable K Fall of Year | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Initial | 1980 | 1981 | 1982 | 1983 | 1984 | 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 (%) =

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

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 treatments 1 and 2 |
| 4 | 120 lb/ac $CaCl_2$ | |
| 5 | 100 lb/ac Gypsum $CaSO_4$ | $Ca^{2+}$ source to compare treatments 3 and 4 |
| 6 | 200 lb/ac Gypsum $CaSO_4$ | |
| 7 | 92 lb/ac $K_2SO_4$ | $K^+$ source to compare with treatments 1 and 2 |
| 8 | 184 lb/ac $K_2SO_4$ | |
| 9 | 99 lb/ac Gypsum $CaSO_4$ | S source to compare treatments 7 and 8 |
| 10 | 198 lb/ac Gypsum $CaSO_4$ | |
| 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 of treatments 13 and 14 |
| 17 | 204 lb/ac $K_2O$ as 0-0-60 KCl | |

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.

| Treatment | Yield bu/ac | Protein % | Bushel Wt. lb/bu | Population plant/ac | Forage Yield lb/ac | Forage Concentration P ppm | Forage Concentration K ppm | Forage Concentration Ca ppm | Forage Uptake P lb/ac | Forage Uptake K lb/ac | Forage Uptake Ca lb/ac | Root Rot Index 7/10 | Root Rot Index 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 Test Weight | Grain Plumps | Grain Thins | Population | Forage Dry Matter |
|---|---|---|---|---|---|---|
| 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.