Soil Series 117

A Report on Field Research in Soil Science

The 1987 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.

Sincere appreciation is expressed for materials, financial assistance or program support from several organizations including: Potash and Phosphorus Institute of North America, Cenex, Farmland, Howe Incorporated, Minnesota Crop Improvement Association, American Soybean Association, Golf Course Superintendents Association, Sugarbeet Research and Education Board of Minnesota and North Dakota, Minnesota Soybean Research and Promotion Board, Minnesota Limestone Producers Association, Minnesota Plant Food and Chemicals Association, Minnesota Soil and Water Conservation Committee, Pioneer Hybrid International, Inc., U.S. Borax and Chemical Corporation, Shaklee Corporation, Dow Chemical, Terra Chemical, Allied Chemical Corporation, Shell Development, Monsanto, BASF Wyandotte Corporation, Ciba Geigy Corporation, Minnesota Soil Conservation Service, Minnesota Dept. for Energy and Economic Development, Minnesota Wheat Council, Minnesota Soybean Council, Malting Barley Improvement Association, The Red River Valley Potato Growers Association, The Iron Range Resources Commission, The Minnesota State Planning Agency, Minnesota Water Planning Board, The Water Resources Research Center of the Graduate School, The Staples Vo-Tech Institute, Tennessee Valley Authority-National Fertilizer Development Center, The North Central Forest Experiment Station, SKW Trostberg AG., The Sulfer Institute, Fluid Fertilizer Foundation, Potash Corporation of Saskatchewan, Corklin Company Inc., Minnesota Food Processors Association, Harris Laboratories Inc., American Crystal Sugar Quality Laboratory, A and L Midwest Agricultural Laboratories Inc., Minnesota Valley Testing Laboratories Inc., Holden Farms, Pillsbury-Green Giant, Birdseye-General Foods, and Ferti-Flo Fertilizer.

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

Some of the results are from 1986 experiments and should be regarded on this basis. Since most data are from only 1986 studies, conclusions may not be conclusive and thus are not for further publication without the written consent of the individual researchers involved.

The University of Minnesota, including the Agriculture Experiment Station, is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, creed, color, sex, national origin, handicap, age or veteran status.

Table of Contents

page

Agricultural Year Precipitation, September 1985 - August 1986.....1

The Lamberton Moisture Year.....5

The Waseca Moisture Year.....9

Air and Soil Temperature Variations.....13

Soil Freezing Depth and Duration.....14

Becker

Management of UAN on the Coarse Textured Irrigated Soils of Minnesota for Efficient Corn Production.....16

Influence of Nitrogen Application Time and Nitrification Inhibitor Rate on Sweet Corn Production on an Irrigated Sand.....23

Crookston

1986 Weather.....30

The Effects of Sulfur Application on Sugarbeet.....31

Starter Phosphorus Fertilizer on Sugarbeet.....32

The Effect of Nitrogen Rate and Plant Population on Sugarbeet.....33

Timing of Nitrogen Application on Sugarbeet.....34

Foliar Nitrogen Application on Sugarbeet-Timing and Rate.....35

High Phosphorus and Potassium Rates on Continuous Spring Wheat.....39

Intensive Fertilizer Management on Spring Wheat.....41

Micronutrients on Spring Wheat.....44

Yield and Root Rot Responses of Spring Wheat to Chloride Fertilization.....45

Survey of Soil Chloride Status in the Red River Valley.....46

Residual Soil N, Fertilizer N, and Inoculation Effects on Soybean Production in Northwestern Minnesota.....47

Use of Acid Based Fertilizers for more Efficient Soybean Production in Northwestern Minnesota.....49

Evaluation of the Efficiency of Band Placement of P Fertilizer for Corn, Soybean and Wheat....52

Lamberton

The Erosion-Productivity Study at the Southwest Experiment Station....58

Twenty Seven Years of Field Experimentation With Nitrogen Source, Placement, and Time of Application to a Webster Loam at the Southwest Experiment Station....62

Morris

West Central Experiment Station Weather Summary 1986....66

Residual Effect of Heavy Applications of Animal Manures on Corn Growth and Yield and on Soil Properties....67

Manure Rate Study....69

Continuous Corn Silage....71

Investigations of Tillage, N Rate and Corn Hybrid on a Pachic Udic Haploboroll....73

Soil Test Lab Comparison....76

Effects of Liquid Starter Rate, Placement and Analysis on Corn Growth and Yield....81

Soybean Tillage Study....85

Alfalfa Fertility-Management Study....89

Method of foliar Nitrogen Application on Three Spring Wheat Varieties....93

Topdressing Urea on Spring Wheat....95

Staples

Management of Boron for Crop Production on Irrigated Sandy Soils in Minnesota....96

Corn - Soybean Rotation....101

Lupine Bean Study....106

Triticale-Rye Study....113

Waseca

Weather Data 1986....115

Rotation Nitrogen Study....116

Split Application of N for Corn on a Webster Soil....123

Nitrogen Sources for Corn with Conservation Tillage in Southern Minnesota....130

Nitrogen Loss to Tile Lines as Affected by Tillage....138

Starter Fertilizer Placement Effects on Corn Production....141

Soil Test Comparison Study....145

Conservation Tillage for Corn and Soybean Production....149

Tillage Systems for Corn and Soybean Crop Sequences....156

Alfalfa

Liming Materials and Rates of Application for Alfalfa Production on an Acid Sandy Soil....159

Cauliflower

Leaf Tipburn in Cauliflower as Influenced by Genotype and Foliar-Applied Calcium Sprays....161

Compost

Evaluation of 'Agri-Brand' Compost as a Fertilizer Source for Processing Sweet Corn and Snap Beans....165

Corn

Decline Rates of Soil Test P and K in a Corn-Soybean Rotation....171

Nitrogen Sources and Rates for Continuous Corn in Goodhue County....174

Influence of Crop History and Manure Use on Nitrogen Rates for Corn Production in Southeastern Minnesota....177

Fertilizer Placement

Evaluation of the Relationship Between Tillage and Placement of P and K in a Corn-Soybean Rotation....181

Effect of Potassium Placement on Corn Production in a High Yield Environment in Southeast Minnesota....191

Peas

Influence of Seed Inoculation, Nitrogen Source, and Nitrogen Rate on Productivity of Processing Peas....199

Potatoes

Nitrogen Fertilizer Rate and Timing Studies on Irrigated Potatoes....207

Strawberry

Variation in Foliar Nutrient Composition of Strawberry as Influenced by Genotype and Location....211

Sulfur

Sulfur Management for Corn Production on Irrigated Sandy Soils....215

The Effect of Sulfur Fertilization on Yield and Forage Quality of Corn and Alfalfa....218

Tillage

The Effect of Tillage on Corn and Soybean Production in Southeastern Minnesota....229

The Effect of Tillage System on Stand Establishment, Presence of Weeds, Growth, Grain Yield, and Protein Content of Winter and Spring Wheat, and Barley....243

The Effect of Tillage System, Variety, and Fungicide Application on Winter and Spring Wheat, Barley, and Soybean Production....254

Corn - Tillage Residue Management....268

Tillage and Diffuse Source Phosphorus Pollution in the Clearwater River Watershed, Minnesota, 1986....275

The Effect of Tillage on Soil Nitrogen with Corn and Soybean Production in Southeastern Minnesota....284

AGRICULTURAL YEAR PRECIPITATION, September 1985 - August 1986

J.A. Zandlo, State Climatology Office

Precipitation for 1986 again generally continued at above 1951-80 normal rates. The pattern of distribution for the 1986 Agricultural year is presented here in map form as Figure 1. For the Agricultural year ending August 1986, unofficial precipitation totals ranged from 16.23 inches in Kittson county to 52.11 inches in Kandiyohi county. The largest departures from normal were concentrated in the west to east central portions of the state. Portions of Kandiyohi, Meeker, Stearns, Pope, Sherburne, and Pine county received more than 44 inches of precipitation. Conversely, small portions of the northwest and north central regions of the state were actually a few inches below normal for the Agricultural year.

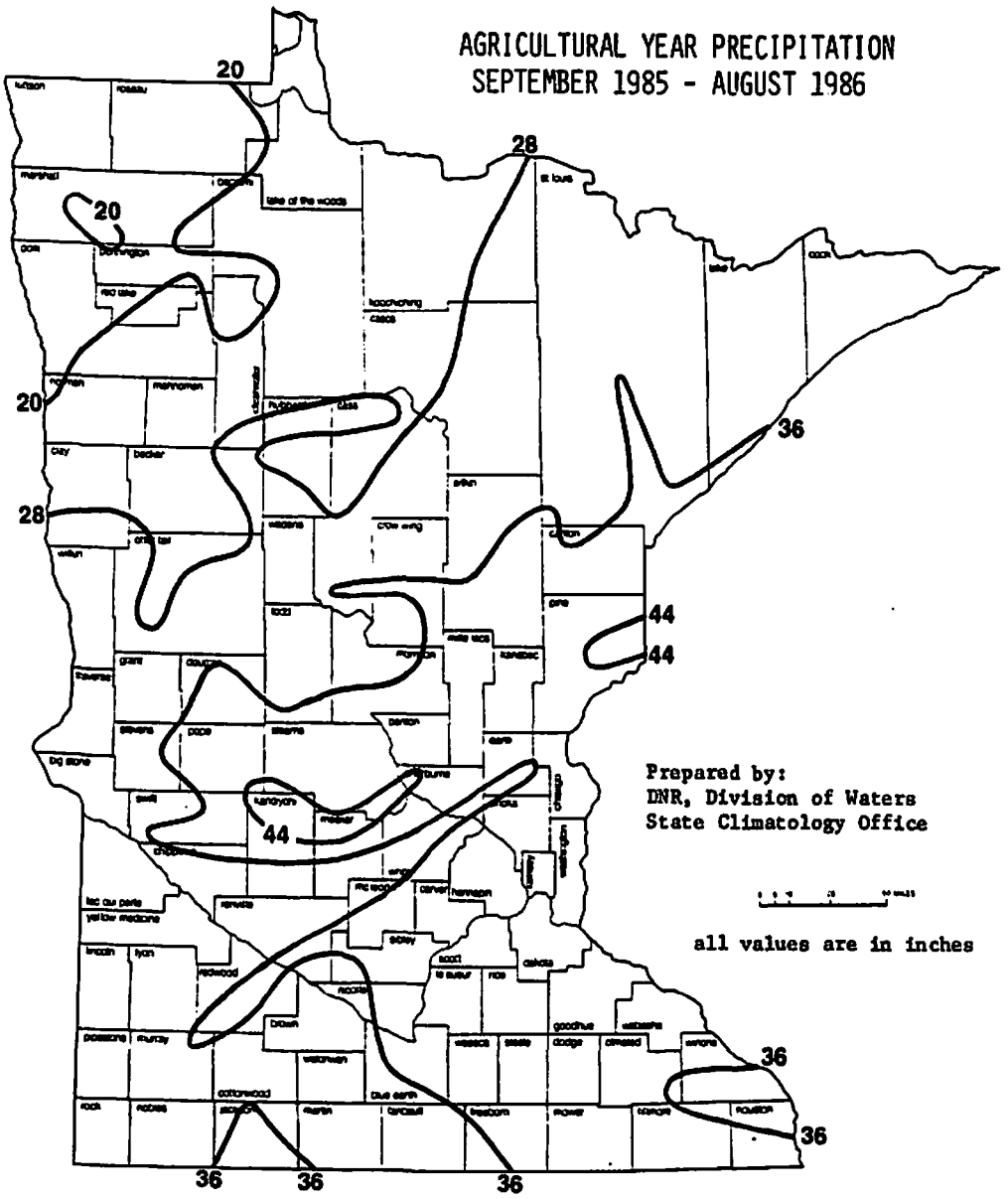
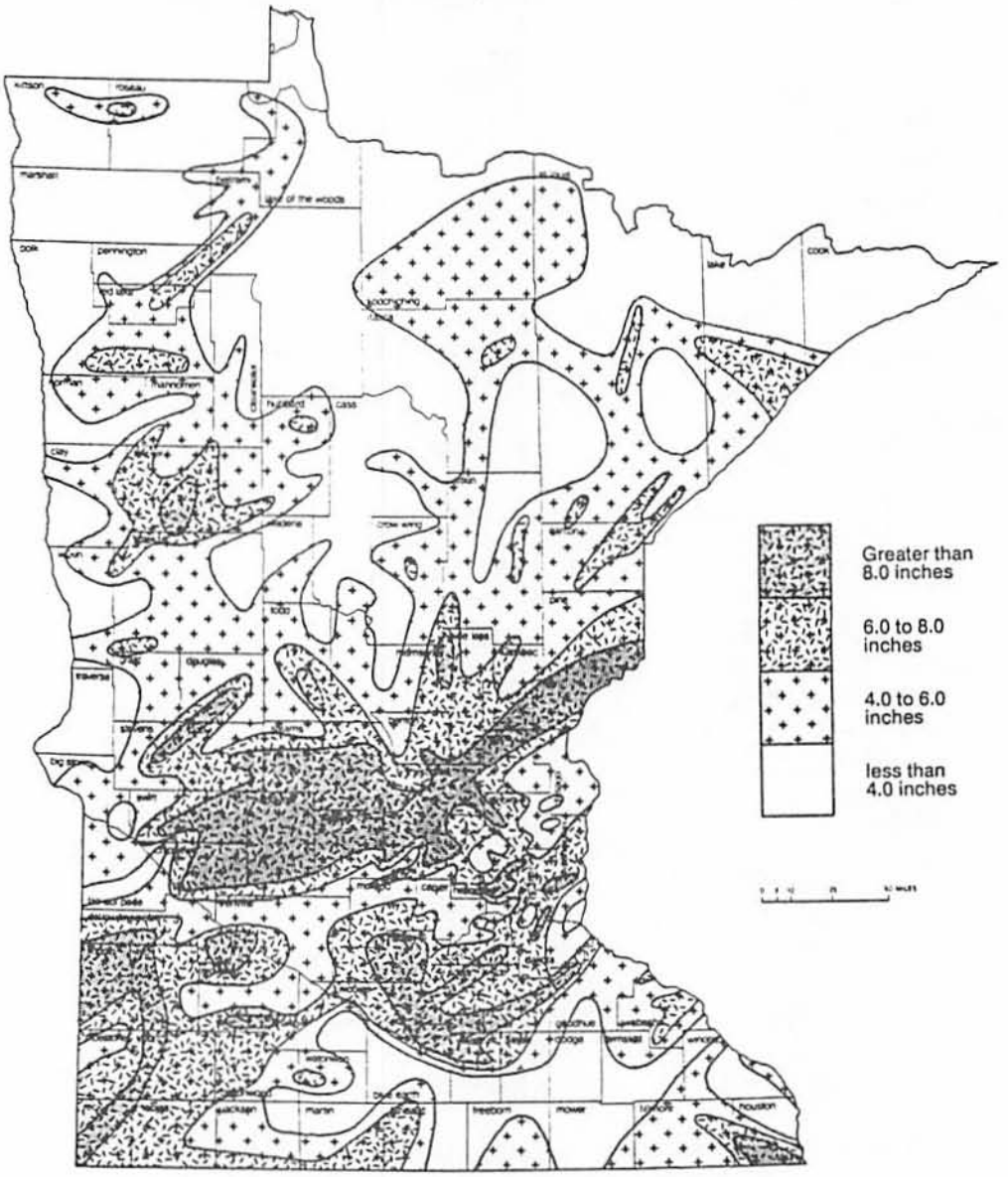


Figure 1. Agricultural precipitation September 1985-August 1986.

While most months since September 1985 were just marginally above normal in most areas of the state, some months were record breakers. September 1985, included in the Agricultural year precipitation totals, was a wet month in portions of Minnesota but September 1986 was even wetter with many all-time September precipitation records broken. The other month with notable excesses over normal was April 1986 which was as much as three times normal in some portions of the state. During the closing months of 1986, October through December, the nearly continuous string of above normal precipitation months starting in late 1985 came to an end.

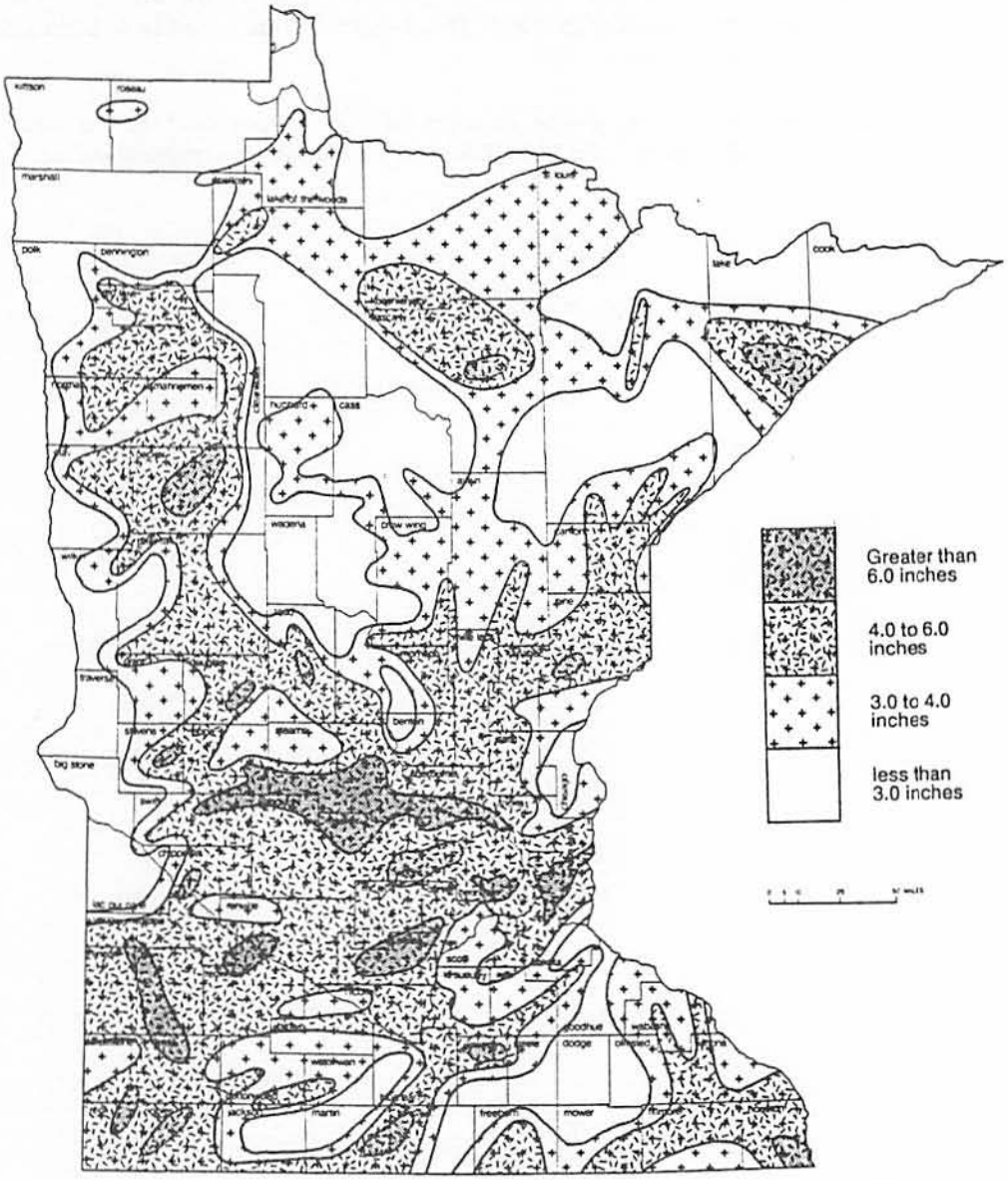
At mid-year, a new 50 inch plus 12 month precipitation total had been recorded by a long term National Weather Service climate station in Minnesota. New London recorded 50.58 inches of precipitation for the period August 1985 through July 1986. 50 inches or more precipitation in a twelve month period for areas of Minnesota outside of the southeast corner has only been observed at Duluth with 52.35 inches in 1882 and at Isle with 53.04 and Long Prarie with 50.68 both in 1972. Many other points in Minnesota experienced new 12 month record levels of precipitation at some time during 1986.



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

Figure 2. Average annual departure from normal precipitation for 1982-1986(5 years).

1986 caps a record breaking 10 year period of wetness for much of the state. Many of the long term climate stations of the National Weather Service had never experienced a wetter 10 year period than the one which ended with December 1986. The 10 year total at Caledonia, 387.82 inches, has the further distinction of being the highest 10 year total ever observed in the state of Minnesota! In order to more readily depict the magnitude and distribution of the continuing tendency for excessive precipitation across Minnesota, two special maps, Fig. 2 and 3, have been prepared; 'Average Annual Departure from Normal Precipitation for 1982-1986 (5 Years)' and 'Average Annual Departure from Normal Precipitation 1977-1986 (10 Years)'.



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

Figure 3. Average annual departure from normal precipitation for 1977-1986 (10 years).

The 5 year departure map shows a broad but broken swath of very large departures extending from the southwest corner through the midsection and into the east central portions of the state. In a rough sense, departures more than 4 inches may be thought as a 'once in 25 years' condition, while amounts greater than 6 inches can be thought as 'once in 40 years' condition. Such an interpretation implies that many people are unlikely to have witnessed such long term wetness at any time in their lives. In fact, the last time such levels of wetness have been so generally distributed across the state appears to have been in the first decade of this century.

The 10 year departure map is not qualitatively different from the 5 year map. However, the most extreme departures do not seem so heavily concentrated in the middle of the state. Portions of the northern sections of the state exhibit departure levels as high as anywhere else in the state. On this map values greater than about 3 inches might be regarded as 'once in 25 years' events, while 4 inches is the threshold for once 'once in 40 years' events.

Note that the interpretation of the shading levels in terms of 'return periods' is the same for both maps. That is, a given type of shading will imply the same frequency of occurence regardless of which map is being examined.

THE LAMBERTON MOISTURE YEAR

D.G. Baker, D.L. Ruschy, W.W. Nelson, and T. Strasser

As noted in the previous section Minnesota has been the beneficiary of above normal precipitation for a relatively lengthy period. For Lamberton it has been five of the last five years and seven of the last 10 years. This represents an unusual period as may be seen by inspection of Fig. 4. (Fig. 4 represents the agricultural year of September-August rather than the more usual calendar year total). This current "wet" period may be considered as making up for the 12 year period of 1966-1977 when the annual precipitation was below average in nine of the 12 years.

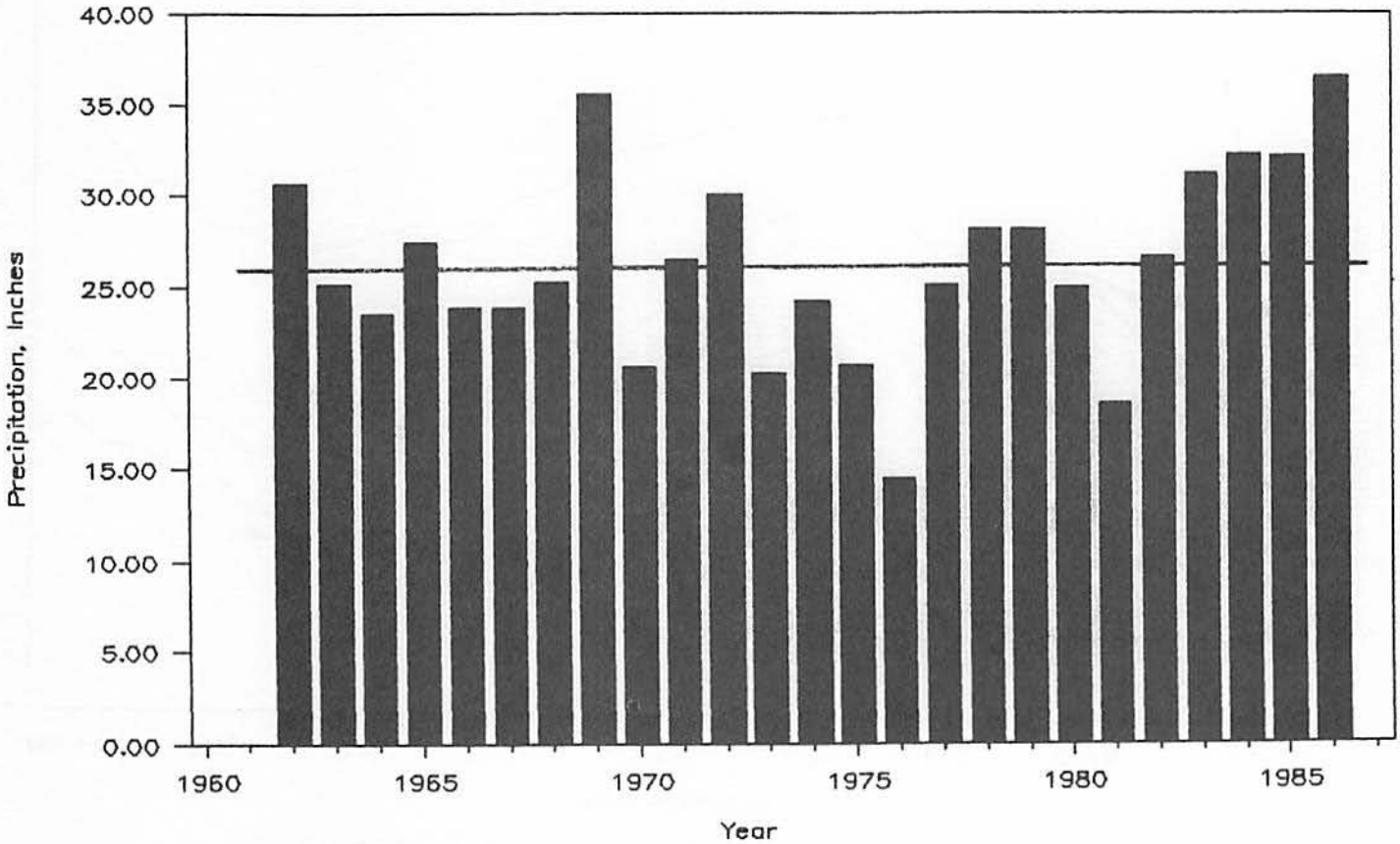


Figure 4. Total agricultural year precipitation at the Southwest Agricultural Experiment Station, Lamberton, 1962 - 1986. The annual average for 1962 - 1985 is 25.77 inches.

There is a phrase that goes "we'll pay for this bye and bye". Which is simply a statement of the fact that there is a general average for the precipitation. Although the current high precipitation may vary considerably from the average for a period of time, there will reach a point when a reversal occurs. Unfortunately the time of the reversal cannot be predicted. But it can be said without fear of contradiction that a change in our precipitation pattern can be expected. The above-average agricultural year precipitation occurring during the last several years in Minnesota, and indeed over a large area of northern United States from the Great Lakes westward to the Rockies, cannot be expected to continue. It may well be a very good thing that we are learning about and have begun practicing conservation tillage now before the reversal in precipitation begins.

The above average precipitation is of course reflected in the soil moisture. Indeed it has altered the average soil moisture picture considerably from what it was. This is evident in Fig. 5, which shows the total plant available soil moisture in a 5-foot soil profile under corn. The lowest line is the 1964-1981 average, the middle one is the 1964-1986 average, and the top one represents the 1982-1986 average. The greatest and most significant change has been the increase in the late July and August soil moisture content. In the past years this has been the period when the soil moisture reserves have been drawn upon so heavily in order to make-up for the large plant requirements and the usually limited precipitation of that period.

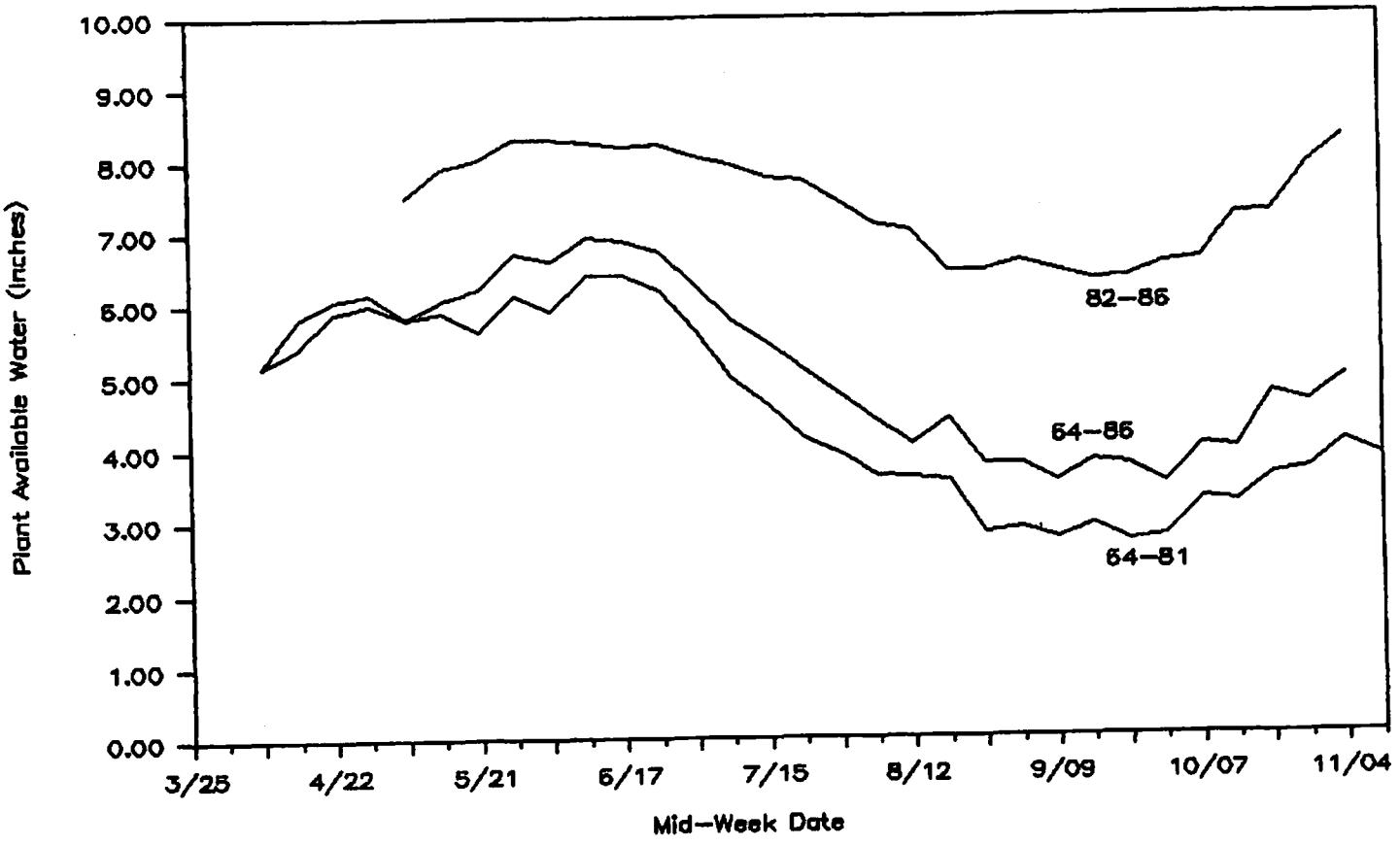


Figure 5. Plant available soil moisture in a 5-foot column of soil under continuous corn at the Southwest Agricultural Experiment Station.

An extremely interesting picture of soil moisture usage is presented is Fig. 6. This shows the average amount of water in each foot of the five-foot soil profile during the 23-year period 1964-1986. Several things are worthy of note. One is the timing of the high and low amounts of soil moisture. The maximum is reached at all depths within about a three week period varying from the week of June 10 to June 24. However, due to plant moisture requirements and plant and root development the mimimum soil moisture within the profile has about a seven week spread. This is shown in greater detail in Table 1.

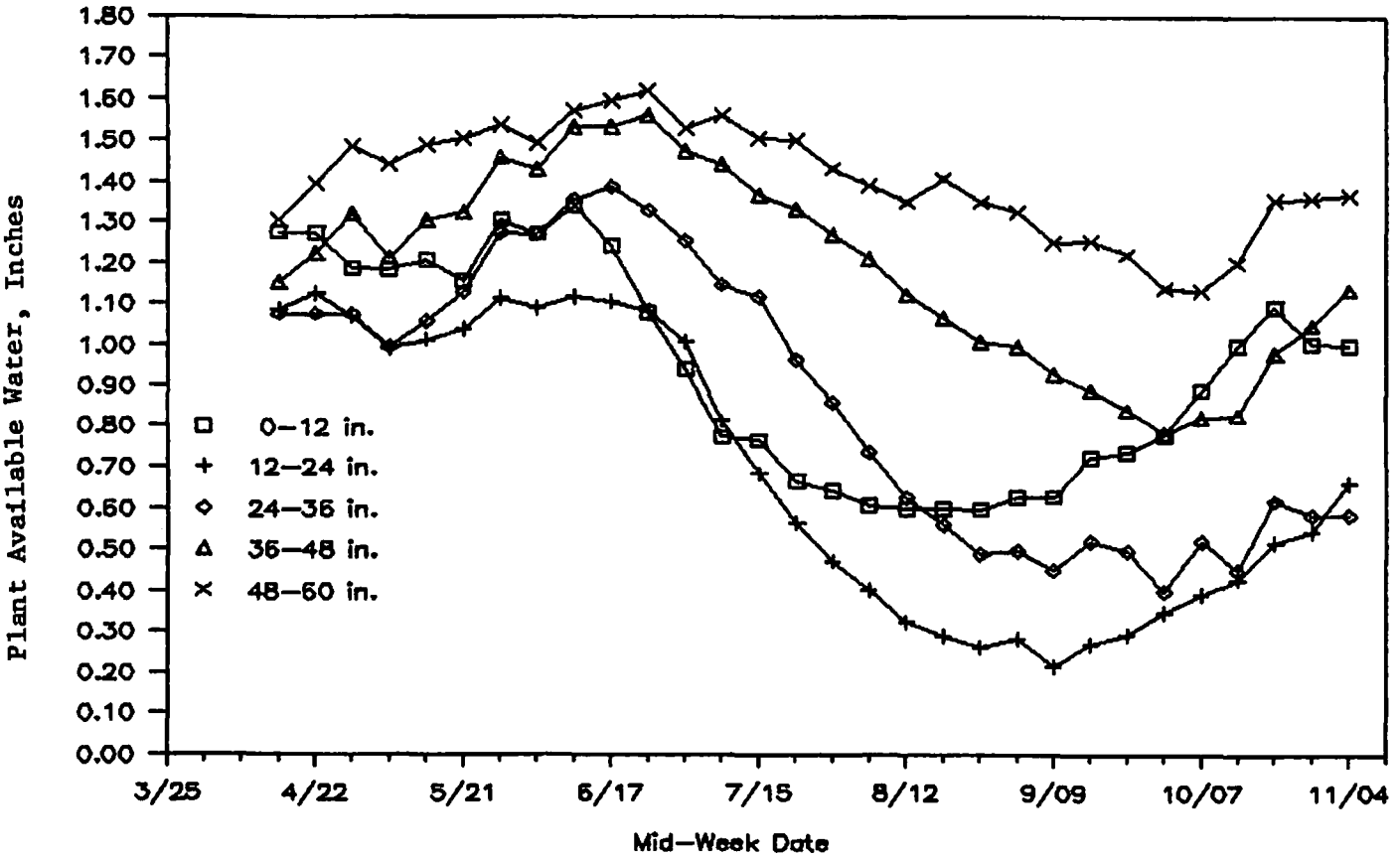


Figure 6. Average amount of plant available soil moisture in each foot of soil under continuous corn at the Southwest Agricultural Experiment Station, Lamberton, 1964 - 1986.

Table 1. The average date of the occurrence of the soil moisture maximum and minimum contents in each foot of soil at Lamberton, 1964-1986.

Depth	Maximum soil moisture	Minimum soil moisture
0-12 in.	June 10	August 17
12-24	June 10	September 9
24-36	June 17	September 23
36-48	June 17	September 30
48-60	June 24	October 7

The amounts of plant available soil water in each foot of soil at the times of maximum and minimum contents are listed in Table 2. The difference between the maximums and minimums is alos shown and represents the water supplied to the crop. This amount plus the precipitation between the period represents then the total water consumed by the crop. This assumes no runoff or downward drainage through the soil profile.

Table 2. The average amount of plant available soil water in each foot of soil at the time of the maximum and minimum contents (see Table 1) at Lamberton, 1964-1986.

Depth	Soil Water at maximum	Soil Water at minimum	Difference
0-12 in.	1.33 in.	0.60 in.	0.73 in.
12-24	1.10	0.22	0.88
24-36	1.38	0.40	0.98
36-48	1.74	0.78	0.96
48-60	1.61	1.14	0.47
Total	7.16	3.14	4.02

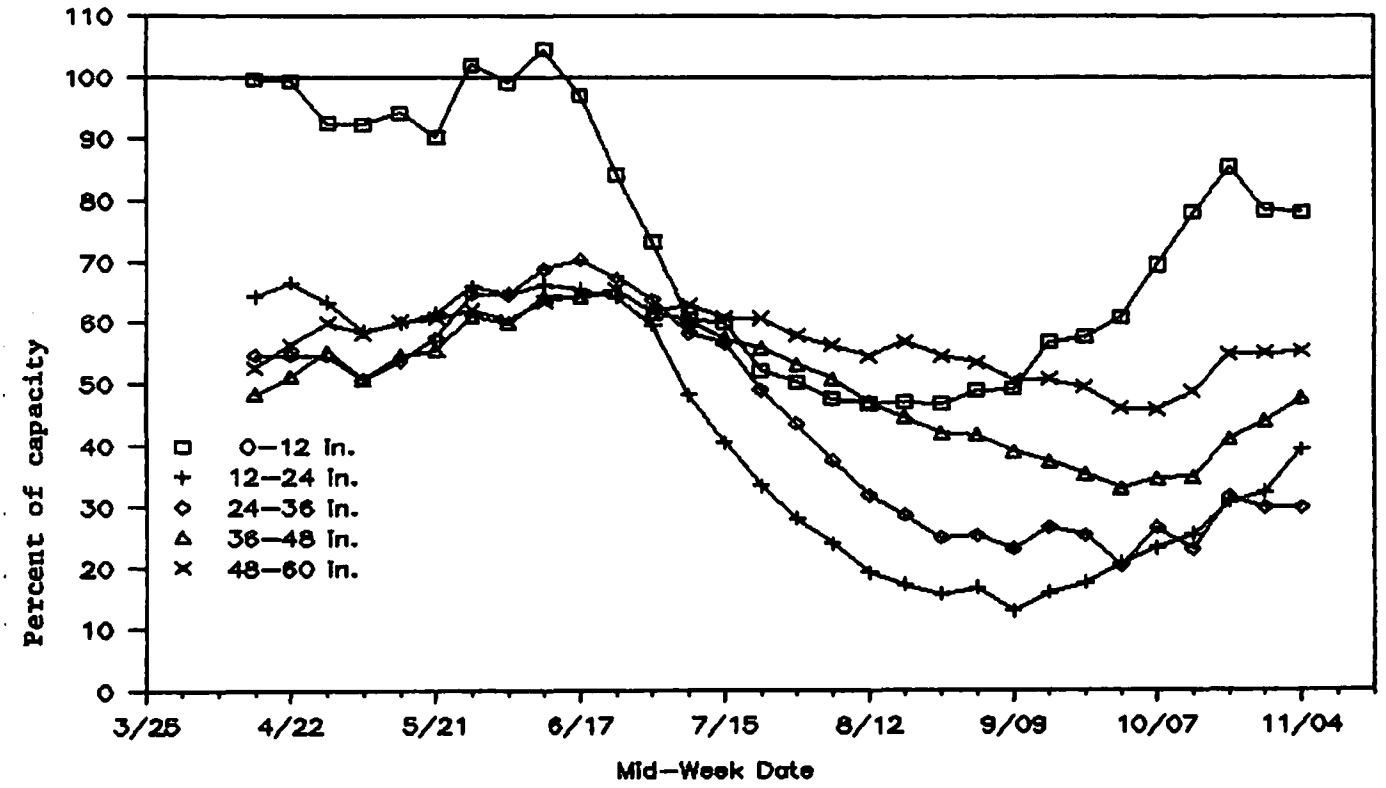


Figure 7. Average amount of plant available soil moisture in each foot of soil expressed as a percentage of the field capacity, Southwest Agricultural Experiment Station, Lamberton, 1964 - 1986.

The moisture profiles for each foot of the Lamberton sampling site are shown in another way in Fig. 7. In this case each foot is expressed as the percent of field capacity. In general it is the 12-24 inch and 24-36 inch depths that are the closest to being depleted of their plant available moisture supplies. This is indicative of the quantity of roots at these depths. It is also shown that the first foot is often above field capacity (above 100%) in mid-June.

THE WASECA MOISTURE YEAR

D.G. Baker, D.L. Ruschy, G.W. Randall, and P. Kelly

Waseca, like Lamberton, has been the object of increased precipitation, though perhaps not quite to the same degree. This is apparent in Fig. 8 in which is shown the totals for each agricultural year. The current 30-year normal, 1951-1980, equals 30.62 inches. We have defined the agricultural year as September through August, because this more nearly represents the water year for most crops.

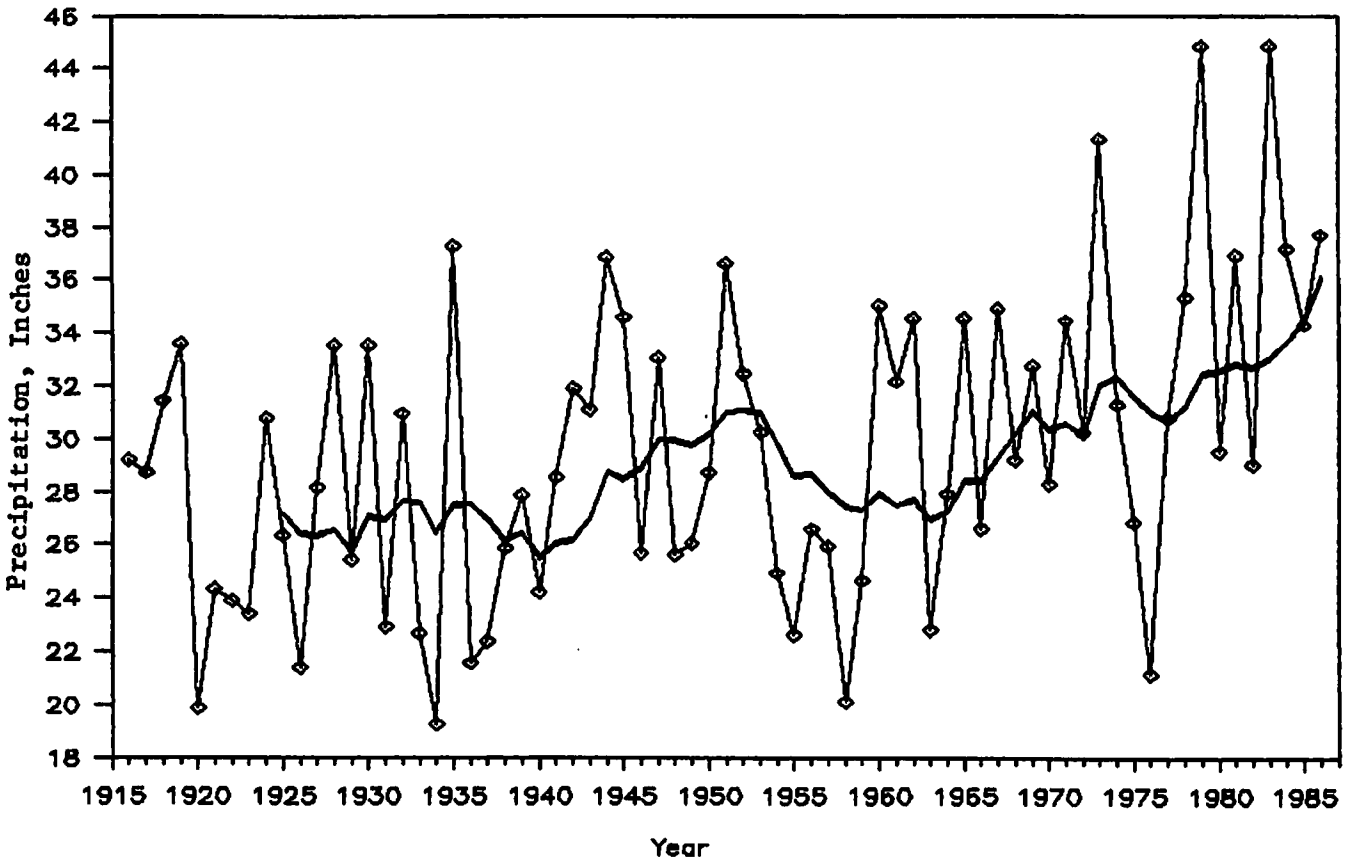


Figure 8. Annual total precipitation for the agricultural year (Sept. thru Aug.) for the period Sept. 1915 - Aug. 1986 at the Southern Agricultural Experiment Station, Waseca. The smoothed line is a 10-year running mean plotted at the end of the 10-year period.

Also shown in Fig. 8 is a 10-year running mean of the agricultural year precipitation. This line smoothes the large variation that is typical of our climate and permits trends to be more readily apparent. The rising trend of the precipitation throughout the period becomes most obvious with the running mean. The increase in the 10-year mean from the early 1960's to the present is an increase of about 8 inches. A truly remarkable increase.

The time of occurrence of the maximum and minimum soil moisture amounts in each foot of the soil is not as regular as at the Lamberton station. This is shown in Fig. 9 and Table 3. In fact the timing of the

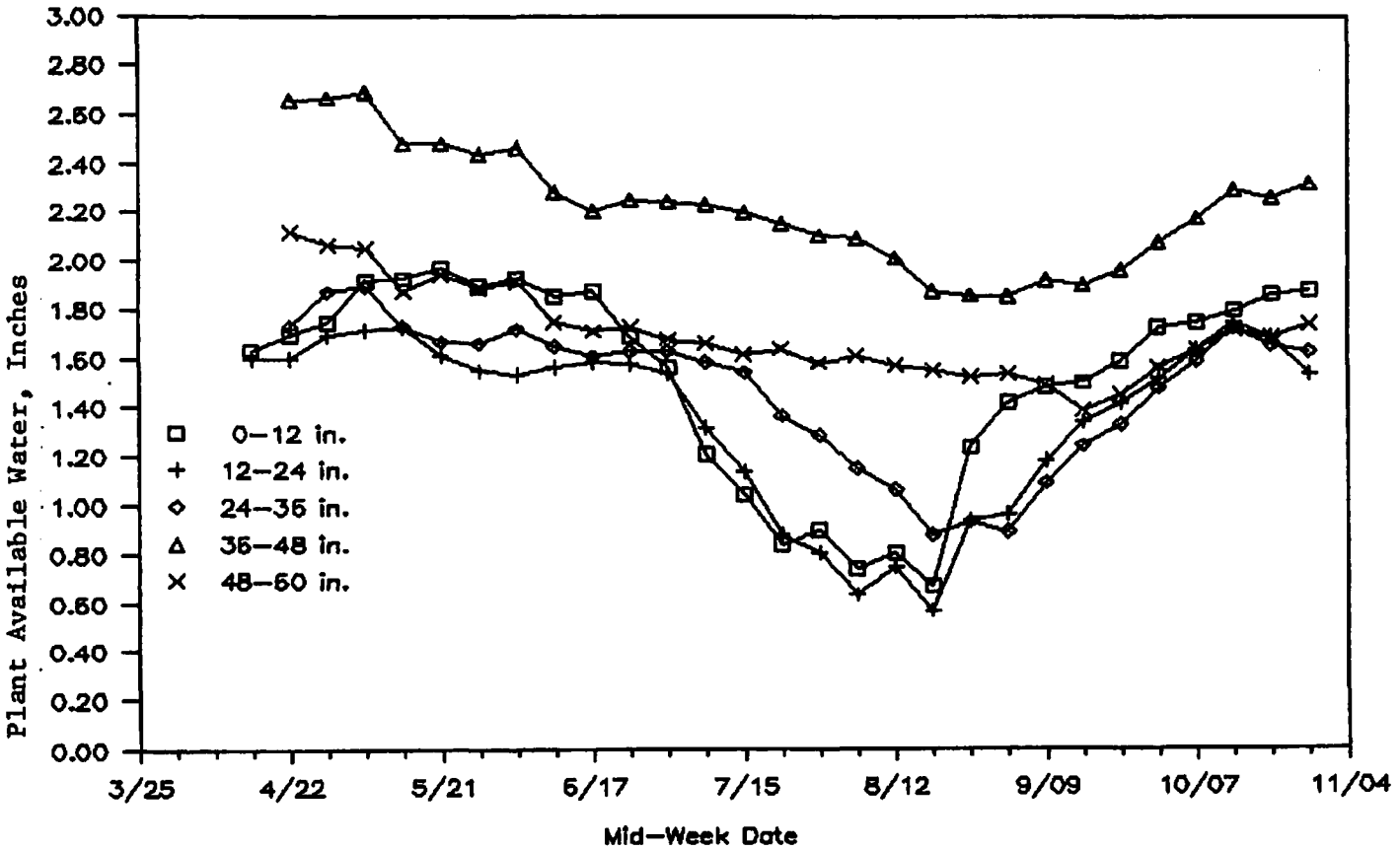


Figure 9. Average amount of plant available soil moisture in each foot of soil under continuous corn at the Southern Agricultural Experiment Station, Waseca, 1977 - 1986.

Table 3. The average date of the occurrence of the soil moisture maximum and minimum contents in each foot of soil at Waseca, 1977-1986.

Depth	Maximum soil moisture	Minimum soil moisture
0-12 in.	May 21	August 19
12-24	May 14	August 19
24-36	May 7	August 19
36-48	May 7	September 2
48-60	April 22	September 16

maximum is most curious with the shallowest depth showing the latest date of ocurrence. This might be an artifact of the relatively brief period of the record. The time when the minimum occurs ranges from August 19 in the first three feet of soil and on September 2 and 16 for the fourth and fifth foot of soil, respectively. This is about as would be expected and agrees fairly well with the longer record at Lamberton.

Fig. 10 is similar to Fig. 7, but it represents the soil moisture situation for the Southern station at Waseca. It is perhaps more evident in this figure than in Fig. 9 that the major withdrawals of moisture occur in the first three feet. Due to the generally higher total precipitation at Waseca than at Lamberton, there is less need for the corn to pull water from the fourth and fifth foot of the soil. Indeed the roots may in general not reach as deep as they do at Lamberton because of the higher moisture content. From Table 5 it appears that on the average nearly an inch or more of water is obtained from the soil at Waseca than at Lamberton. That is, the average total at Waseca is 4.99 inches compared to the 4.02 inches at Lamberton.

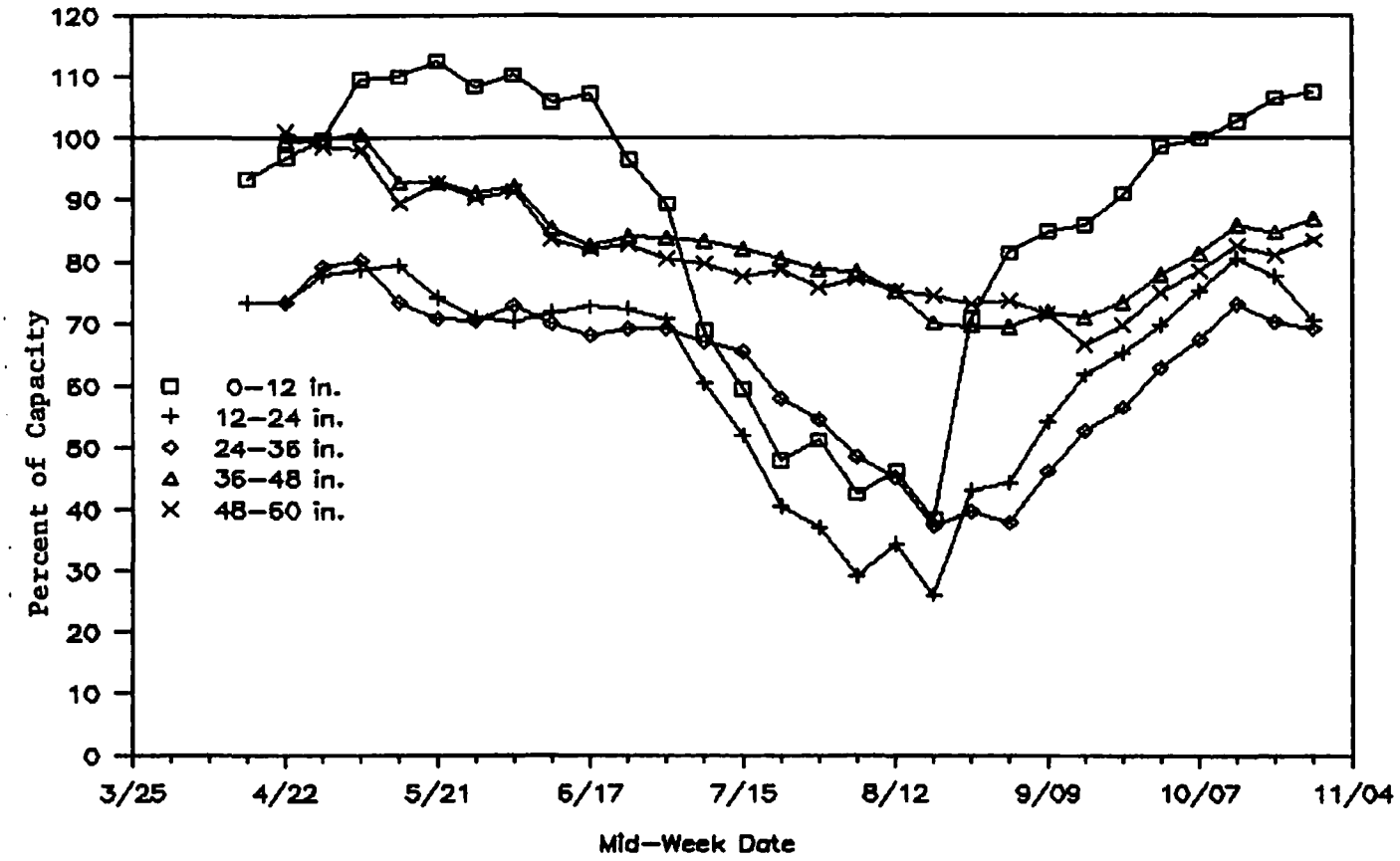


Figure 10. Average amount of plant available soil moisture in each foot of soil expressed as a percentage of the field capacity, Southern Agricultural Experiment Station, Waseca, 1977 - 1986.

Table 5. The average amount of plant available soil water in each foot of soil at the time of the maximum and minimum contents (see Table 4) at Waseca, 1977-1986.

Depth	Soil Water at maximum	Soil Water at minimum	Difference
0-12 in.	1.94 in	0.65 in.	1.29
12-24	1.70	0.52	1.18
24-36	1.86	0.86	1.00
36-48	2.66	1.84	0.82
48-60	2.10	1.40	0.70
TOTAL:	10.26	5.27	4.99

Fig. 10, as already noted, is the soil moisture content in each foot of soil expressed as a percent of the total plant available water that can be held in the soil. The graph indicates that on the average the spring and autumn contents in the first foot are above field capacity. This excess water is available for recharge of the lower depths. The fact that the surplus in the first foot is reached by October 7, so soon after the recent crop season may explain the rather curious timing of the maximum soil moisture amounts in the spring that are listed in Table 4. That is, during the latter part of the autumn and over winter the water will move down to the deeper depths. Thus, the shallow depths, 0-6 inch, for example, can accept a spring recharge and reach their maximum content at a later date than at the deeper depths.

AIR AND SOIL TEMPERATURE VARIATIONS

D.G. Baker and D.L. Ruschy

At the St. Paul campus microclimate station a plot has been devoted to alfalfa. Both soil temperatures at several depths under the alfalfa and air temperatures have been taken at hourly intervals during the growing season. In the course of a study on the effect of the environment upon alfalfa several rather interesting things have been observed. Fig. 11 is an example of one of these occasions during the 1984 season.

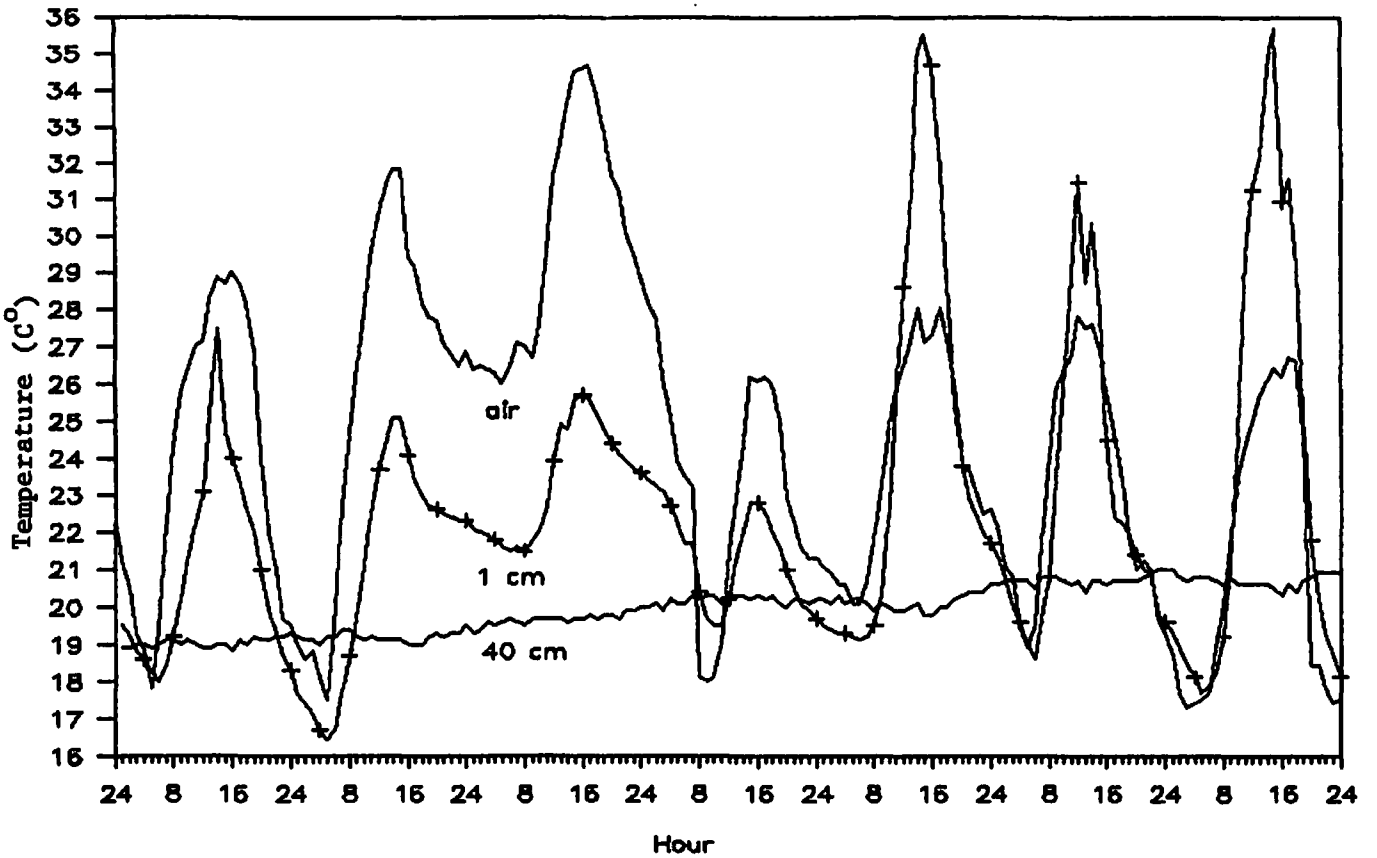


Figure 11. Air and soil temperatures, at 1 cm (0.4 in.) and 40 cm (16 in.) in alfalfa at St. Paul, July 20 - 26, 1984. The time in hours of the day is shown at the bottom; 24 marks the end of each day. Note that from July 20 - 22 the 1 cm soil temperature exceeds the air temperature but a reversal occurs beginning on July 23.

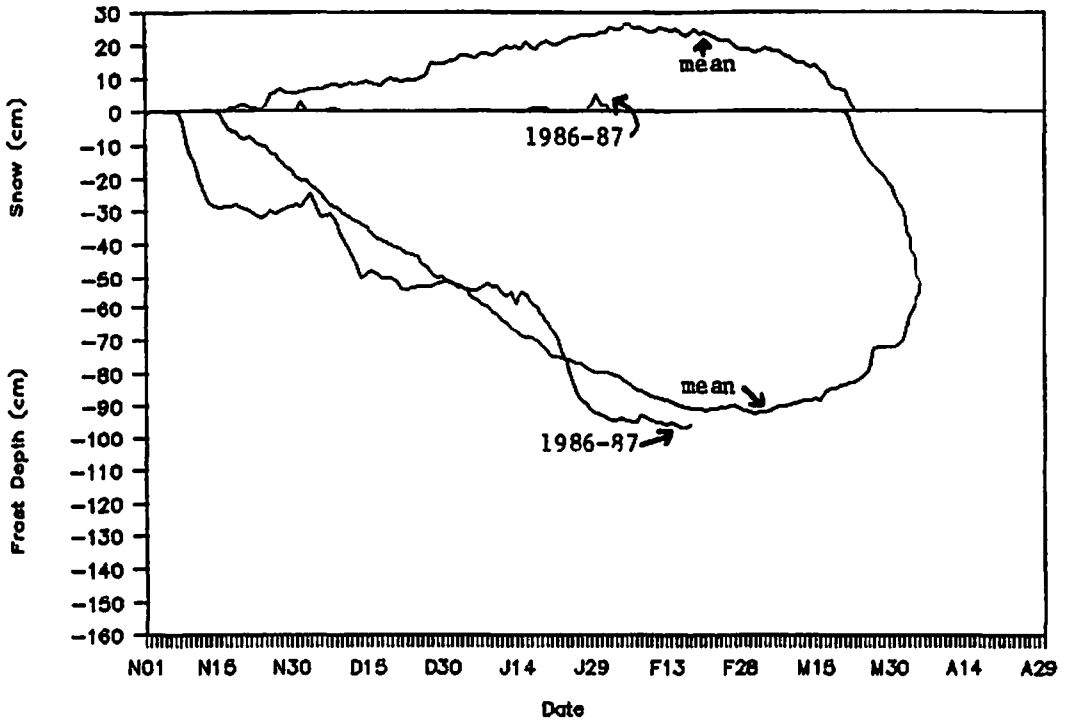
The second 1/10th bloom cutting of the alfalfa was made on July 24. Late on July 22 a cold front passed the station resulting in cooler air for the next several days. With the passage of the cold front on July 22 0.40 inch of rain was measured and the wind shifted from SW to a northerly wind which brought in the cooler air. All of this is pretty well evident in the temperature record. Due to the protection provided by the alfalfa cover (before it was cut) the soil temperature at 1 cm was considerably lower and less variable than the air temperature. However, once the alfalfa was cut and removed the 1 cm soil temperature greatly exceeded the air temperature. The air temperatures are now considerably reduced as a result of the introduction of the cold air, but even with the cold air it can be seen that the soil is absorbing lots of heat. This is reflected in the fact that the 1 cm soil temperature is now much higher than the air temperature. The daily heat wave has essentially no effect upon the daily variation of the soil temperature at 40 cm. This is true even in the absence of the alfalfa cover.

SOIL FREEZING DEPTH AND DURATION

D.B. Wall and D.G. Baker

Over 25 years of snow depth, soil temperature, and air temperature measurements have been made at the St. Paul microclimate station. These measurements have provided data from which the mean snow depth, frost depth, and cumulative freezing index throughout the winter could be determined. The averages are illustrated in Fig. 12. The cumulative freezing index (in °C) was calculated by summing the daily freezing indices (0°C minus the daily mean temperature) throughout the winter. The frost depth is under a plot bare of vegetation. On the average the soil begins to freeze on November 17 and gradually freezes to an average maximum depth of 94 cm (37 in) on March 3. The maximum freezing depth has varied between 27 and 175 cm (80 in) over the last 22 years. This variation is primarily due to differences in snow depth and air temperature, with snow depth being the most important variable influencing frost depth. The accumulated snow depth on the non-vegetated surface is greatest on the average in late February (26 cm or 10 in).

The 1986-1987 winter (through February) has had very unusual climatic conditions, with virtually no snow cover and temperatures much higher than normal. The 1986-1987 snow depth and cumulative freezing index are also shown in Fig. 12. The cumulative freezing index by Feb. 15, 1987, was 315 °C compared to mean of 785 °C on this date. While the 1986-1987 winter temperatures through mid-February have been much warmer than normal, the mid-February frost depth is about equal to the mean frost depth. The lack of snow cover this winter is the primary reason that the frost depth has penetrated past the mean frost depth even though temepratures were much higher than normal. This indicates that an average winter snow cover by mid-February has nearly the same effect on frost penetration as does a reduction of the cumulative freezing index by 470°C, a 60% reduction as experienced this winter.



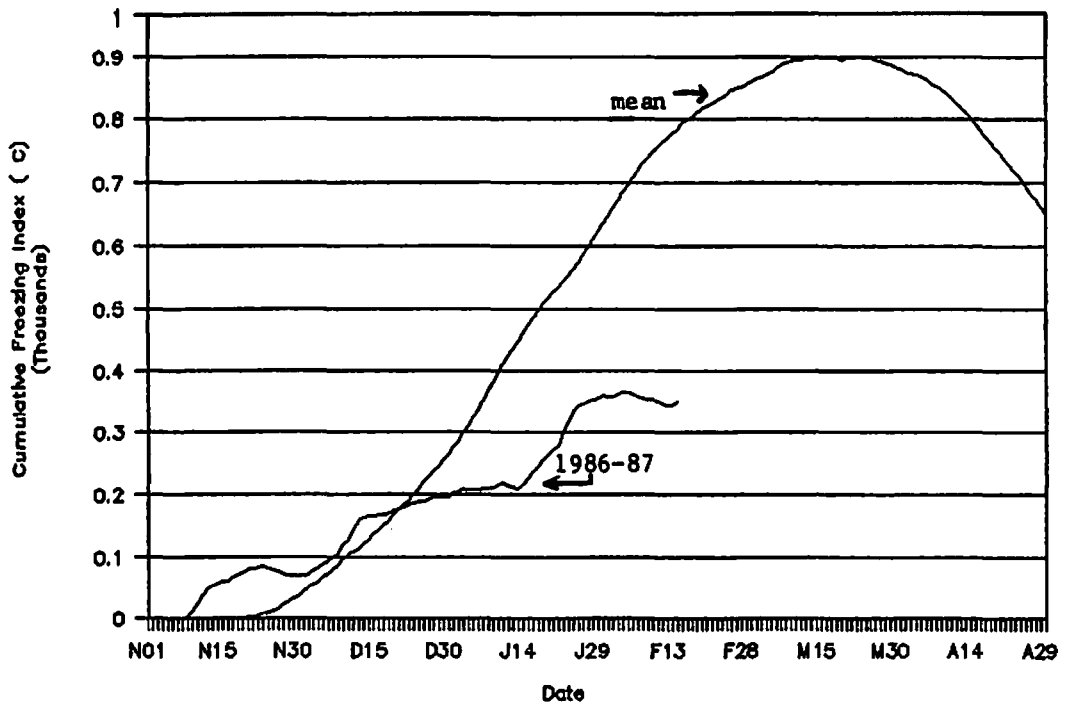


Fig. 12 (Top) Mean snow depth and frost depth (1964-84) compared to the snow and frost depth (1986-87). The soil is bare of vegetation. (Bottom) Mean cumulative freezing index for 1964-84 compared to the index for 1986-87. Note how much lower the 1986-87 cumulative freezing index is than the mean cumulative freezing index.

MANAGEMENT OF UAN ON THE COARSE TEXTURED IRRIGATED SOIL OF MINNESOTA FOR EFFICIENT CORN PRODUCTION BECKER, MN 1986

G.L. Malzer and T. Graff

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

Experimental Procedures

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

Experiment 1 consisted of 25 treatments with four replications arranged in a randomized complete block design. Treatment variables included factorial combinations of six N rates of UAN (100, 134, 168, 202, 235, and 269 kg/ha) and four methods of application (2/3 of N rate early 1/3 late, all late, 2/3 early with DCD 1/3 late, and 2/3 early with N-Serve 1/3 late), plus a zero N control. Early N treatments were applied at the 4-5 leaf growth stage (May 29) while late applications were made at the 8-9 leaf growth stage (June 12). All treatments were injected into the soil on 76 cm centers approximately 8 cm deep and 18 cm away from the row. Nitrification inhibitors were mixed with the UAN prior to application and were applied at rates of 7.84 kg/ha for DCD and 0.56 kg/ha a.i. for N-Serve.

Experiment 2 consisted of 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 applications (4-leaf and 8-leaf growth stages). Nitrification inhibitor (DCD and N-Serve similar to above) treatments were included to provide comparisons for all injected N treatments at the four-leaf growth stage. Four additional treatments were included with a new test inhibitor (ACP 2500), applied with UAN at the rate of 0.28 kg/ha a.i.. N rates of 100 and 168 kg/ha either injected or broadcast with the UAN at the 4-leaf stage of plant growth.

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

Leaf samples from opposite and below the ear at mid-silking were obtained on July 14th, dried and anlyzed for N. Total dry matter production and grain yields were determined on September 16 and 18th 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 June 18th and continued through September 2nd with a total of 20.2 cm being applied through irrigation. An additional 55.37 cm of water was obtained during the growing season as rainfall.

General Results:

The 1986 growing season provided excellent conditions for high yields. The growing season precipitation was slightly lower in 1986 than was experienced at this location in 1985 and was characterized by being relatively dry during the months of May and June with no single excessive rainfall event at any time during the growing season. With these weather conditions significant nitrate leaching would not be expected to occur. Likewise, the impacts of nitrogen management techniques such as time of application, placement and use of nitrification inhibitors would be expected to have a minimal influence on grain yield and N utilization. The results for experiment 1 are presented in tables 1 and 2 and the experiment 2 results are presented in tables 3 and 4.

Experiment 1: Yield increases in excess of 110 bu/A (6.9 mt/ha) could be associated with fertilizer N application. The optimum rate of N application was 150 lbs/A (168 kg/ha), similar to what was obtained in 1985. A significant rate by method of application interaction suggests that high N rates applied as one single late application was inferior to split applications with or without a nitrification inhibitor. Nitrification inhibitors applied at the lowest N rate tended to reduce yields, but at rates closer to the optimum, this trend was negated. Single N applications late in the season significantly reduced stover and total dry matter production. Nitrification inhibitors and single late applications significantly increased the N concentrations in the grain. Nitrification inhibitors increased the N removal in the grain and total N removal when compared to treatments that did not have a nitrification inhibitor. This significant increase in N removal did not result in a consistant significant increase in grain yield, although some positive trends were noted with N-Serve.

Experiment 2: The apparent optimum N rate was the same in expt. 2 as that which was obtained in expt. 1, at 150 lbs/A (168 kg/ha). Injected applications of UAN with a nitrification inhibitor had no influence on grain yield or N removal, although significant increases in leaf N concentrations were obtained at silking when a nitrification inhibitor was used. Time of N application had no influence on grain yield or N removal suggesting that early season N leaching losses were minimal. Increased concentration of N in both the grain and the stover were obtained when the UAN was injected rather than broadcast. Injection also resulted in increased total N uptake by the crop. Since leaching losses were apparently minimal the decreased efficiency associated with the broadcast applications could be due to either volitalization, increased immobilization of N in the soil or positional unavailability. Although it is not possible to differentiate these processes in this experiment, previous experimental results at this location under similar experimental conditions would suggest that volitalization losses are minimal.

Table 1. Influence of N rates, nitrification inhibitors and method of application on grain yield, and dry matter production on irrigated corn Becker, MN - 1986.

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	----	----	----	---	85.4	5.4	4.52	5.31	9.83
100	67	----	34	1	187.0	11.7	9.92	7.75	17.67
100	----	----	100	2	184.0	11.5	9.74	7.48	17.23
134	90	----	44	1	171.9	10.8	9.12	7.37	16.49
134	----	----	134	2	188.3	11.8	9.99	7.64	17.63
168	112	----	56	1	186.1	11.7	9.86	8.20	18.08
168	----	----	168	2	182.0	11.4	9.65	7.37	17.02
202	134	----	68	1	188.3	11.8	9.99	7.82	17.81
202	----	----	202	2	178.6	11.2	9.48	7.17	16.62
235	157	----	78	1	195.9	12.3	10.39	8.62	19.02
235	----	----	235	2	179.3	11.2	9.50	8.09	17.61
269	179	----	90	1	191.8	12.0	9.97	8.15	18.30
269	----	----	269	2	188.1	11.8	9.97	7.15	17.11
100	67	DCD	34	3	176.9	11.1	9.39	7.46	16.84
100	67	NS	34	4	172.8	10.8	9.16	7.17	16.33
134	90	DCD	44	3	182.6	11.4	9.68	8.00	17.67
134	90	NS	44	4	191.7	12.0	9.97	8.02	18.19
168	112	DCD	56	3	196.0	12.3	10.39	8.20	18.59
168	112	NS	56	4	194.8	12.2	10.33	7.91	18.23
202	134	DCD	68	3	182.1	11.4	9.65	7.44	17.09
202	134	NS	68	4	196.4	12.3	10.42	8.24	18.66
235	157	DCD	78	3	196.0	12.3	10.39	8.51	18.91
235	157	NS	78	4	192.8	12.1	10.21	8.06	18.28
269	179	DCD	90	3	192.1	12.0	10.19	8.11	18.28
269	179	NS	90	4	194.9	12.2	10.33	8.00	18.32
P-Value					99	99	99	99	99
BLSD (.05)					12.6	0.8	0.66	0.82	0.24
Main Effects									
Rates kg/ha									
100					180.2	11.3	9.54	7.45	17.00
134					183.6	11.5	9.72	7.75	17.47
168					189.7	11.9	10.05	7.90	17.96
202					186.3	11.7	9.85	7.66	17.53
235					191.0	12.0	10.12	8.31	18.43
269					191.7	12.0	10.08	7.84	17.98
P-Value					99	99	99	99	99
BLSD (.05)					7.5	0.4	0.38	0.43	0.67
Method	Early	Late							
1	2/3	1/3			186.8	11.7	9.90	7.97	17.87
2	---	3/3			183.4	11.5	9.63	7.45	17.16
3	2/3+DCD	1/3			187.6	11.7	9.94	7.92	17.87
4	2/3+NS	1/3			190.6	11.9	10.08	7.88	17.98
P-Value					70	70	70	99	99
BLSD (.05)								0.35	0.57
Rate X Method					97	97	97	67	96

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 - 1986.

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	----	----	----	----	1.48	1.10	0.37	49.8	19.8	69.7
100	67	----	34	1	2.53	1.34	0.47	132.6	36.5	169.2
100	----	----	100	2	2.80	1.47	0.58	143.0	43.3	186.3
134	90	----	44	1	2.97	1.43	0.57	130.5	41.7	172.2
134	----	----	134	2	2.95	1.43	0.59	142.6	45.1	187.7
168	112	----	56	1	3.08	1.46	0.57	143.6	46.6	190.2
168	----	----	168	2	2.98	1.55	0.67	149.6	49.6	199.2
202	134	----	68	1	2.99	1.50	0.67	149.9	53.1	203.1
202	----	----	202	2	3.09	1.52	0.69	143.2	49.6	192.8
235	157	----	78	1	2.94	1.50	0.65	156.0	54.9	211.0
235	----	----	235	2	3.04	1.56	0.68	148.2	55.0	203.3
269	179	----	90	1	2.91	1.48	0.64	150.2	52.3	202.6
269	----	----	269	2	2.87	1.51	0.69	150.7	49.8	200.5
100	67	DCD	34	3	2.90	1.39	0.54	130.8	40.5	171.4
100	67	NS	34	4	2.86	1.36	0.54	124.5	38.2	162.8
134	90	DCD	44	3	2.86	1.50	0.60	145.0	47.7	192.8
134	90	NS	44	4	2.75	1.50	0.51	151.7	41.4	193.1
168	112	DCD	56	3	3.07	1.50	0.61	155.8	50.3	206.1
168	112	NS	56	4	3.05	1.52	0.67	157.4	53.0	210.4
202	134	DCD	68	3	2.99	1.57	0.70	150.9	52.4	203.4
202	134	NS	68	4	3.08	1.53	0.66	158.7	54.6	213.4
235	157	DCD	78	3	2.98	1.75	0.67	181.3	57.4	238.8
235	157	NS	78	4	3.18	1.65	0.66	168.4	53.2	221.7
269	179	DCD	90	3	3.16	1.60	0.72	162.9	58.6	221.6
269	179	NS	90	4	2.88	1.63	0.74	168.3	59.1	227.5
P-Value					99	99	99	99	99	99
BLSD (.05)					0.22	0.09	0.87	14.0	9.0	18.7
Main Effects										
Rates										
100					2.77	1.38	0.53	132.7	39.6	172.3
134					2.90	1.46	0.56	142.4	43.9	186.4
168					3.04	1.50	0.63	151.5	49.8	201.4
202					3.03	1.52	0.68	150.6	52.4	203.1
235					3.03	1.61	0.66	163.5	55.1	218.6
269					2.95	1.55	0.69	158.0	54.9	213.0
P-Value					99	99	99	99	99	99
BLSD (.05)					0.12	0.04	0.04	2.0	4.3	9.4
Method	Early	Late								
1	2/3	1/3			2.90	1.45	0.59	143.8	47.4	191.4
2	---	3/3			2.95	1.50	0.65	146.1	48.7	194.9
3	2/3+DCD	1/3			3.00	1.55	0.64	154.4	51.1	205.6
4	2/3+NS	1/3			2.96	1.53	0.63	154.7	49.9	204.8
P-Value					77	99	81	99	72	99
BLSD(.05)						0.04		2.1		8.3
Rate X Method					89	93	33	98	21	93

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. - 1986.

N-Rate	Treatments Method	Inh.	Time	Grain Yields		Dry Matter Production Grain	Stover	Total
kg/ha				Bu/A	mt/ha	---------mt/ha----------		
Control	---------	----	----	86.8	5.4	4.61	5.04	9.63
100	Broadcast	----	1	178.0	11.2	9.43	7.15	16.58
100	Broadcast	----	2	189.4	11.9	9.59	6.90	16.96
100	Injected	----	1	192.6	12.1	10.21	7.68	17.88
100	Injected	----	2	185.3	11.6	9.83	7.32	17.14
100	Injected	DCD	1	189.6	11.9	10.06	7.66	17.72
100	Injected	NS	1	191.3	12.0	10.15	7.93	18.05
168	Broadcast	----	1	192.4	12.1	10.19	8.04	18.23
168	Broadcast	----	2	198.7	12.5	10.53	7.62	18.14
168	Injected	----	1	198.6	12.5	10.53	8.04	18.57
168	Injected	----	2	191.9	12.0	10.17	7.50	17.67
168	Injected	DCD	1	203.6	12.8	10.80	8.09	18.88
168	Injected	NS	1	195.9	12.3	10.39	7.93	18.32
235	Broadcast	----	1	194.7	12.2	10.33	7.80	18.12
235	Broadcast	----	2	191.2	12.0	10.12	7.84	17.96
235	Injected	----	1	193.3	12.1	10.24	8.09	18.32
235	Injected	----	2	199.4	12.5	10.57	7.68	18.23
235	Injected	DCD	1	192.6	12.1	10.21	7.91	18.12
235	Injected	NS	1	197.7	12.4	10.48	8.22	18.70
100	Broadcast	ACP2500	1	178.7	11.2	9.48	7.12	16.60
100	Injected	ACP2500	1	180.6	11.3	9.59	7.35	16.91
168	Broadcast	ACP2500	1	190.4	11.9	10.10	7.91	17.99
168	Injected	ACP2500	1	197.1	12.3	10.46	7.37	17.81
Control	--------	------	--	80.9	5.0	4.28	5.00	9.27
P-Value				99	99	99	99	99
BLSD (.05)				13.8	0.8	0.73	0.77	1.30
Factorial Arrangement (N-Rate X Inhibitor DCD and N-Serve)								
N-Rate								
100				189.7	11.9	10.03	7.63	17.69
168				197.5	12.4	10.46	7.88	18.34
235				195.8	12.3	10.37	7.95	18.34
P-Value				99	99	99	73	57
BLSD (.05)				5.0	0.3	0.26		
Inhibitor								
None				193.5	12.2	10.64	7.70	17.96
DCD				195.2	12.2	10.34	7.88	18.23
N-Serve				195.0	12.2	10.32	8.01	18.34
P-Value				27	27	27	68	64
BLSD (.05)								
N-Rate X Inhibitor				68	68	68	7	38

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 - 1986.

	Treatments			N-Concentration			N-Removal		
N-Rate	Method	Inh.	Time	Leaf	Grain	Stover	Grain	Stover	Total
kg/ha				---------%----------			---------kg/ha----------		
Control	---------	----	---	1.36	1.15	0.45	50.1	22.8	76.3
100	Broadcast	----	1	2.74	1.35	0.54	127.1	38.3	165.4
100	Broadcast	----	2	2.90	1.44	0.55	144.2	37.7	181.9
100	Injected	----	1	2.71	1.48	0.58	151.2	45.3	196.6
100	Injected	----	2	2.84	1.44	0.55	141.1	40.8	181.9
100	Injected	DCD	1	2.97	1.36	0.58	137.2	44.7	181.9
100	Injected	NS	1	2.87	1.44	0.52	145.8	42.0	187.8
168	Broadcast	----	1	3.09	1.49	0.58	151.8	46.5	198.3
168	Broadcast	----	2	2.76	1.50	0.58	157.4	44.1	201.6
168	Injected	----	1	2.99	1.58	0.67	166.8	54.4	221.3
168	Injected	----	2	2.84	1.54	0.69	156.6	52.0	208.6
168	Injected	DCD	1	3.09	1.57	0.63	169.7	51.4	221.2
168	Injected	NS	1	3.09	1.64	0.70	170.9	55.5	226.4
235	Broadcast	----	1	3.11	1.53	0.64	158.5	49.9	208.5
235	Broadcast	----	2	3.07	1.44	0.68	146.1	53.6	199.7
235	Injected	----	1	2.64	1.58	0.75	162.3	60.5	222.8
235	Injected	----	2	2.75	1.55	0.67	164.3	51.1	215.5
235	Injected	DCD	1	3.15	1.60	0.74	163.0	58.8	221.8
235	Injected	NS	1	3.22	1.53	0.81	159.9	66.8	226.7
100	Broadcast	ACP2500	1	2.66	1.35	0.47	128.3	33.7	162.0
100	Injected	ACP2500	1	2.80	1.40	0.65	134.4	48.1	182.5
168	Broadcast	ACP2500	1	2.80	1.41	0.65	141.8	51.3	193.1
168	Injected	ACP2500	1	2.97	1.49	0.66	155.5	48.4	203.9
Control	---------	----	---	1.48	1.11	0.45	47.9	22.6	70.5
P-Value				99	99	99	99	99	99
BLSD (.05)				0.24	0.12	0.08	15.5	8.7	20.0
Factorial Arrangement (N-Rate X Inhibitor DCD and N-Serve)									
N-Rate									
100				2.84	1.42	0.56	143.8	43.1	178.0
168				3.00	1.58	0.67	165.9	53.3	219.4
235				2.93	1.56	0.74	162.4	59.2	221.6
P-Value				51	99	99	99	99	99
BLSD (.05)					0.05	0.03	7.6	4.4	9.7
Inhibitor									
None				2.79	1.52	0.65	157.0	50.6	207.7
DCD				3.06	1.51	0.65	156.6	51.6	208.3
N-Serve				3.05	1.53	0.67	158.8	54.7	213.5
P-Value				99	21	54	13	75	48
BLSD (.05)				0.12					
N-Rate X Inhibitor				94	82	97	58	70	21

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	---------mt/ha----------		
Factorial Arrangement (N-Rate X Method X Time)								
N-Rate								
100				186.3	11.7	9.85	7.25	17.13
168				195.4	12.2	10.34	7.79	18.14
235				194.7	12.2	10.34	7.84	18.14
P-Value				97	97	97	99	97
BLSD (.05)							0.38	
Method								
Broadcast				190.7	11.9	10.10	7.54	17.65
Injected				193.5	12.1	10.23	7.70	17.96
P-Value				65	65	65	70	76
Time								
Early				191.6	12.0	10.14	7.77	17.94
Late				192.6	12.1	10.19	7.45	17.67
P-Value				28	28	28	95	68
Rate X Method				27	27	27	63	56
Rate X Time				6	6	6	27	19
Method X Time				78	78	78	53	76
Rate X Method X Time				87	87	87	12	36

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	2.79	1.42	0.55	140.8	40.5	181.4
168	2.92	1.52	0.63	158.1	49.2	207.4
235	2.89	1.52	0.68	157.8	53.7	211.5
P-Value	97	99	99	99	99	99
BLSD (.05)		0.05	0.03	8.5	4.0	10.4
Method						
Broadcast	2.94	1.45	0.59	147.5	45.0	192.5
Injected	2.79	1.52	0.65	157.0	50.6	207.7
P-Value	99	99	99	99	99	99
Time						
Early	2.87	1.50	0.62	152.9	49.1	202.1
Late	2.85	1.48	0.62	151.5	46.8	198.1
P-Value	39	59	32	29	85	61
Rate X Method	99	5	83	11	35	1
Rate X Time	99	67	25	39	1	28
Method X Time	78	63	86	81	88	90
Rate X Method X Time	47	78	80	94	68	65

INFLUENCE OF NITROGEN APPLICATION TIME AND NITRIFICATION INHIBITOR RATE ON SWEET CORN PRODUCTION ON AN IRRIGATED SAND

C. J. Rosen and H. J. Buchite

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

EXPERIMENTAL PROCEDURES

The experiment was conducted at the Sand Plains Research Farm in Becker, MN. Prior to planting and fertilizer application, the soil (Hubbard loamy sand) had the following test values (0-6"): pH, 6.3; Bray P1, 85 lb/A; ammonium acetate extractable K, 185 lb/A; KCl extractable NH_4-N (0-12"), 1.5 ppm; KCl extractable NO_3-N (0-12"), 1.6 ppm. The previous crop at this site was rye. Prior to planting 150 lb/A potassium-magnesium sulfate (0-0-22) was broadcast and incorporated.

Treatments consisted of two hybrids 'Code 5' (early season maturing) and 'Jubilee' (mid-season maturing), 150 lb N/A as anhydrous ammonia either preplant or split applied (75 lb N/A preplant and 75 lb N/A sidedressed) and three rates of N-Serve (0, 0.5, or 1.0 lb ai/A). A split-plot design with four replications was used with timing and inhibitor rate as main plots and hybrid as subplots. Preplant treatments were applied April 30, 1986. Both hybrids were planted May 2 with a banded application of 150 lb/A 0-14-42. Stands were thinned to approximately 24,000 plants/A with spacing set at 30" rows. The sidedress treatments were applied June 13 (10-12 leaf stage). The split N treatments had half the inhibitor applied preplant and the remainder applied with the sidedress. Soil samples were collected in the anhydrous ammonia bands (samples bulked over hybrid) May 30, July 9 and July 31 and stored moist at 4 C until extracted with 2N KCl for nitrate-N and ammonium-N determination. Whole plant samples collected at the 10-12 leaf stage (before sidedress application) and leaf samples opposite and above the ear at mid-silking were dried and ground for subsequent nutrient determination. From May through July, precipitation totalled 12.3". This rainfall was supplemented with 6.7" of water through an overhead irrigation system.

Code 5 was harvested on July 29 and Jubilee was harvested August 4. Total green yield, husked yield and stover yield were obtained by harvesting two 15 ft center rows within each plot. Subsamples of ears, husk, and stover were taken to determine % moisture for N uptake calculations. As a measure of product quality, % kernel moisture and % useable ears (5.5" or greater with unfilled tip removed - COC eligible) were determined.

RESULTS

Both N timing and nitrification inhibitor rates had significant effects on levels of soil ammonium-N (Table 1) and nitrate-N (Table 2). Because samples were taken in the anhydrous ammonia band, values presented are valid for that area and do not represent average levels through the field. At the first sampling date (prior to the sidedress application), ammonium-N levels increased with increasing inhibitor rate and were higher when all N was applied as preplant. Most of the ammonium-N was concentrated in the

top 12" of soil at all sampling dates. By the second and third sampling dates, ammonium-N levels were higher with the split applications compared to the preplant application. The highest inhibitor rate corresponded to the highest ammonium-N levels when N applications were split. Ammonium-N levels decreased dramatically with all preplant treatments. In contrast to ammonium-N, nitrate-N decreased with increasing inhibitor rate at the first and second sampling dates. Timing of N application had no apparent effect on nitrate-N levels at the first sampling date, but split applications tended to result in higher levels at the later sampling dates. These data clearly indicate that N-Serve significantly suppressed nitrification which resulted in relatively high ammonium-N soil levels in N-Serve treated plots.

Unhusked (green) and husked yield of both hybrids increased with increasing inhibitor rate and with split applications of N (Table 1). Because of rainfall events greater than 1" on June 21, July 5 and July 19, nitrate-N loss was apparently sigificant (see Table 2). The main response to inhibitor and sidedress N was probably due to greater N availablity during the later part of the season. Jubilee appeared to respond to a greater extent to split applications than did Code 5. Moisture in kernels at harvest decreased with increasing inhibitor rate when N was applied preplant but increased with inhibitor rate when N applications were split. The reasons for this response are not clear from the present experiment. The effect of inhibitor on COC eligible ears was highly significant for Code 5 but minimal for Jubilee. This response to inhibitor by Code 5 but not Jubilee may be due to differences in hybrid response to ammonium nutrition. Unfortunately, in plots not receiving N-Serve, significantly more nitrate-N may have leached out of the root zone resulting lower N availability. Therefore, it cannot be determined from the present experiment whether the difference between hybrids is specifically due to ammonium nutrition or to greater availability of N in the root zone.

Nitrogen composition of and uptake by the two hybrids are presented in Table 4. Concentrations of N in plants sampled at the 8-10 leaf stage were not significantly affected by inhibitor rate or N timing. Concentrations of N in stover and ears generally increased with inhibitor rate and split applications. Inhibitor appeared to increase N concentrations to a greater extent when N was split applied compared to a preplant application. Husk N composition was not significantly affected by any of the treatments. Total N removed in ears and stover also increased with inhibitor rate and split application. For ear N, this effect was more pronounced with Jubilee than with Code 5. Greater N uptake with inhibitor and split N applications was most likely due to less nitrate-N leaching with these treatments. Mid-silk leaf elemental concentrations are presented in Table 5. All leaf N levels were in the optimum range for sweet corn production. In general, inhibitor increased leaf P and decreased leaf Ca and Mn.

General Comments:

Use of N-Serve, a nitrification inhibitor, on irrigated sandy soils, significantly increased yield and quality of processing sweet corn. This effect was observed even when inhibitor was applied in combination with split applications. Differences in hybrid response to inhibitor were evident in earfill characteristics as measured by COC eligible ears. Although soil ammonium-N levels increased with inhibitor rate, nitrate-N levels were generally low by earfill. The response to inhibitor may have been due to a combination of greater N availability as well as to ammonium nutrition.

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

Table 1. Influence of timing of N fertilizer application (150 lb/A) and rate of nitrification inhibitor on soil ammonium - N levels at three depths.

		Sampling Date								
		May 30			July 9			July 31		
Timing	NI rate (lb. ai/A)[1]	0-6"	6-12"	12-24"	0-6"	6-12"	12-24"	0-6"	6-12"	12-24"
		ppm								
preplant	0	72.0	30.0	1.1	7.2	5.5	3.6	0.7	0.5	0.3
preplant	0.5	57.4	19.8	1.0	11.3	5.4	1.6	1.0	8.5	0.5
preplant	1.0	58.7	41.9	1.3	5.3	9.7	2.8	0.9	7.7	0.9
split	0	1.2	16.8	0.5	12.5	57.0	5.0	0.6	1.8	0.3
split	0.5	29.4	26.5	0.4	48.2	78.6	4.3	12.6	38.7	2.1
split	1.0	64.6	50.3	0.5	128.6	80.3	22.8	60.7	43.6	3.9
Statistics										
Timing										
preplant		62.7	30.4	1.2	8.0	6.8	2.7	0.9	5.5	0.5
split		31.8	31.2	0.5	63.3	72.0	10.7	24.6	28.0	2.1
Significance		NS	NS	+	**	**	+	*	++	*
NI Rate										
0		36.6	23.2	0.8	9.9	31.2	4.3	0.7	1.1	0.3
0.5		43.4	23.1	0.7	30.0	42.0	2.9	6.8	23.6	1.3
1.0		61.7	46.1	0.9	67.0	45.0	12.8	30.8	25.6	2.4
Significance		NS	NS	NS	**	NS	NS	*	+	++
Linear		NS	+	NS	**	NS	NS	*	++	*
Quad		NS	NS	NS	NS	NS	NS	NS	NS	NS
Time x NI Rate										
Significance		NS	NS	NS	**	NS	NS	*	NS	NS

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

Table 2. Influence of timing of N fertilizer application (150 lb. N/A) and rate of nitrification inhibitor on soil nitrate-N levels at three soil depths.

		Sampling Date								
		May 30			July 9			July 31		
Timing	NI rate (lb. ai/A)[1]	0-6"	6-12"	12-24"	0-6"	6-12"	12-24"	0-6"	6-12"	12-24"
		ppm								
preplant	0	68.0	59.3	5.7	7.2	11.9	7.3	4.9	3.7	1.7
preplant	0.5	34.9	38.6	4.6	4.9	3.7	1.6	5.2	4.1	1.7
preplant	1.0	29.2	30.3	5.3	4.7	3.0	2.4	4.7	3.4	1.8
split	0	58.0	59.0	5.5	10.6	23.0	7.8	7.9	9.9	2.4
split	0.5	31.6	29.4	3.8	5.9	10.9	3.9	11.0	9.0	3.6
split	1.0	38.4	23.4	4.4	3.3	2.5	2.1	7.9	6.7	2.8
Statistics										
Timing										
preplant		44.0	42.7	5.2	5.6	6.2	3.8	4.9	3.7	1.7
split		42.7	37.2	4.6	6.6	12.1	4.6	8.9	8.5	2.9
Significance		NS	NS	NS	NS	**	NS	**	*	**
NI Rate										
0		63.0	59.1	5.6	8.9	17.4	7.5	6.4	6.8	2.1
0.5		33.2	33.9	4.2	5.4	7.3	2.7	8.1	6.5	2.6
1.0		33.8	26.8	4.9	4.0	2.8	2.3	6.3	5.1	2.3
Significance		*	*	NS	**	**	**	+	NS	NS
Linear		*	**	NS	**	**	**	NS	NS	NS
Quad		+	NS	+	NS	+	*	++	NS	+
Time x NI Rate										
Significance		NS	NS	NS	*	++	NS	NS	NS	NS

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

Table 3. Nitrogen fertilizer timing (150 lb. N/A) and nitrification inhibitor rate effects on yield and quality of two sweet corn hyrbrids.

Timing	NI rate (lb. ai/A)[1]	Hybrid	Yield (T/A) Green	Yield (T/A) Husked	% Kernel Moisture	% CCC Eligible
preplant	0	Code 5	5.83	3.80	76.1	72
preplant	0.5	Code 5	6.55	4.27	76.6	87
preplant	1.0	Code 5	6.24	4.13	74.5	82
split	0	Code 5	6.09	3.94	74.1	75
split	0.5	Code 5	6.26	4.20	74.8	90
split	1.0	Code 5	6.80	4.48	76.2	90
preplant	0	Jubilee	6.60	4.28	76.5	91
preplant	0.5	Jubilee	7.27	5.03	75.1	91
preplant	1.0	Jubilee	7.66	5.24	73.0	97
split	0	Jubilee	7.62	5.37	72.1	99
split	0.5	Jubilee	7.93	5.84	74.4	97
split	1.0	Jubilee	8.33	5.87	74.3	97
Statistics						
Main Effects						
Hybrid						
		Code 5	6.30	4.13	75.4	83
		Jubilee	7.57	5.27	74.2	95
Significance			**	**	*	**
Timing						
		preplant	6.69	4.45	75.3	87
		split	7.17	4.95	74.3	91
Significance			++	**	*	+
NI Rate						
	0		6.53	4.35	74.7	84
	0.5		7.00	4.82	75.2	91
	1.0		7.26	4.93	74.5	92
Significance			++	*	NS	+
Linear			**	**	NS	*
Quad			NS	+	NS	+
Interactions						
Hybrid x Timing			++	**	NS	NS
Hybrid x NI Rate			NS	NS	NS	**
Timing x NI Rate			NS	NS	**	NS
Hybrid x NI Rate x Timing			NS	NS	NS	NS

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

Table 4. Nitrogen fertilizer timing (150 lb. N/A) and nitrification inhibitor effects on N composition of and uptake by two sweet corn hybrids.

Timing	NI Rate (lb. ai/A)[1]	Hybrid	% N Whole Plant (6-8 leaf)	% N Ear (Harvest)	% N Husk (Harvest)	% N Stover (Harvest)	N Content Ear (lb N/A)	N Content Husk (lb N/A)	N Content Stover (lb N/A)	Total N Uptake lb. N/A
preplant	0	Code 5	4.88	1.49	.83	1.41	25.5	5.2	57.7	88.4
preplant	0.5	Code 5	5.02	1.47	.80	1.39	28.9	6.1	59.3	94.2
preplant	1.0	Code 5	4.97	1.48	.77	1.41	29.5	5.4	57.8	92.7
split	0	Code 5	4.86	1.52	.81	1.44	27.7	5.5	63.6	96.8
split	0.5	Code 5	4.89	1.53	.81	1.66	30.9	5.3	72.8	109.0
split	1.0	Code 5	4.74	1.54	.82	1.83	31.7	6.3	79.7	117.7
preplant	0	Jubilee	4.87	1.51	.75	1.14	29.8	5.8	55.4	91.0
preplant	0.5	Jubilee	5.26	1.56	.71	1.02	36.9	5.4	58.0	100.2
preplant	1.0	Jubilee	4.89	1.50	.75	1.19	39.4	5.9	66.7	112.0
split	0	Jubilee	5.07	1.46	.80	1.23	37.6	5.4	67.1	110.2
split	0.5	Jubilee	5.08	1.56	.87	1.34	45.0	5.8	77.5	128.3
split	1.0	Jubilee	5.22	1.69	.83	1.59	47.8	6.6	80.6	135.0
Statistics										
Main Effects										
Hybrid										
		Code 5	4.89	1.50	.81	1.52	29.0	5.6	65.1	99.8
		Jubilee	5.06	1.55	.78	1.25	39.4	5.8	67.5	112.8
Significance			*	+	NS	**	**	NS	NS	**
Timing										
		Preplant	4.98	1.50	.79	1.26	31.7	5.6	59.1	96.4
		Split	4.97	1.55	.82	1.51	36.8	5.8	73.6	116.2
Significance			NS	**	*	**	**	NS	**	**
NI Rate										
		0	4.92	1.50	.80	1.30	30.2	5.5	61.0	96.6
		0.5	5.06	1.53	.80	1.35	35.4	5.6	66.9	107.9
		1.0	4.95	1.55	.79	1.50	37.1	6.0	71.2	114.3
Significance			+	*	NS	**	**	NS	*	**
Linear			NS	++	NS	**	**	++	**	**
Quad			++	NS	NS	NS	+	NS	NS	NS
Interactions										
Hybrid x Timing			++	NS	++	NS	**	NS	NS	NS
Hybrid x NI Rate			NS	+	NS	NS	++	NS	NS	NS
Timing x NI Rate			NS	**	NS	**	NS	NS	NS	NS
Hybrid x NI Rate x Timing			+	NS	NS	NS	NS	NS	NS	NS

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

Table 5. Influence of timing of N fertilizer application (150 lb. N/A) and rate of nitrification inhibitor on leaf elemental concentration at mid-silking.

Timing	NI Rate (lb. ai/A)[1]	Hybrid	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			%					ppm				
preplant	0	Code 5	3.41	0.32	2.82	0.51	0.37	102	93	23	8	8
preplant	0.5	Code 5	3.20	0.32	2.71	0.47	0.34	295	50	20	8	7
preplant	1.0	Code 5	3.41	0.35	2.70	0.47	0.35	94	51	21	8	8
split	0	Code 5	3.33	0.33	2.83	0.51	0.35	100	74	22	8	9
split	0.5	Code 5	3.37	0.35	2.72	0.47	0.36	94	46	19	8	10
split	1.0	Code 5	3.51	0.36	2.83	0.47	0.34	98	49	21	8	7
preplant	0	Jubilee	2.82	0.29	2.55	0.51	0.41	77	92	26	7	8
preplant	0.5	Jubilee	2.93	0.30	2.57	0.46	0.35	80	62	26	8	9
preplant	1.0	Jubilee	2.80	0.31	2.46	0.47	0.38	77	48	25	8	8
split	0	Jubilee	2.83	0.30	2.50	0.51	0.39	77	67	24	8	7
split	0.5	Jubilee	3.02	0.32	2.51	0.47	0.36	78	53	25	8	7
split	1.0	Jubilee	3.07	0.33	2.59	0.44	0.34	84	51	27	9	8
Statistics												
Main Effects												
Hybrid												
		Code 5	3.37	0.34	2.77	0.48	0.35	130	60	21	8	8
		Jubilee	2.91	0.31	2.53	0.48	0.37	79	62	26	8	8
Significance			**	**	**	NS	*	+	NS	**	NS	NS
Timing												
		Preplant	3.09	0.32	2.63	0.48	0.37	121	66	24	8	8
		Split	3.19	0.33	2.66	0.48	0.36	88	57	23	8	8
Significance			++	*	NS	NS	NS	NS	*	NS	NS	NS
NI Rate												
		0	3.09	0.31	2.68	0.51	0.38	89	81	24	8	8
		0.5	3.13	0.32	2.63	0.47	0.35	137	53	23	8	8
		1.0	3.20	0.34	2.64	0.46	0.35	88	49	23	8	8
Significance			NS	**	NS	**	+	NS	**	NS	NS	NS
Linear			++	**	NS	**	*	NS	**	NS	NS	NS
Quad			NS	NS	NS	*	+	+	*	++	NS	NS
Interactions												
Hybrid x Timing			NS	NS	NS	NS	NS	NS	NS	NS	NS	*
Hybrid x NI Rate			++	NS	NS	NS	NS	NS	NS	NS	NS	NS
Timing x NI Rate			+	NS	+	NS	NS	NS	*	NS	NS	NS
Hybrid x NI Rate x Timing			NS	NS	NS	NS	NS	NS	NS	++	NS	*

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

1986 WEATHER

J.A. Lamb

The weather for 1986 was closer to the 90-year average when compared to the cool 1985 weather. The mean temperature for 1986 was the same as the 90-year average 39.4°F. Eight of the 12 months had average temperatures that were above the 90-year average. The remaining four months were below the average. Early growing season temperatures were above average which encouraged rapid growth of the spring crops. This extra growth helped compensate for the cool August and September temperatures. The last frost of the spring was May 2, 1986 (31°F) and the first hard killing frost was October 5, 1986 (31°F). Scattered frost occurred September 12, 1986 (32°F) which killed frost-tender crops in the research area of the Station. This made for a 123-day and 156-day growing season.

The 1986 precipitation was 1.5" less than the 90-year average. Eight of the 12 months had precipitation amounts less than the 90-year average. The remaining months were greater. The snow melt occurred somewhat earlier in 1986 and it was thought an early planting season would be possible. The rainfall in April delayed the planting season into mid May. The rains in July helped finish the small grain crop after a drier than normal June. August and October were drier than normal. Even with the normal rainfall in September the fall soil moisture content at the Northwest Experiment Station was low.

Table 1. Weather summary for 1986 with 90-year averages for precipitation and mean temperature.

Month	Precipitation 1986	Precipitation 1890-1979		Mean Temperatures 1986	Mean Temperatures 1890-1979
	--------inches--------			--------degrees F---------	
January	0.34	0.56		9.9	3.7
February	0.51	0.59		8.3	8.1
March	0	0.84		29.3	22.9
April	5.01	1.57		42.0	41.4
May	1.99	2.59		58.4	54.6
June	1.09	3.56		65.9	64.4
July	3.71	3.09		70.0	69.6
August	1.62	2.90		63.9	67.4
September	2.24	2.16		55.0	57.5
October	0.29	1.43		43.0	45.3
November	2.16	0.78		19.5	26.7
December	0.19	0.60		16.5	11.5
Total	19.2	20.67	Mean	39.4	39.4

THE EFFECTS OF SULFUR APPLICATION ON SUGARBEET

J.A. Lamb

OBJECTIVE: Determine if sugarbeets grown in the Red River Valley would respond to sulfur fertilization.

PROCEDURE: This study was located at the Northwest Experiment Station, Crookston, MN. Table 1 shows the soil parameters for this location. Elemental sulfur was applied at rates of 0, 25, and 50 pounds S per acre, spring 1986. The experimental design was a randomized complete block with four replications. Maribo 403 was planted May 15, 1986 and thinned back to 125 plants per 100 ft of row. The experiment was harvested September 24, 1986 and quality determined by American Crystal Sugar Tare Lab, East Grand Forks, MN.

Table 1. Soil parameters NWES sulfur study.

NO_3^--N (0-2')	41 #/A
P ($NaHCO_3$)	7 #/A
K	220 #/A

RESULTS AND DISCUSSION: The yield and quality results are reported in Table 2. The application of sulfur to the soil caused a trend toward decreasing root yields and sugar content. The impurities were increased with increasing S rate as noted by the impurity index and the decrease in pounds of sugar recovered per ton of sugarbeet. As a combination of the decreasing root yield, sugar content, and increasing impurity index, the recoverable sugar per acre was significantly decreased with increasing sulfur application. A yield response would not be expected at this location or on any Red River Valley soils because of the gypsum (calcium sulfate) content.

Table 2. Root yield, sugar content, recoverable sugar, sugar per ton of sugarbeet impurity index for sulfur study NWES, 1986.

Sulfur #/A	Yield Ton/A	Sugar %	Recoverable Sugar #/A	Recoverable Sugar/Ton #/Ton	Index
0	20.5	18.7	7066	344	523
25	19.9	18.3	6682	336	548
50	19.4	18.1	6417	330	597
Statistical Analyses					
Sulfur	NS	NS	++	+	NS
Linear	+	+	*	++	+
CV %	4.8	2.4	4.6	2.7	10.3

*, ++, + and NS are 0.05, 0.10, 0.20, and not significant, signicance levels, respectively.

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

STARTER PHOSPHORUS FERTILIZER ON SUGARBEET

J.A. Lamb

OBJECTIVE: Determine if sugarbeet will respond to starter fertilizer.

MATERIALS AND METHODS: This study was conducted at the Northwest Experiment Station in 1986. The soil test results are as follows; 40 # NO_3^--N (0-2'), $NaHCO_3$ P 7 #/A, and K 220 #/A. There are eight treatments in this study. Four treatments were ammonium polyphosphate 10-34-0 broadcast and incorporated or row applied at planting at 3 or 6 gallon/A rates. Three treatments were preplant application of Minnesota recommendations alone, or with 3 and 6 gallon/A of row applied 10-34-0. In 1986, the Minnesota recommendations were 80 # N/A and 70 # P_2O_5/A. The final treatment was an unfertilized check. The treatments were arranged in a randomized complete block design with four replications. The study was planted May 15, 1986 using KW3394 sugarbeet variety. Harvest occurred the third week of September with the quality determined by the American Crystal Tare Lab in East Grand Forks, MN.

RESULTS AND DISCUSSION: Table 1 lists the 1986 yield and quality results. Sugar content and recoverable sugar per ton were not affected by the treatments. The addition of fertilizer increased yield and recoverable sugar per acre. The treatments with Minnesota recommendations had larger root yields than those without. The addition of starter fertilizer to the Minnesota recommendation treatments increased yields. The treatments with just starter fertilizer the row application yielded better than the broadcast and the 6 gallon/A yielded better than 3 gallon/A.

The recoverable sugar per acre was effected similar to the root yield by the treatments. The exceptions to this would be the 6 gallon/A broadcast and Minnesota recommendation + 3 gallon/A row. These treatments were lower in relative comparison to the other treatments. This was caused by somewhat lower sugar contents. These responses in root yield and recoverable sugar per acre were caused by the phosphorus applied in the fertilizer. The low soil test P confirms this observation.

Table 1. Treatment means and statistical analyses for yield and quality for sugarbeet starter study, 1986.

	Root		Recoverable		
Treatment	Yield Ton/A	Sugar %	Sugar #/A	Sugar/Ton lb/Ton	Index
Check	15.9	18.5	5421	340	522
3 Gallon Row	18.7	18.6	6426	344	501
6 Gallon Row	19.8	18.7	6856	346	487
3 Gallon Broadcast	17.4	19.0	6137	352	500
6 Gallon Broadcast	16.2	18.6	5543	341	557
MN Rec.	20.3	18.5	6901	339	535
MN Rec. + 3 Gal. Row	20.6	18.3	6819	332	616
MN Rec. + 6 Gal. Row	21.7	18.3	7194	332	619
Statistical Analyses					
Treatment	**	NS	**	NS	++
C.V.%	5.5	2.8	6.2	3.6	11.1

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

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

THE EFFECT OF NITROGEN RATE AND PLANT POPULATION ON SUGARBEET

J.A. Lamb

OBJECTIVE: Determine if adjustment in nitrogen fertilization on above-optimum spaced sugarbeet will increase yield and quality.

MATERIALS AND METHODS: A study with nitrogen and plant population variables was established at Crookston with N treatments of 40, 120, and 200 pounds (soil N + fertilizer N) N per acre and plant populations established by overplanting and thinning to the following populations of 100, 150, and 200 plants/100 ft of row. The treatment design was split-plot with N rate as the whole plot and plant population as the subplot. Four replications were planted May 22, 1986 to Maribo 403. Harvest occurred the third week of September. The soil test NO_3^--N was 40 # N/A (0-24").

RESULTS AND DISCUSSION: Root yield was significantly increased with the addition of N even up to the 200 # N/A level. When the population was increased, the root yield decreased. There was no significant interaction. The optimum yield was at 100 sugarbeet plants per 100 foot of row and 200 # N/A. Increased N did significantly decrease the sugar content and population did not have an effect. The recoverable sugar per acre was slightly increased by N but more directly decreased with increasing population. Recoverable sugar per ton was negatively effected by increasing N rate. Plant population did effect recoverable sugar per ton of sugarbeet. The negative N effect was caused by the increased impurities at the higher N levels. The addition of N does compensate for the detrimental effects of above optimum plant populations but does not totally replace the recoverable sugar loss caused by not having an optimum population.

Table 1. Yield and quality as affected by plant population and nitrogen in 1986.

		Root		Recoverable	
N Rate	Population	Yield Ton/A	Sugar %	Sugar #/A	Sugar/Ton #/Ton
40	100	15.4	17.1	4778	310
	150	12.7	17.5	4046	320
	200	10.9	16.9	3305	305
120	100	15.2	17.1	4695	309
	150	13.1	16.7	3951	301
	200	12.5	16.6	3704	297
200	100	15.8	16.3	4496	285
	150	15.6	16.6	4595	295
	200	13.7	16.2	3934	286
N Rate					
	40	13.0	17.1	4043	311
	120	13.6	16.8	4117	302
	200	15.0	16.4	4341	289
Population					
	100	15.5	16.8	4656	301
	150	13.8	16.9	4197	305
	200	12.4	16.5	3648	296
Statistical Analyses					
N Rate		*	**	NS	**
Linear		*	**	+	**
Quadratic		NS	NS	NS	NS
Population		**	NS	**	NS
Linear		**	NS	**	NS
Quadratic		NS	NS	NS	NS
N Rate * Population		NS	NS	NS	NS
C.V.%		12.8	3.6	12.9	5.0

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

TIMING OF NITROGEN APPLICATION ON SUGARBEET

J.A. Lamb

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

MATERIALS AND METHODS: The plots were established at the Northwest Experiment Station, Crookston, MN. Urea Ammonium Nitrate solution (UAN, 28% N) was used to apply N at four dates, May 5, June 4, June 26, and July 18. The applications were knifed with anhydrous ammonia knives spaced 22 inches apart. The total amount of N applied was 80 #/A. The soil test was 41 # NO_3^--N/A (0-2'). This brought the total N to 120 #N/A. Hilleshog Dippe II was originally planted May 5, 1986. Because of crusting problems the experiment was replanted to the same variety May 22 and thinned to 125 plants per 100 feet of row. The treatments, which are reported in Table 1, were arranged in a randomized complete block design with four replications. The sugarbeets were harvested September 25, 1986 and the quality was determined by the American Crystal Sugar Tare Lab, East Grand Forks, MN.

RESULTS AND DISCUSSION: The results for 1986 are contained in Table 1. The addition of N did not significantly effect the sugar content, recoverable sugar per ton of sugarbeet, Na, K, and impurity index. An increase in root yield and recoverable sugar per acre from N fertilization occurred. There were no significant differences in root yield and recoverable sugar per acre caused by the different application treatments. This was different from the results in 1985. In 1985 the later applications of N decreased the sugar and quality of the sugarbeet. The amino N content was significantly affected by the treatments applied. These differences do not follow any logical pattern as far as an explanation.

Table 1. Root yield, sugar content, recoverable sugar, sugar per ton sugarbeet, and impurities for N timing study, NWES, 1986.

Application Date				Root		Recoverable		Impurities			
5/5	6/4	6/26	7/18	Yield	Sugar	Sugar	Sugar/Ton	Na	K	Amino N	Index
--------#N/A---------				Ton/A	%	#/A	lb/Ton	------ppm-------			
0	0	0	0	14.2	17.5	4541	320	248	2105	393	565
20	20	20	20	17.5	17.7	5643	324	288	1960	428	564
40	40	0	0	18.1	17.6	5775	320	240	2033	513	615
40	0	40	0	16.7	18.0	5512	330	233	2108	400	550
40	0	0	40	17.9	17.8	5845	324	238	2200	423	583
0	40	40	0	16.7	17.4	5325	316	245	2248	393	589
0	40	0	40	16.9	17.0	5213	308	290	2093	453	622
0	0	40	40	16.3	17.4	5194	315	270	2195	463	632
80	0	0	0	18.9	17.0	5767	304	275	2260	573	708
0	80	0	0	18.1	17.7	5863	326	245	2058	358	532
0	0	80	0	16.8	17.1	5249	312	295	2108	400	590
0	0	0	80	17.6	17.0	5468	309	283	2073	423	602
Statistical Analyses											
Treatment				NS	NS	NS	NS	NS	NS	**	NS
Check vs Rest				*	NS	++	NS	NS	NS	+	NS
CV %				17.5	3.5	17.9	4.6	22.7	8.0	15.1	13.0

**, *, ++, +, and NS are 0.01, 0.05, 0.10, 0.20, and not significant significance levels, respectively.

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

FOLIAR NITROGEN APPLICATION ON SUGARBEET-TIMING AND RATE

J.A. Lamb and J.T. Moraghan

OBJECTIVE: Determine effects of foliar N application on sugarbeet yield and quality after early yellowing under optimum fertilizer rates and under inadequate N conditions.

MATERIALS AND METHODS: A cooperative study was established at the Northwest Experiment Station, Crookston, MN with the foliar and preplant soil treatments listed in Table 1.

Table 1. Treatments for foliar N trial, NWES 1986.

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

The soil NO_3^--N (0-2') was 41#/A. Six replications were planted to ACH 164 in a randomized complete block design May 22. The plots were overplanted and thinned back to 125 plants per 100 feet of row. The soil treatments were applied and incorporated October 25, 1985 as urea. The foliar treatments were urea ammonium nitrate (UAN 28%) solution applied at 20# N/A increments on June 28, July 15, and July 30. Petiole and blade samples were taken July 10, July 28, and August 20 for N determination. Roots and tops were hand harvested September 25 with quality determined by American Crystal Tare Lab and N determined at Dr. J.T. Moraghan's laboratory at NDSU.

RESULTS AND DISCUSSION: Yields: Root yields were increased with the application of foliar N (Table 2.). The 20# N/A foliar treatment caused the yield increase with addition amounts not increasing root yield further. The 100# N/A soil N treatment had the greater yields than the 0# N/A treatments. The 20# N/A foliar application increased yields by 2 tons/A at the 0# N/A soil treatment where the 20# N/A foliar at the 100# N/A soil treatment only increased yields 0.7 tons/A.

The sugar content was increased by foliar N at the 0# N/A soil applied level and decreased by foliar N at the 100# N/A soil. This is because the foliar treatment has added too much N to the plant at the 100# N/A level and thus decreasing sugar content. The 0# N/A level is deficient in N and was able to utilize the additional N supplied.

Recoverable sugar per acre was increased with the addition of as little as 20# N/A foliar August 1. Additional N application either to the soil or as a foliar spray did not further increase recoverable sugar per acre. With the current payment program the foliar treatments at the soil N of 100#/A would decrease payments because of the negative effect on sugar per ton of sugarbeets. This negative effect did not occur with the foliar N treatments at the soil N of 0#/A.

Top yields were increased with increasing amounts of nitrogen both foliar and soil applied. The amount of N for maximum top yield does not correlate to the maximum recoverable sugar per acre. This response for top growth is similar to results of other studies.

Impurities: The impurities are reported in Table 3. All three factors measured for impurities were effected by N fertilization. Sodium (Na) and Amino N contents increased with the addition of N both foliar and in the soil preplant. The K content was decreased with increasing soil and foliar N. The overall effect of N on impurities as reflected by the index value, is generally greater with the addition of both foliar and soil N.

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

Table 2. Sugarbeet root and top yield, sugar content, recoverable sugar per acre, and recoverable sugar per ton sugarbeet, foliar study, NWES, 1986.

Soil N #/A	Foliar N #/A	Yield Ton/A	Sugar %	Recoverable Sugar #/A	Recoverable Sugar/Ton #/Ton	Top Yield #/A
0	0	12.1	19.0	4297	356	2210
0	20	14.1	19.3	5066	360	3407
0	40	14.3	19.4	5148	359	3527
0	60	13.4	19.3	4811	360	3504
100	0	13.8	19.2	4908	356	3765
100	20	14.5	18.5	4929	340	4230
100	40	14.0	18.7	4770	341	4067
100	60	14.5	18.6	4918	338	4700
	Foliar N #/A					
	0	12.9	19.1	4603	356	2988
	20	14.3	18.9	4997	350	3819
	40	14.2	19.0	4957	350	3797
	60	14.0	18.9	4865	349	4102
	Soil N #/A					
	0	13.5	19.2	4830	359	3162
	100	14.2	18.7	4881	344	4190
Statistical Analyses						
Soil N		*	**	NS	**	**
Foliar N		**	NS	*	NS	**
Soil x Foliar N		++	*	**	*	NS
CV %		7.1	2.3	7.1	2.9	12.6

**, *, ++, and NS are 0.01, 0.05, 0.10, and not significant, significance levels, respectively.

Petiole N: At the first two sampling dates, July 10 and 28, the petiole N level was not significantly effected by the foliar appications (Table 4). Petiole N was greater under the 100# N/A applied to the soil as compared to the 0# N/A. At the August 20 sampling date both soil applied and foliar N treatments increased petiole N. The increasing amount of foliar applied N increased petiole N accordingly.

Table 3. Sugarbeet root impurities, foliar study, NWES, 1986.

Soil N #/A	Foliar N #/A	Impurities Na	K	Amino N	Index
		ppm			
0	0	192	2218	218	436
0	20	205	2223	245	446
0	40	237	2262	288	477
0	60	198	2085	260	435
100	0	218	2055	375	493
100	20	275	2072	430	553
100	40	297	2100	476	580
100	60	293	2052	503	590
	Foliar N #/A				
	0	205	2137	297	465
	20	240	2148	338	500
	40	266	2181	383	529
	60	246	2068	382	513
	Soil N #/A				
	0	208	2197	253	449
	100	271	2070	446	554
Statistical Analyses					
Soil N		**	**	**	**
Foliar N		*	++	**	**
Soil x Foliar N		NS	NS	++	++
CV %		21.5	4.6	11.4	8.2

**, *, ++, and NS are 0.01, 0.05, 0.10, and not significant, significance levels, respectively.

Blade N: The blade N values for July 10 and 28, were increased by the addition of 100# N/A to the soil preplant. The foliar treatments that were applied (60# N/A at July 10 sampling and 40 and 60# N/A at the July 28 sampling) increased blade N content. The August 20 sampling results indicate the blade N contents are affected differently, depending on the soil N level. At the 100# N/A soil level, the 40 and 60 # N/A foliar treatments had greater blade N contents. The 20# N/A foliar did not have an increased blade N content. The blade N content for the 0# N/A, increased with a foliar application but the increase was the same for all foliar levels.

Conclusion:

1) From this data it can be noted that in most cases the N content of the blade will indicate the addition of foliar N fertilizer. The petiole N was not as reliable.

2) The addition of N did effect the impurity level, increasing impurities with increasing N (soil or foliar).

3) For 1986, 20 #N/A applied foliar July 30 or 40# N/A foliar applied as 20# N/A July 15 and July 30, at the 0# N/A soil level and the 0# N/A foliar at the 100 # N/A soil level, would have given the highest return per acre. Remember this is a conclusion from one location and one year's data. This could possibly be different next year.

Table 4. Influence of soil and foliar N application on % N in petioles and blades of sugarbeets, NWES, 1986.

Soil N #/A	Foliar N #/A	Petiole N 7/10	Petiole N 7/28	Petiole N 8/20	Blade N 7/10	Blade N 7/28	Blade N 8/20
		% N					
0	0	2.36	0.92	0.68	4.59	3.27	2.65
0	20	2.41	0.97	0.83	4.66	3.31	3.37
0	40	2.18	1.00	0.80	4.55	3.52	3.22
0	60	2.35	1.09	0.83	4.81	3.57	3.49
100	0	3.24	1.54	0.96	4.96	4.28	3.65
100	20	3.09	1.64	1.03	5.05	4.12	3.51
100	40	3.18	1.75	1.13	4.95	4.47	3.93
100	60	3.31	1.76	1.17	5.08	4.35	3.90
	Foliar N #/A						
	0	2.80	1.23	0.82	4.78	3.78	3.15
	20	2.75	1.31	0.93	4.86	3.72	3.44
	40	2.68	1.38	0.97	4.75	4.00	3.58
	60	2.83	1.43	1.00	4.95	3.96	3.70
	Soil N #/A						
	0	2.33	1.00	0.79	4.65	3.42	3.18
	100	3.21	1.67	1.07	5.01	4.31	3.75
Statistical Analyses							
Soil N		**	**	**	**	**	**
Foliar N		NS	NS	**	**	**	**
Soil * Foliar N		NS	NS	NS	NS	NS	*

**, *, and NS are 0.01, 0.05, and not significant, significance levels, respectively.

HIGH PHOSPHORUS AND POTASSIUM RATES ON CONTINUOUS SPRING WHEAT

J.A. Lamb and R.K. Severson

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

EXPERIMENTAL PROCEDURE: Ten treatments consisting of P and K combinations and applications made to date are shown in Table 1. Treatments applied in the fall of 1985 were broadcast and plowed down. Nitrogen, as urea, was fall applied at 100 lb N/ac and incorporated with a field cultivator on October 29, 1985. Marshall wheat was planted on April 25, 1986 and harvested for grain yields on August 14, 1986. Whole plant samples were taken at soft dough August 7, 1986 for elemental analyses and used to determine forage yields, P, and K uptakes. Soil samples were taken after crop removal to measure the residual effects of the treatments. The plant samples are in the process of being analyzed at the time of this report so will not be reported.

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

Treatment No.	Application Date: Spring 1980 Fall 1985	Fall 1980	Fall 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

RESULTS AND DISCUSSION: Table 2 reports the grain yield, test weight, and protein. The significant differences in yield can be attributed to phosphorus fertilizer. There were no yield differences between the different phosphorus treatments. The phosphorus treatments generally had high test weights and lower protein content. The lower protein content reflected the larger grain yields for these treatments.

Table 3 lists the soil test data for 1985 and 1986. The addition of phosphorus for treatments 3-10 in the fall 1985 is generally reflected in the increases of soil test P. Treatment 1 and 2 have maintained the same very low P level since the beginning of this study. The soil exchangeable K is larger for the treatments (2, 3, 4, 5, 7, 8, 9, and 10) that have received K fertilizer in 1986.

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

Table 2. Grain yield, test weight, and protein for 1986.

Treatment	Grain Yield	Grain Test Weight	Grain Protein
	bu/A	#/bu	%
1	27.1	56.6	14.9
2	30.6	58.0	14.7
3	36.0	59.2	12.8
4	35.6	60.1	13.0
5	36.7	58.8	13.9
6	35.5	59.0	13.5
7	37.1	60.2	13.2
8	37.4	59.3	12.9
9	37.0	57.9	13.2
10	38.4	58.8	13.7
Statistical Analyses			
Treatment	**	*	**
C.V.	10.9	2.3	5.1
LSD .05	5.6	1.9	1.0

Table 3. Soil test 0-6" pH, $NaHCO_3$-P, and exchangeable K for 1985 and 1986.

Treatment	pH		$NaHCO_3$ P		Exchangeable K	
	1985	1986	1985	1986	1985	1986
			ppm			
1	8.3	8.4	3	3	135	142
2	8.3	8.3	4	3	180	194
3	8.3	8.3	12	13	168	181
4	8.2	8.4	20	27	176	185
5	8.3	8.3	8.5	18	181	191
6	8.3	8.5	22	25	130	137
7	8.4	8.3	21	28	145	154
8	8.1	8.3	21	28	153	169
9	8.3	8.3	6.5	13	136	146
10	8.3	8.4	4	10	129	155
Statistical Analyses						
TRT	+	*	**	**	**	**
C.V.	1.4	1.0	16.6	19.3	9.5	7.9
LSD .05	0.16	0.12	3.0	4.8	21	18.9

INTENSIVE FERTILIZER MANAGEMENT ON SPRING WHEAT

J.A. Lamb and R.K. Severson

In the past five years a large amount of information on the intensive management of inputs on small grains has been reported from Europe and the eastern United States. These practices emphasize the use of several different fertilization practices such as high yield goals, starter, and foliar application of N. These practices have proven to be effective in increasing yields and protein content in these areas. Little data exists for the effectiveness of these practices on spring wheat grown in the soil and atmospheric environments similar to those found in northwestern Minnesota and eastern North Dakota. With this in mind, in 1985 a study was started at the Northwest Experiment Station to evaluate: 1) if these intensive fertilization practices will increase spring wheat grain yield and quality, 2) if there was an increase in yield and quality, what practice or combination of practices were effective, and 3) what effect does the use of intensive fertilization practices have on the residual soil fertility.

This study has been conducted in 1985 and 1986 and will be concluded after the 1987 cropping season. The treatments involved are: 1) preplant fertility for two yield goals (60 and 110 bushels/A), 2) starter fertilizer (0 or 100 #/A 18-46-0 in 1985 and 180 #/A 10-34-0 in 1986), 3) foliar N applied at flag leaf (0, and 15 # N/A as Urea disolved in water), and 4) two applications of fungicide (0, or 2 #/A M-45).

In the two years we have conducted this study, we have had two different weather and growing conditions. In 1985 the potential for high yields was present. The growing season had adequate moisture and temperatures, low disease pressure, early planting date (May 2, 1985) and a long grain fill period. The growing season in 1986 did not have as great yield potential because of early wet weather, dry weather in July, and disease pressure caused by leaf rust, scab, and leaf disease. The 1986 planting date was May 5. Marshall wheat was used both years because of its short stature which reduces lodging, and the large number of acres it occupies in the spring wheat production areas of Minnesota and North Dakota. The soil tests for 1985 and 1986 are listed in Table 1. From the soil test information, the appropriate amounts of preplant fertilizer was applied to obtain the 60 and 110 bu/A yield goals (Table 2).

In both years grain yield and protein were increased with increased preplant fertility (Table 3). Grain yields in 1985 were increased by 8% while in 1986 the increase was not as large, 3%. The protein content was increased 1% and 0.6% in 1985 and 1986, respectively. Grain yields and protein are not directly related. The wheat will use N for increasing grain yield first before translocation into the grain to increase protein content. Because of the larger grain yields in 1985 when compared to 1986, the protein content was less on the average in 1985 when compared to 1986. The additional fertilization from 60 bu/A to 110 bu/A yield goal also cause a larger increase in protein content in 1985.

In 1985, the addition of 15 # N/A as a foliar spray at flag leaf stage increased the grain yield at the 60 bu/A yield goal (Table 4). This did not occur at the 110 bushel yield goal in 1985, nor at either yield goal in 1986. Normally, you would not expect grain yield increase from foliar spray at flag leaf because most of the N for plant growth has been taken up by the plant at that stage of growth. The longer grain fill period of 1985 may explain why this occurred. The protein levels were not effected by foliar N application in either year.

Table 5 lists the effects of fungicide and yield goal on grain yield and protein in 1985 and 1986. This data suggests that when the nutrient status is at optimum or above optimum, the application of fungicide to decrease the loss of grain yield from disease is advantageous. If the nutrient status is below optimum, there is no benefit from fungicide application. Other studies have shown that increased soil fertility status, particularly N, increased the plant growth and increased the incidence of disease. The 110 bu/A yield goal in both years have had larger grain yields when fungicide has been applied than where no fungicide has been applied. The 60 yield goal has not shown this response.

The use of starter fertilizer did not influence grain yield or protein content in either year.

How is the residual soil nutrient status influenced by the increased addition of fertilizer? Table 1 indicates an increase in soil test NO_3^--N and P from fertilizer applied to meet a 110 bu/A yield

---

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

goal. Even with the resultant increased grain yield, the crop did not use all of the nutrients supplied. The NO_3^--N content in the 0-24" depth was 100 # NO_3^--N/A greater in the 110 bu/A yield goal plots when compared to the 60 bu/A yield goal in the spring, 1986 soil test. The NO_3^--N content was decreased in the 60 bu/A yield goal plot but increase in the 110 bu/A yield goal when compared to the 1985 soil test. The phosphorus content was increased for both yield goals when compared to the original soil test in spring, 1985. The 110 bu/A yield goal fertilization increased the soil test P more than the 60 bu/A yield goal. The potassium soil test was not effected significantly. These increased soil test levels indicate there are some consequences to a producer's soil fertility management from using high fertilizer inputs. If a producer is raising sugarbeets or malting barley in rotation with spring wheat, with additional N could hurt the quality of the crop. This makes the need for a soil test more important than ever.

In summary, the following conclusions can be drawn in the first two years of this study:

1. Increasing preplant N fertilization will increase grain yield and protein.
2. Setting a realistic yield goal is important.
3. Addition of starter fertilizer did not effect yield or quality.
4. If an N deficient situation exists, the addition of N by foliar spray at flag leaf stage can increase yield.
5. If you are at optimum or above soil fertility, the use of a fungicide may be necessary.
6. Excess fertilizer use will increase the soil test values and may influence the future management of soil fertility.

Table 1. Spring soil tests for intensive management study, Northwest Experiment Station, 1985 and 1986.

	Spring, 1985 Yield Goal	Spring, 1986 Yield Goal	
	All Plots	60	110
OM %	3.1	2.7	2.7
NO_3^--N (0-24")	96	40	143
P (0-6")	8	22	30
K (0-6")	320	270	325
pH (0-6")	8.2	8.2	8.2
Salts (0-6")	0.3	0.3	0.3

Table 2. The quantity of preplant fertilizer applied for intensive management study, Northwest Experiment Station, 1985 and 1986.

	1985 Yield Goal		1986 Yield Goal	
	60	110	60	110
	---lbs/A--		---lbs/A--	
N	25	150	80	102
P_2O_5	70	100	30	30
K_2O	0	50	30	50

Table 3. The effect of yield goal (preplant fertilization) on grain yield, protein, and test weight.

Yield Goal bu/A	Yield bu/A 1985	Yield bu/A 1986	Protein % 1985	Protein % 1986	Test Weight #/bu 1985	Test Weight #/bu 1986
60	77.2	66.5	12.8	15.2	58.9	59.8
110	83.4	68.8	13.7	15.8	56.8	59.4

Table 4. Effect of foliar N and yield goal on grain yields and protein in 1985 and 1986.

	Yield bu/A				Protein %			
	1985		1986		1985		1986	
	foliar #/A							
Yield Goal bu/A	0	15	0	15	0	15	0	15
60	74.8	79.9	66.3	66.7	12.8	12.7	15.2	15.2
110	84.4	82.6	69.4	68.3	13.6	13.8	15.7	15.8

Table 5. The effect of fungicide and yield goal on grain yield and protein in 1985 and 1986.

	Yield bu/A				Protein %			
	1985		1986		1985		1986	
	fungicide #/A							
Yield Goal bu/A	0	2	0	2	0	2	0	2
60	78.4	76.0	67.7	65.3	12.9	12.7	15.3	15.1
110	80.6	86.3	66.0	71.6	13.7	13.8	15.7	15.8

MICRONUTRIENTS ON SPRING WHEAT

J.A. Lamb, R.K. Severson and E. Bernhardson

OBJECTIVE: Update existing secondary and micronutrient response data for spring wheat.

MATERIALS AND METHODS: This study utilized a missing element design involving iron, copper, sulfur, zinc, and manganese. Chloride was also added as a separate treatment to evaluate the possibilities of a Cl response in the Red River Valley. These treatments were replicated four times in a randomized complete block design. Table 1 reports the soil test for the Clay County location. The treatments were applied and the study planted to Marshall wheat May 16, 1986. The grain was harvested August 21, 1986 with a plot combine.

RESULTS AND DISCUSSION: The grain yield data in Table 1 indicates no response occurred in this study. As the soil test in Table 1 indicates, the soil nutrient status was high in many of the nutrients used. Wheat traditionally does not respond in grain yield to the addition of micronutrients and did not in this study. The addition of fertilizer (N) decreased the test wieght and the exclusion of any micronutrient did not influence the test weight.

Table 1. Soil test for micronutrient study, Clay County, 1986.

Soil Test	Sample Depth	Value
OM	0-6"	6.0%
NO_3^--N	0-24"	55 #/A
$NaHCO_3$-P	0-6"	29 #/A
K	0-6"	490 #/A
Zn	0-6"	1.4 ppm
SO_4^--S	0-6"	50 ppm
pH	0-6"	8.0
Salts	0-6"	0.7 mmhos
Cl	0-24"	109 #/A

Table 2. Grain yield and test weight for the micronutrient study, Clay County, 1986.

Treatments	Grain Yield	Grain Test Weight
	bu/A	#/bu
Check	36.4	57.6
Minnesota Recommendation (MR)	38.6	55.2
MR + 48 Cl as KCl	41.6	55.8
MR + 48 Cl as $CaCl_2$	41.0	56.4
MR + All	38.3	54.7
MR + All - Iron	40.4	54.6
MR + All - Copper	40.0	54.8
MR + All - Sulfur	39.7	54.7
MR + All - Zinc	38.6	55.2
MR + All - Manganese	35.9	52.4
Statistical Analyses		
Treatment	NS	**
CV%	9.6	1.8
LSD (.05)	-	2.3

All = 20 #/A Mn as $MnSO_4$
10 #/A Zn as $ZnSO_4$
10 #/A Cu as $CuSO_4$
10 #/A Fe as $FeSO_4$
20 #/A S as S

MR = 65 # N/A as Urea
0 # P_2O_5
0 # K_2O

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

YIELD AND ROOT ROT RESPONSES OF SPRING WHEAT TO CHLORIDE FERTILIZATION

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 grain yield and/or incidence of common root rot caused by *Cochliobolus sativus*.

METHODS AND MATERIALS: In 1986, a field study located in Polk County Minnesota was conducted using five rates of chloride (0, 12, 24, 36 and 48 # Cl/A) and two sources ($CaCl_2$ and KCl). The factorial combination of these treatments were arranged in a randomized complete block design with four replications. The plots were fertilized according to soil test for all nutrients but chloride. The chloride soil test was 71 #/A (0-2'). Other soil test information is included in Table 1. The treatments were broadcast-applied April 10, 1986 and incorporated. Marshall wheat was planted. Plant populations were determined before tillering occurred. Whole plant samples were taken at the soft dough stage for ICP analysis. The grain was harvested by plot combine on August 21, 1986. 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 August 12 (50 plants per 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 (DI) was calculated using the McKinney's "infection index".

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

RESULTS AND DISCUSSION: Table 2 contains the currently available data for 1986. Grain yields were increased by the application of chloride. The maximum grain yield occurred with the 24 # Cl/A rate. This increase was not a K response because there were no differences in the grain yields between the fertilizer sources (KCl vs $CaCl_2$). Also, the K soil test was extremely high (730 #/A). The chloride soil test was 71 #/A (which is higher than the 60 # Cl/A soil test value that South Dakota research suggests as nonresponsive) which suggests that a reduction in root disease may have been responsible for the yield increase. The test weight was also increased with use of Cl. The disease index results are reported as a root rot index (0-100 scale); in which the larger the value the greater the severity of root rot. There was a trend where greater yields correspond with the lower root rot indexes, but this was not a strong relationship.

ACKNOWLEDGEMENT: The authors thank Allan Dragseth for providing land and John Lee, Minnesota Valley Testing Lab for soil chloride analysis.

Table 1. Soil test information for Chloride experiment, Dragseth location, 1986.

Soil Parameter	Depth inches	Unit	Value
OM	0-6	%	4.4
NO_3--N	0-24	#/A	138
$NaHCO_3P$	0-6	#/A	49
K	0-6	#/A	730
pH	0-6		8.0
Salts	0-6	mmhos	0.7
Cl	0-24	#/A	71

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

SURVEY OF SOIL CHLORIDE STATUS IN THE RED RIVER VALLEY

J. Lamb, C. Holen, B. Holder, C. Nygaard, J. Arneson, and E. Bernhardson

OBJECTIVE: Determine the soil chloride status in the Red River Valley.

METHODS AND MATERIALS: In August, 1986 soil samples were taken from three counties in the Red River Valley (Clay, West Polk, and Kittson). The locations were chosen from the following criteria: 1) Include three soil series in common with each county (Wheatville, Donaldson, and Fargo) and one other soil series which was predominate in that county, and 2) the locations had no history of manure application or fertilization with KCl. The soil samples were taken in wheat stubble to a depth of 24" with increments of 0-6", 6-12", and 12-24".

RESULTS AND DISCUSSION: Table 1 lists the location, soil series, and chloride values for 1986. There was a large range in numbers. There is no relationship between chloride content and soils series. The extremely high value in Kittson County is caused from the high salt content of the soil at that location. South Dakota State research indicates that a soil with a chloride content of greater than 60 #/A (0-24") will not produce a yield response. Seven of the twelve sites were greater than that value.

ACKNOWLEDGEMENT: The authors would like to thank John Lee, Minnesota Valley Testing Lab for doing the chloride analyses.

Table 1. Chloride values for 1986 survey.

		Chloride #/A			
County	Soil Series	0-6"	6-12"	12-24"	0-24"
Kittson	Fargo	99	146	464	709
	Northcote	27	14	11	52
	Donaldson	33	23	18	74
	Wheatville	27	11	33	71
West Polk	Fargo	50	38	26	114
	Bearden	22	9	13	44
	Donaldson	82	70	79	231
	Wheatville	17	13	20	50
Clay	Fargo	16	9	16	41
	Bearden	20	30	75	125
	Donaldson	12	8	16	36
	Wheatville	21	35	74	130

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

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

J.A. Lamb and R.K. Severson

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

MATERIALS AND METHODS: Three sites were located in 1986. The NO_3^--N (0-2') contents were 97, 53, and 22 #/A for the St. Hilaire, Marshall County, and Norman County, respectively. The N fertilizer (Urea) treatments (0, 30, 60, 90, and 120 # N/A) and inoculation treatment (none and inoculated) were applied and the plots planted to McCall soybean May 23, 26 and 28 for St. Hilaire, Marshall County, and Norman County sites, respectively. The most recently matured trifoliate leaves were sampled at 50% bloom July 21 and 22 for nitrogen analysis. The plots were harvested by combine September 23 at the St. Hilaire and Marshall County locations and October 3 at Norman County.

RESULTS AND DISCUSSION: Table 1 and 2 list the statistical analyses, grain yield, and trifoliate N contents for 1986. At the St. Hilaire location the soil test NO_3^--N content was 97 #/A (0-2'). The grain yield was not affected by inoculation or N fertilization. The trifoliate N content was increased by addition of N fertilizer but not by inoculation. At Marshall County N fertilizer increased grain yield 3.5 bu/A with 120 # N/A. The use of inoculant increased grain yields 1.1 bu/A. The trifoliate N contents were increased by N fertilization but not by inoculant. The Norman County site soybean yields were not affected by the treatments. This was not expected since the NO_3^--N soil test was low at 22 #/A (0-2'). The trifoliate N contents at the Norman County site were increased with increasing N fertilization. Except at the 120 # N/A rate the inoculated treatments had greater trifoliate N contents than the uninoculated treatments.

Since none of the locations had a soybean cropping history the chance of forming nodules on soybean plant in the noninoculated treatments were low. The observation for 1986 was if inoculant was applied propertly, the soybean plant would form nodules. If the soybean was not inoculated, nodules did not form.

Table 1. Grain yields (bu/A) and statistical analyses for 1986.

N Rate	St. Hilaire			Marshall County			Norman County		
#/A	0	I	$\bar{X}$	0	I	$\bar{X}$	0	I	$\bar{X}$
0	43.1	42.7	42.9	35.4	37.0	36.2	32.9	32.4	32.6
30	44.5	42.6	43.6	37.0	37.6	37.3	31.6	31.8	31.7
60	44.1	43.1	43.6	36.5	37.5	37.0	31.6	31.8	31.7
90	44.3	44.8	44.5	37.3	37.7	37.5	31.6	30.6	31.1
120	44.1	43.2	43.6	38.8	40.6	39.7	32.5	32.6	32.6
$\bar{X}$	44.0	43.3	43.6	37.0	38.1	37.6	32.0	31.8	31.9
Statistical Analysis									
I		NS			+			NS	
N		NS			*			NS	
Linear		NS			**			NS	
Quadratic		NS			N			+	
I * N		NS			N			NS	
C.V.%		6.0			5.0			5.7	

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

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

Table 2. Trifoliate N contents (%N) and statistical analyses for 1986.

N Rate	St. Hilaire			Marshall County			Norman County		
#/A	0	I	X	0	I	X	0	I	X
0	5.94	5.87	5.90	5.87	5.54	5.68	4.64	4.38	4.53
30	5.99	5.91	5.95	5.85	5.76	5.80	4.56	4.65	4.60
60	6.00	6.03	6.01	6.04	5.94	5.99	5.29	4.97	5.11
90	6.15	5.97	6.06	6.00	6.04	6.02	5.52	5.56	5.54
120	6.02	6.03	6.02	6.09	5.99	6.04	5.72	5.65	5.67
X	6.02	5.96	5.99	5.97	5.85	5.91	5.07	5.08	5.07
Statistical Analysis									
I		NS			NS			++	
N		+			*			**	
Linear		*			**			**	
Quadratic		NS			NS			NS	
I * N		NS			NS			NS	
C.V.%		2.3			3.8			4.7	

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

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

J.A. Lamb, R.K. Severson, and G.W. Rehm

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

MATERIALS AND METHODS: This study was located at two sites; Norman County - Johnson site, and Marshall County - Anderson site. The soil test information is reported in Table 1. McCall soybeans were planted on May 26, 1986, and June 2, 1986 at the Marshall County and Norman County sites, respectively. The fertilizer treatments listed in Table 2 were applied as a starter placement 2" x 2" from the row. The treatments were in a randomized complete design with four replications. Small whole plants and population counts were taken three weeks after emergence. The Marshall County and Norman County plots were harvested September 23, 1986 and October 3, 1986, respectively.

RESULTS AND DISCUSSION: Norman County Location: Table 3 lists the results for the Norman County site. A small yield increase was detected when comparing the untreated check with the fertilizer treatments. This was probably a P response. The only fertilized treatment effect was a reduction in yield with the acid + Fe and nonacid + Fe treatments.

An increase in P concentration and uptake occurred from fertilizer addition. The acid treatments did have a higher P uptake than the nonacid. This effect did not increase yields.

Overall the addition of fertilizer did not effect Zn and Fe concentrations or uptake when compared to the untreated check. There were some differences between fertilizer treatments. The acid fertilizers did have higher Zn and Fe concentrations and uptakes than the nonacid.

This location had a marginal Zn soil test and although it was the most likely candidate for a grain yield response to Zn, no response occurred.

Marshall County Location: Table 4 lists the results for the Marshall County site. The yield for the acid fertilizer treatments was slightly higher than the nonacid treatments but the treated plots were not significantly better than the check.

The application of fertilizer significantly increased the concentrations and uptakes of P and Zn. The acid + Zn and acid + Fe + Zn treatments had greater Zn concentrations and uptakes than the corresponding nonacid treatments.

The acid fertilizer treatment had a lower plant population than the nonacid. This may have been caused by the fertilizer placement (2 x 2 starter). The reduction in population did not have a strong correlation with yield (r=.38).

Although there was grain yield difference between fertilizer treatments there was no increase of yield over the untreated check thus indicating the use of fertilizer for P, Zn, and Fe would not be an economical input for soybean production.

ACKNOWLEDGEMENTS:

We would like to thank Lynn Johnson and Dwight Anderson for allowing us to conduct these studies on their land and also thank Ray Thompson and Ken Pazdernik for their help in locating these sites.

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

Table 1. Soil test information for soybean fertilizer carrier study, 1986.

	Depth	Norman County	Marshall County
OM%	0-6"	4.0	4.7
NO_3^--N #/A	0-24"	22	53
$NaHCO_3$ P #/A	0-6"	12	38
K #/A	0-6"	510	280
pH	0-6"	8.0	7.7
Salts mmhos	0-6"	0.5	0.4
Zn ppm	0-6"	1.0	1.6
Fe ppm	0-6"	14.3	32.4

Table 2. Treatments for soybean fertilizer carrier study, 1986.

Carrier	Micronutrient
1. Acid fertilzier (4-21-0-4)	-
2.	1 # zn
3.	1 # Fe
4.	Zn + Fe
5. 10-34-0 + 12-0-0-26 (8-21-0-4)	-
6.	1 # Zn
7.	1 # Fe
8.	Zn + Fe
9. Check no fertilizer	

Table 3. Treatment means and statistical analyses for yield, small plant P, Zn, and Fe concentrations and uptakes and population for Norman County location.

	Yield bu/A	P ppm	P Uptake #/A	Zn ppm	Zn Uptake #/A	Fe ppm	Fe Uptake #/A	Population plants/A
Acid	31.2	3781	20.9	23.6	.13	618	3.50	101,277
Acid + Zn	33.1	4006	20.9	29.5	.15	562	2.96	103,455
Acid + Fe	29.6	3459	17.8	26.3	.13	823	4.00	102,366
Acid + Zn + Fe	30.6	3402	17.6	26.6	.14	539	2.75	100,188
Nonacid	33.4	3457	16.5	23.6	.11	592	2.90	100,188
Nonacid + Zn	31.6	3538	17.0	25.5	.12	601	2.87	101,277
Nonacid + Fe	29.4	3409	16.2	23.0	.11	482	2.29	95,832
Nonacid + Fe + Zn	32.3	3666	19.4	24.8	.13	527	2.88	107,811
Check	29.4	2938	14.8	25.2	.13	589	2.97	99,099
Check vs Rest	+	**	++	NS	NS	NS	NS	NS
Acid	NS	NS	++	++	*	+	*	NS
Iron	*	+	NS	NS	NS	NS	NS	NS
Zinc	NS	NS	NS	++	*	NS	NS	NS
A * I	NS	++	++	NS	NS	+	NS	NS
A * Zn	NS	NS	NS	NS	NS	++	*	NS
I * Zn	NS	NS	NS	NS	NS	NS	NS	NS
A * I * Zn	++	NS	NS	NS	NS	NS	+	NS
C.V.	6.9	10.5	18.0	13.9	15.3	26.7	24.6	9.4

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

Table 4. Treatment means and statistical analyses for yield, small plant P, Zn, and Fe concentrations and uptakes, population for Marshall County location.

	Yield bu/A	P ppm	P Uptake #/A	Zn ppm	Zn Uptake #/A	Fe ppm	Fe Uptake #/A	Population plants/A
Acid	35.4	5053	64.7	18.2	.24	240	3.26	76,230
Acid + Zn	34.9	4265	69.6	39.7	.65	233	3.81	90,387
Acid + Fe	36.1	5434	83.2	24.1	.36	251	3.66	69,696
Acid + Zn + Fe	35.9	4325	72.1	37.1	.58	226	3.60	82,764
Nonacid	33.3	4701	62.1	15.2	.21	240	3.27	84,942
Nonacid + Zn	34.4	4549	68.0	23.8	.34	240	3.41	88,209
Nonacid + Fe	34.0	5098	80.1	19.6	.31	260	4.09	82,764
Nonacid + Fe + Zn	33.2	4885	73.2	27.2	.40	191	2.84	91,476
Check	34.8	3420	43.4	18.2	.22	210	2.57	84,942
Check vs Rest	NS	**	**	**	**	NS	++	NS
Acid	**	NS	NS	**	**	NS	NS	**
Iron	NS	+	++	+	+	NS	NS	NS
Zinc	NS	**	NS	**	**	+	NS	**
NS* I	NS	NS	NS	NS	NS	NS	NS	NS
A * Zn	NS	*	NS	*	*	NS	NS	NS
I * Zn	NS	NS	NS	+	+	+	+	NS
A * I * Zn	NS	NS	NS	NS	NS	NS	NS	NS
C.V.	4.8	10.8	22.2	20.0	28.9	18.7	28.4	10.4

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

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

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

OBJECTIVES: The primary objective of this study was to evaluate the efficiency of deep band placement methods for P fertilizers over the diverse environmental conditions of Minnesota. Results obtained from these studies relate closely to the Northern Great Plains and for much of the Corn Belt. Under this broad objective are the following specific objectives:

1. Determine the efficiency of deep band application of P as compared to broadcast application on a wheat-soybean rotation in Northwestern Minnesota and a corn-soybean rotation in Southern and Western Minnesota.

2. Determine the effect of distance from the row of a deep band in row crops and the distance between of bands in solid seeded crops on both P uptake by crops and subsequent yield.

3. Determine the effect of soil test P level on the efficiency of deep bands.

4. Determine residual effects of deep band and broadcast placement of fertilizer P on P uptake and crop yield.

MATERIALS AND METHODS: This study was conducted at three locations; Waseca, Lamberton, and Crookston, MN in 1986. Corn and soybean were grown at Waseca and Lamberton and spring wheat and soybean grown at Crookston. Table 1 presents the soil test information for each location. The following variables were measured on corn at Waseca and Lamberton; grain yield, forage yield, forage P concentration and uptake, ear leaf P concentration at silking, and grain moisture content. Soybean variables measured at all locations were; grain yield, forage yield, forage P concentration and uptake, leaf P concentration at mid-flower, and grain moisture. At Crookston the parameters measured on the wheat were grain yield, grain protein content, bushel weight, grain moisture content, forage yield, and whole plant P concentration and uptake at anthesis. Only part of the P analyses, Lamberton corn ear leaf and soybean leaf, are available from the laboratory at the time of this report. The grain moisture has been incorporated into the grain yield data. The corn, soybean, and wheat grain yields have been corrected to 15.5, 13.5, and 13.5% moistures, respectively.

Table 1. Soil test values for P-efficiency study, 1986.

	Crookston*		Waseca**		Lamberton**	
	Wheat	Soybean	Corn	Soybean	Corn	Soybean
pH	7.8	7.9	5.9	5.9	6.2	6.1
OM%	3.0	2.4	3.5	3.5	3.8	3.9
Salts mmho	0.2	0.4	-	-	-	-
NO_3^--N 0-24"	8	10	-	-	-	-
P #/A	10	9	10	10	3	7
K #/A	230	240	331	382	259	290

* $NaHCO_3$-P
** Bray-P

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

Table 2 lists the treatments that were established on all six sites. Four replications of a complete factorial arrangement of three methods of phosphorus placement and five phosphorus rates were established. The broadcast method was incorporated at all locations. The knife method at Waseca (corn and soybean) and Lamberton (corn and soybean), placed a preplant band of fertilizer at a 6-inch depth between the 30 inch width rows. At the Crookston (spring wheat) site the knife method placed preplant fertilizer 6 inches deep with a shank spacing of 15 inches. The knife method for Crookston soybean was two 15" width preplant bands between the 30" rows applied at a 6" depth. The row method at Waseca (corn and soybean), Lamberton (corn and soybean), and Crookston (soybean) involved a band of fertilizer applied at planting 5 to 7 inches from the row and 2.5 to 3 inches deep. The Crookston (spring wheat) site row treatment involved placement of fertilizer directly with the seed. The phosphorus rates were 0, 10, 20, 30 and 40 pounds P per acre. Ammonium polyphosphate, 10-34-0, was the P source at all locations.

RESULTS AND DISCUSSION: Tables 3, 4, and 5 list the means for each treatment and each level of each factorial effect at all locations. Also included is a summary of significance probabilities for each measured observation.

Corn - Grain and forage yield at Waseca and Lamberton were increased by P fertilization. This would be expected because for the low soil test value for phosphorus. Grain yields were maximized at 30 lb P/A according to the regression. Method of application did not effect grain yields. At Waseca the forage yield was maximized at a P rate greater than 40 lb P/A. No method effect occurred for forage yield. At Lamberton there was a significant method by P rate interaction for forage yield. With all methods, forage yields increased with P fertilization. The broadcast method produced larger yields at the same P rate when compared to row and knife except at the 40 lb P/A P rate. The knife treatment had greater forage yields than the row treatments at the lower rates. At 40 lb P/A row, knife, and broadcast application methods performed similarly. With row and knife treatments the maximum forage yield occurred at 40 lb P/A. The maximum forage yield for the broadcast treatment occurred at the 30 lb P/A rate. The broadcast treatment at Lamberton was more efficient than the banded treatment for forage yield.

Ear leaf P was increased by P application at Lamberton. The broadcast method had larger concentration of P in the ear leaf than the banded methods. There were no differences in P concentration between knife and row application methods.

Soybean - Soybean grain and forage yields were increased at Waseca and Lamberton from P fertilizer. Also, soybean leaf P concentrations were increased at Lamberton. No response in grain yield occurred at Crookston, but a forage yield increase did occur from P fertilization. No method response occurred at Waseca for grain and forage yields or at Crookston for forage yield.

Lamberton had a significant method effect on grain yield, forage yield, and leaf P concentration. In all cases the broadcast treatments were larger than the banded treatments. There were no significant differences between row and knife method of application.

Wheat - The spring wheat grain yields at Crookston were significantly increased by P application. The maximum yield occurred at the 20 lb P/A rate. No method effects occurred.

Grain yields at all sites except the Crookston soybean site, responded to P application. Only the Lamberton corn and soybean sites had a method response. The broadcast application had significantly higher soybean grain yields, corn and soybean forage yields, corn ear leaf P concentrations, and soybean leaf P concentrations, than the banded applications (row and knife).