A Report on Field Research in Soils

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SOIL SERIES 128
A Report on Field Research in Soil Science

This "bluebook" compiles data collected and analyzed throughout Minnesota. Information is contributed by personnel of the University of Minnesota Department of Soil Science; by soil scientists at the Minnesota Agricultural Experiment Station branch ststions at Crookston, Lamberton, Morris and Waseca, and at the Becker and Staples research farms; and by 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, and the Departments of Agriculture and Natural Resources also contribute.

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

DISCLAIMERS

Some of these results are from 1988 experiments and should be regarded on this basis. Since most of the data is from 1988 studies only, conclusions may not be conclusive and thus are not for further publication without the written consent of the individual researchers involved.

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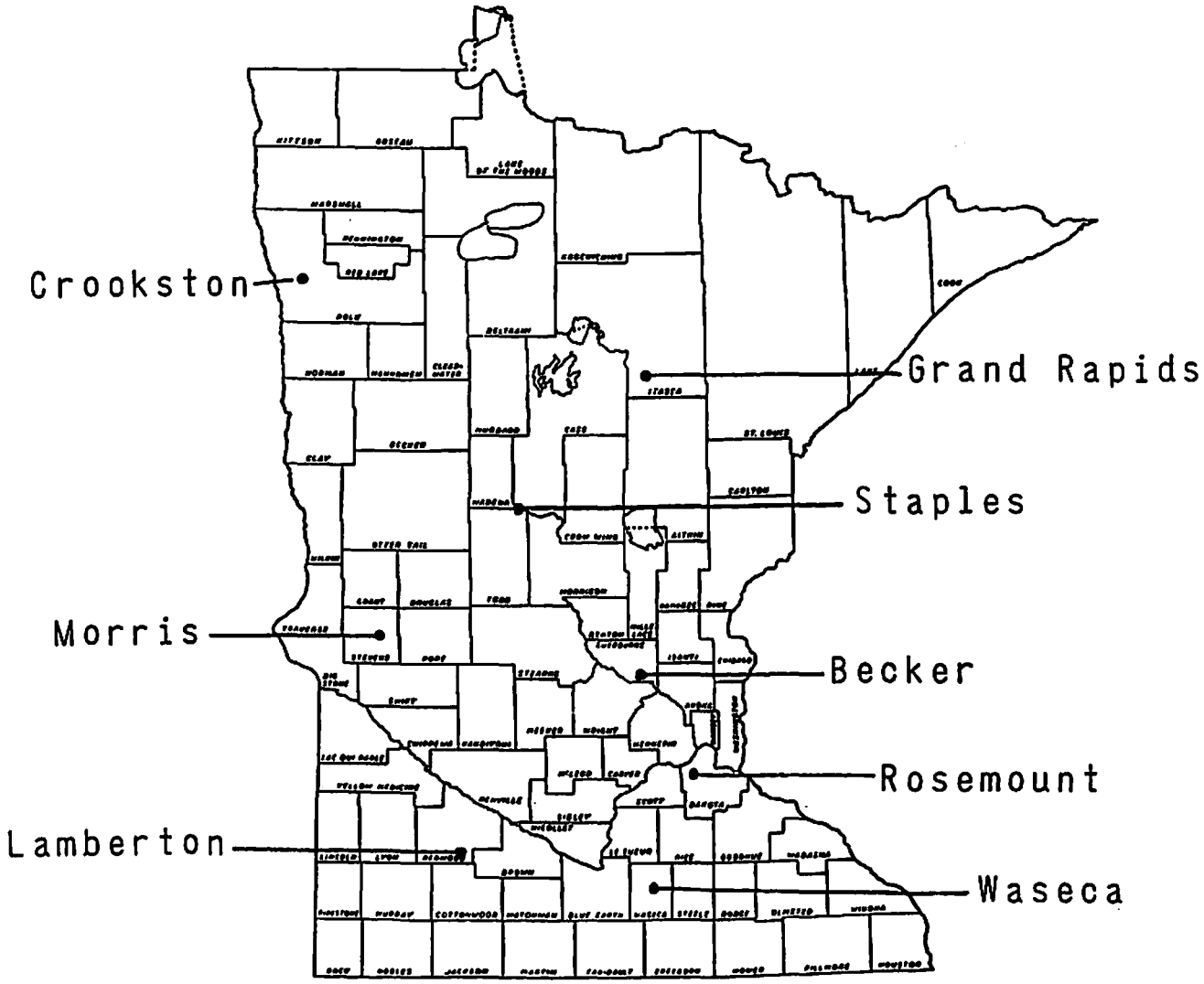
MINNESOTA EXPERIMENT STATIONS AND RESEARCH FARMS



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THE CLIMATE OF MINNESOTA

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A. The Amazing Climatic Extremes of 1976-1988

1. The General Climate

The drought of 1976 was centered in west-central Minnesota and its influence extended well beyond the state's borders. Because Minnesota was essentially spared the effects of the 1954 and 1956 droughts that were centered over Missouri (but affecting a very large region east and west), serious droughts in Minnesota had not occurred since the 1930's.

Following 1976 the climate of Minnesota, and indeed of a good share of northern United States, made a complete reversal. The following decade through September, 1986, was an extremely wet one. In parts of Minnesota the annual precipitation averaged more than 4.5 inches above normal each year, as shown in Fig. 1. In other words, in this 10-year span the equivalent of almost two full years of extra precipitation was received. This decade was the second highest in the 152-year Eastern Minnesota record, and 1983-1987 was the wettest consecutive 5 years in this record, Fig. 2.

It should be remembered that this wet period of 1977-1986 was the occasion for some real problems that developed due to rising lake levels. Numerous news items recited the problems due to the rising level of Great Salt Lake in Utah, Devil's Lake in North Dakota, Lake Carnelian in Washington Co. and other lakes in Minnesota, and the Great Lakes. Although it could not be predicted which year would revert to more normal conditions, revert it must and revert it did. Of course, the climate did revert but much more severely and tragically than could be foreseen. However, as severe as 1988 was, it should be remembered that even within one life span a more serious and widespread drought occurred in the 1930's, with the year 1934 being the worst year in almost every way of the several bad years of that decade.

2. Surface Temperatures

Because the soil was so dry little of the sun's energy was expended in the evaporation process and the extra energy went into heating the soil. As a result some very extreme surface temperatures occurred. In Fig. 3 are shown the daily maximum temperatures of a sod surface at St. Paul during July, 1988. On a soil bare of vegetation or on a sunlit soil between plant rows the temperatures would have been even higher. The highest sod surface temperature in that 31-day period was 137°F. These temperatures are high enough to kill many plants, or at least the portion of the plant, such as the plant stem, in contact with such temperatures.

3. Soil Moisture

The soil moisture reserves which normally provide for the plant requirements between rainfalls were rapidly depleted: first, because of the lack of spring rainfall and second, because in many cases the reserves had not been replenished during the previous fall.

A good example of soil reserves that were low at the beginning of the season and just kept getting lower and lower during the growing season is from Morris, Minnesota and is shown in Fig. 4. In this figure it is evident that the plant roots were exploiting as much water as could be reached, since the water content was pulled even below the wilting point. But obviously the roots never developed the depth

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required to reach the water in the 4th and 5th foot of soil. This is similar to what happened in the 1976 drought in which the corn plants, for example, were unable to reach reserves that still remained in the deeper part of the soil.

In Fig. 5 is shown a comparison between the soil moisture at Lamberton during the course of the two recent droughts, 1976 and 1988. It is apparent that in the spring of 1988 the soil water reserves were actually higher than they were in 1976. As a result, although higher air temperatures were reached in 1988 at Lamberton, the corn, and other crops, too, were able to obtain more water from the soil and better yields resulted.

In Fig. 6 is shown the course of the soil moisture reserves at Waseca during 1988 compared to the average. Although well below average Waseca remained in a generally better moisture status. It is very apparent at Lamberton and Waseca, Fig. 5 and 6, respectively, that by the end of the growing season the moisture reserves were still below average. This is also true at Morris where the departure from average is about 4 inches. Since the autumn, 1988, soil moisture recharge period has come and gone, it is evident that many of our agricultural soils remain 2-4 inches below average. We must conclude that the drought is still with us in parts of the state. We are therefore left with spring, 1989, as the remaining recharge period for the soils. Otherwise the 1989 season will hinge upon the occurrence of frequent and timely rains. In Fig. 7 and 8 are shown the probabilities that the spring precipitation (April 5 - May 15, the approximate period between spring thaw and corn planting) will be sufficient to bring the soil moisture up to its average amount for that time of year. For example, at Morris about 4 inches of water are required to bring the soil up to its average May 15 content. Based on Fig. 7 the probability of receiving that amount of precipitation by May 15 is not quite 30%. For the approximately 2 inches of soil water required at Waseca the probability of reception is around 80%. At Crookston the probability of receiving 3 inches of precipitation by May 15 is only about 30%.

The Morris, Lamberton, and Waseca examples of soil moisture content during the 1988 season, Fig. 4, 5 and 6 respectively, are for fields in corn. The results shown could differ appreciably if another crop was grown in 1988. This feature is quite apparent with respect to soil moisture measurements under different crops that were obtained in a Northwest Agricultural Experiment Station (Crookston) study. At the West Central Experiment Station at Morris it has also been found that large differences in the 1988 corn yield could be directly attributable to the previous year's crop. For example, in 1988 it was frequently found that corn following small grain did quite well, whereas corn following corn or corn following alfalfa resulted in greatly reduced yields. Therefore, the previous year's crop is a feature that should be considered in plans for this spring if one is operating on soils of reduced moisture content.

The estimated amounts of water in the soils of the state are shown in Fig. 9. These estimates are based upon a limited number of soil moisture measurements and a large number of precipitation measurements across the state. These estimates are intended to be valid for a 5-foot column of soil that can hold 10 inches of plant available water. Soils of different water holding capacities would vary accordingly.

4. Comparison of 1988 With Previous Years

It would be most interesting if the weather of 1934 or 1936 had been monitored as closely as it was in 1988. As a result comparisons between these two years are essentially limited to air temperature and precipitation. Based on the Twin Cities record the 1934 and 1864 agricultural years (September - August) were drier by several inches than 1988. In fact 1988 is tied with 1958 as the third driest agricultural year in the 1837-1988 eastern Minnesota record. For the May-June period 1934 was warmer by 1.3°F. However, July 1988, was the warmest on record.

The St. Paul campus solar radiation record, 1963-1988, shows that the 1988 solar radiation was the highest within that 26-year period. As is evident in Fig. 10, the 1988 radiation exceeded the other drought year, 1976, by a considerable amount. The increased radiation reception is, of course, a reflection of the fact that there was far less cloudiness than usual. The increased energy received from the sun added to the

already critical water shortage problem. In a sense the drought fed upon itself and served to intensify an already critical period.

B. The 1988 Total Precipitation and Departure from 1951-1980 Normals

For the second consecutive year, annual precipitation totals, Fig. 11, over large areas of Minnesota fell below historical averages. With the exception of northeastern Minnesota, most of the state reported precipitation amounts four or more inches below normal. Negative departures of eight or more inches were common in central and south central Minnesota, Fig. 12.

For much of Minnesota, 1988 brought the worst drought conditions since 1976. In many ways the drought of 1988 was the worst since 1934. The combined effects of deficient precipitation and abnormally hot temperatures (an all-time record for May through August) caused significant yield reductions and in many cases, total crop failure.

Although bolstered by near normal fall precipitation, soil moisture reserves remain below typical levels for many of the agricultural production areas of Minnesota. In these areas, the success or failure of the 1989 cropping season will be highly dependent on growing season precipitation.

Indications of just how different the 1987-1988 hydrologic year was from the previous five years is shown in Fig. 13 and Fig. 14. The first, Fig. 13, shows the average departure of the October 1986 - September 1988 hydrologic years from the 1951-1980 normal. Departures that were 4 or more inches below average occurred over all but the northeastern part of the state. In fact, in east-central Minnesota the departure was 8 inches or more below average. This nearly coincided with the area that received so much precipitation in the previous five years.

In marked contrast is the preceding five years which constituted about the wettest five years on record, Fig. 14. Every station recorded positive departures, and they varied from less than 2 to more than 10 inches greater than normal. Kandiyohi, Meeker, and parts of Stearns, Pope and Wright counties all recorded at least 8 inches above average per year.

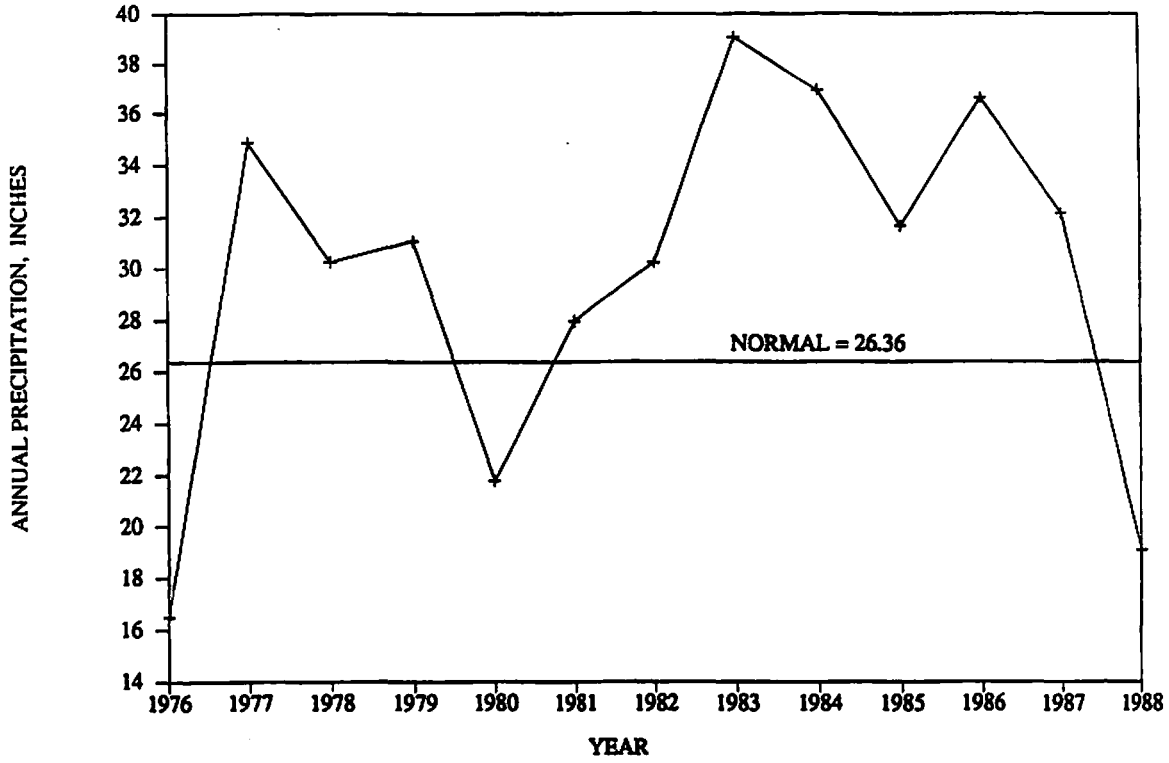

Fig. 1. Annual total precipitation at Minneapolis - St. Paul, 1976-1988.

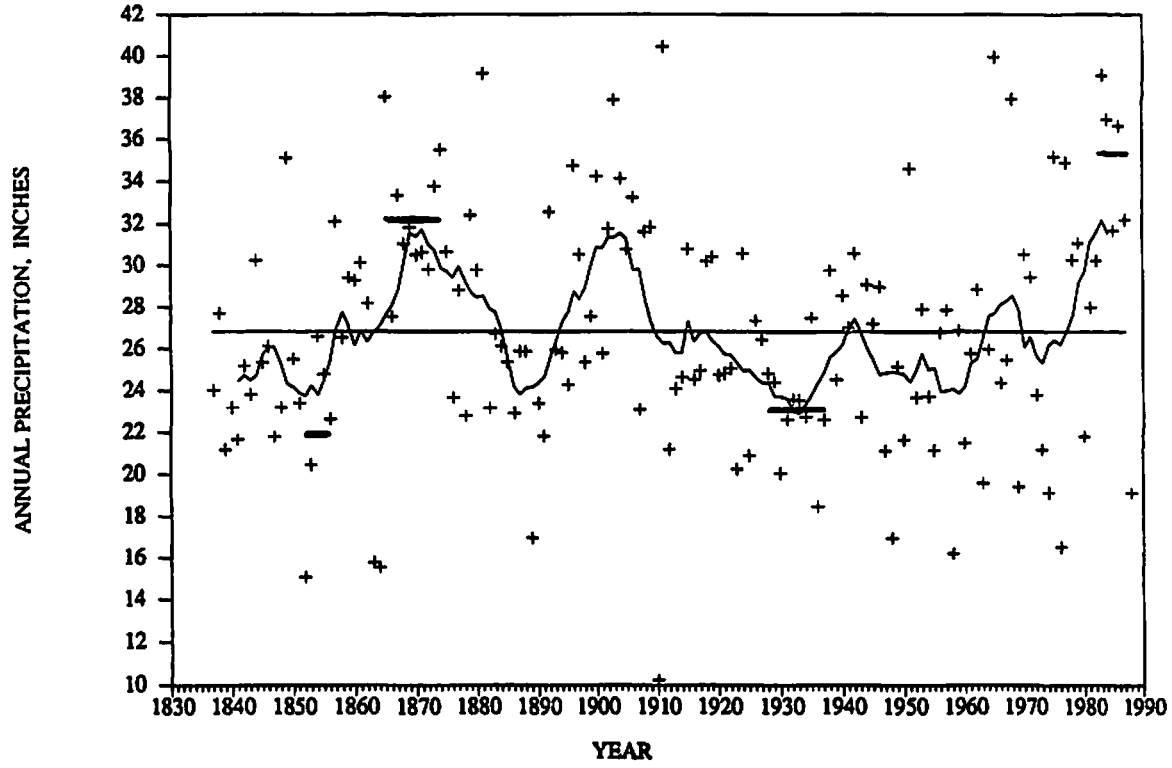

Fig. 2. The 1837-1988 annual total precipitation at Minneapolis - St. Paul. The crosses indicate the value for each individual year, the horizontal line shows the overall mean of 26.78 in., and the other line is the smoothed annual values so a trend (if any) can be seen. The horizontal bars show the driest 5 years (21.91 in.; 1852-1856), the driest 10 years (23.02 in.; 1928-1937), the wettest 10 years (32.19 in.; 1865-1874), and the wettest 5 years (1983-1987).

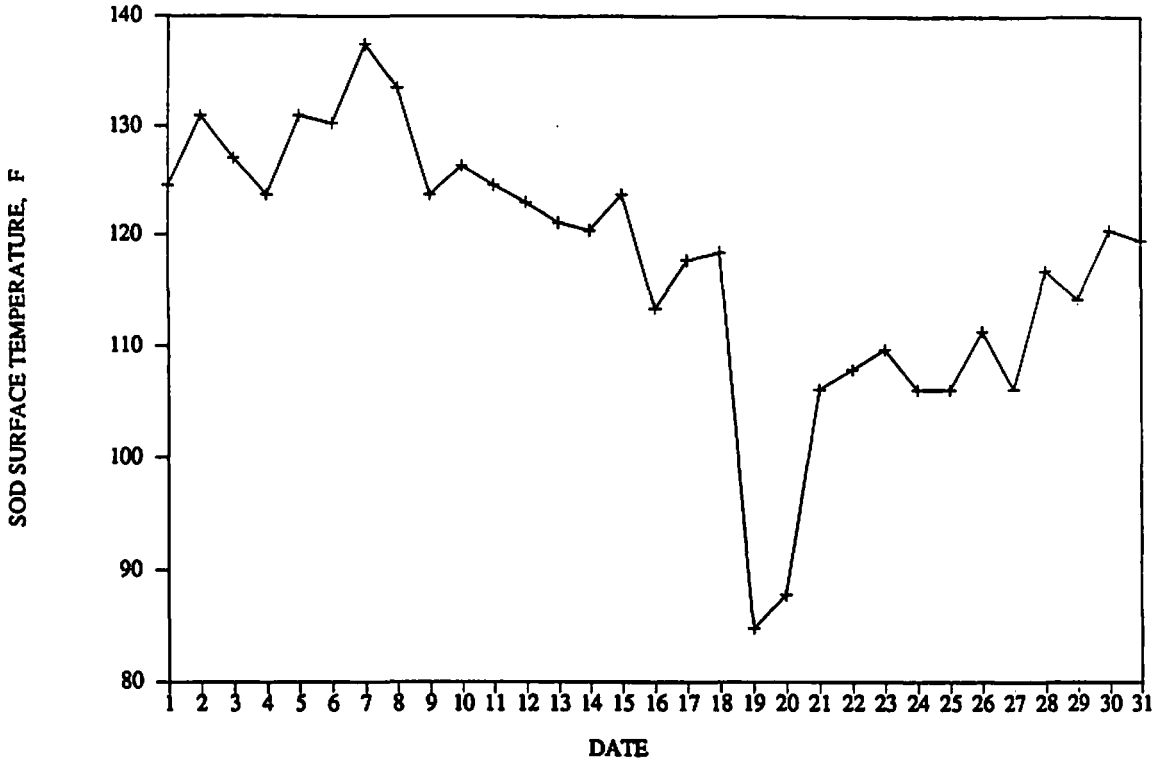

Fig. 3. Daily maximum sod surface temperatures measured at the U. of MN. climatological observatory, St. Paul, July, 1988.

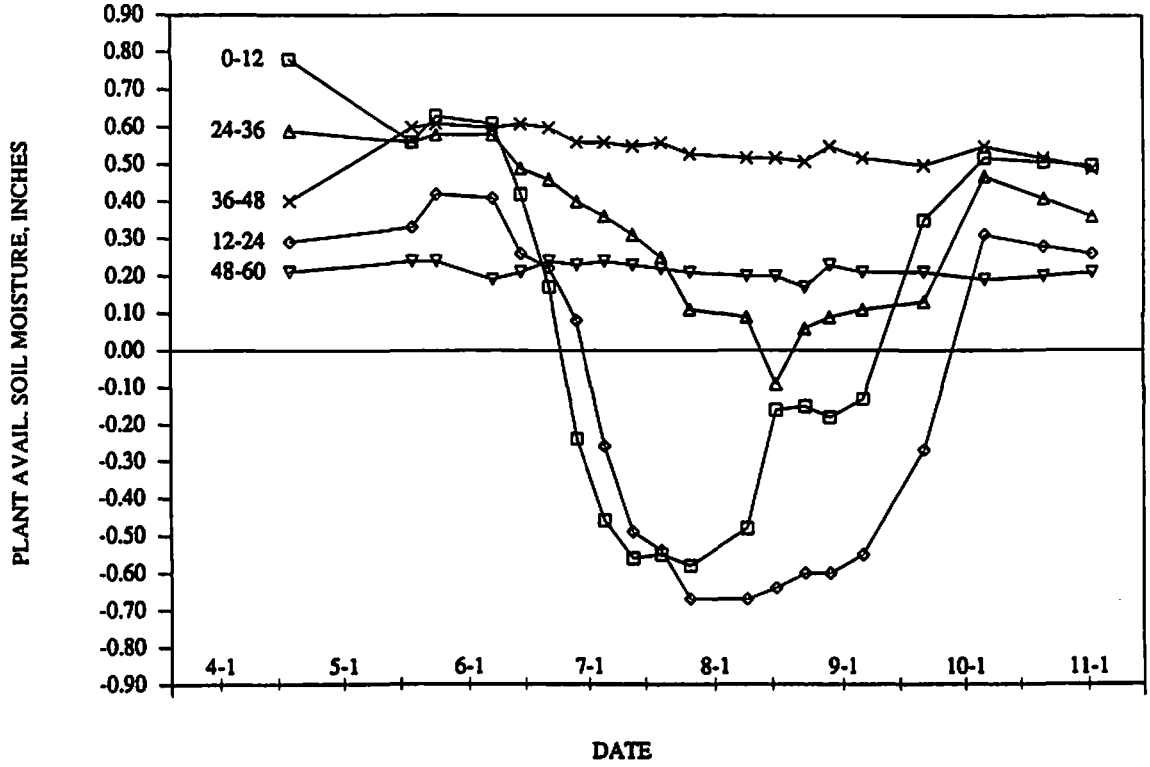

Fig. 4. Water content of each foot of soil (1-5 feet in depth) in a Tara silt loam soil planted to corn at the West Central Agricultural Experiment Station, Morris, MN, 1988.

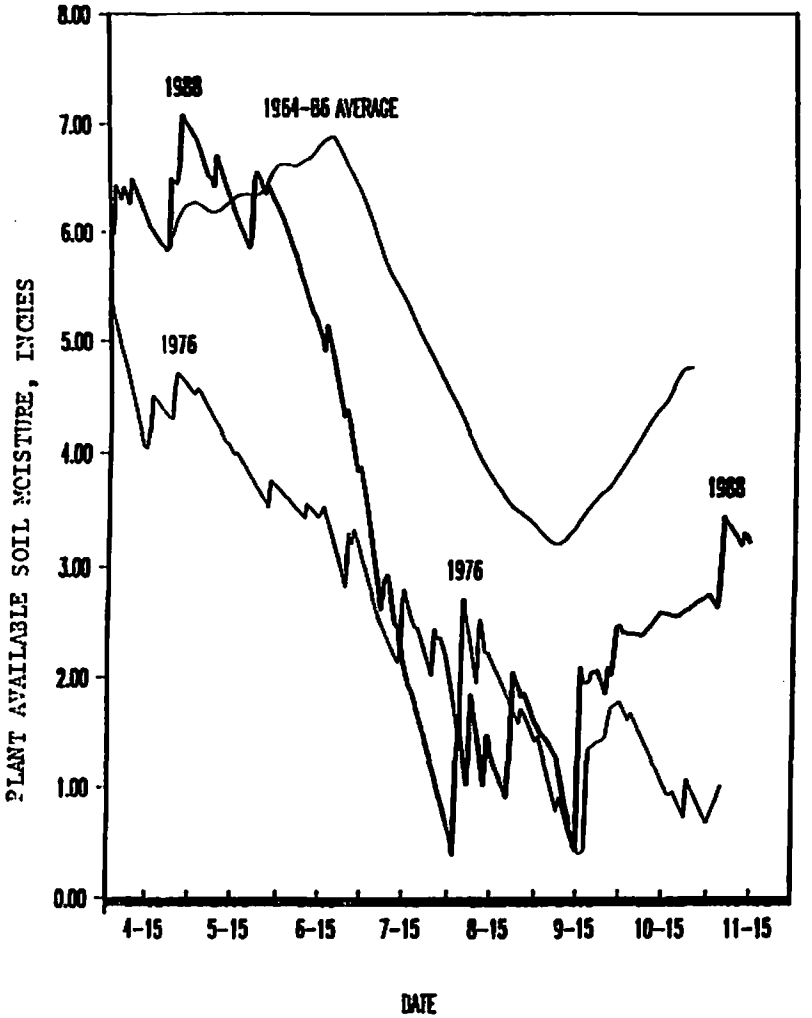

Fig. 5. Total plant available soil water in Webster silty clay loam planted to corn at the Southwest Agricultural Experiment Station. The 1964-1986 average values are shown along with the 1976 and 1988 growing season values.

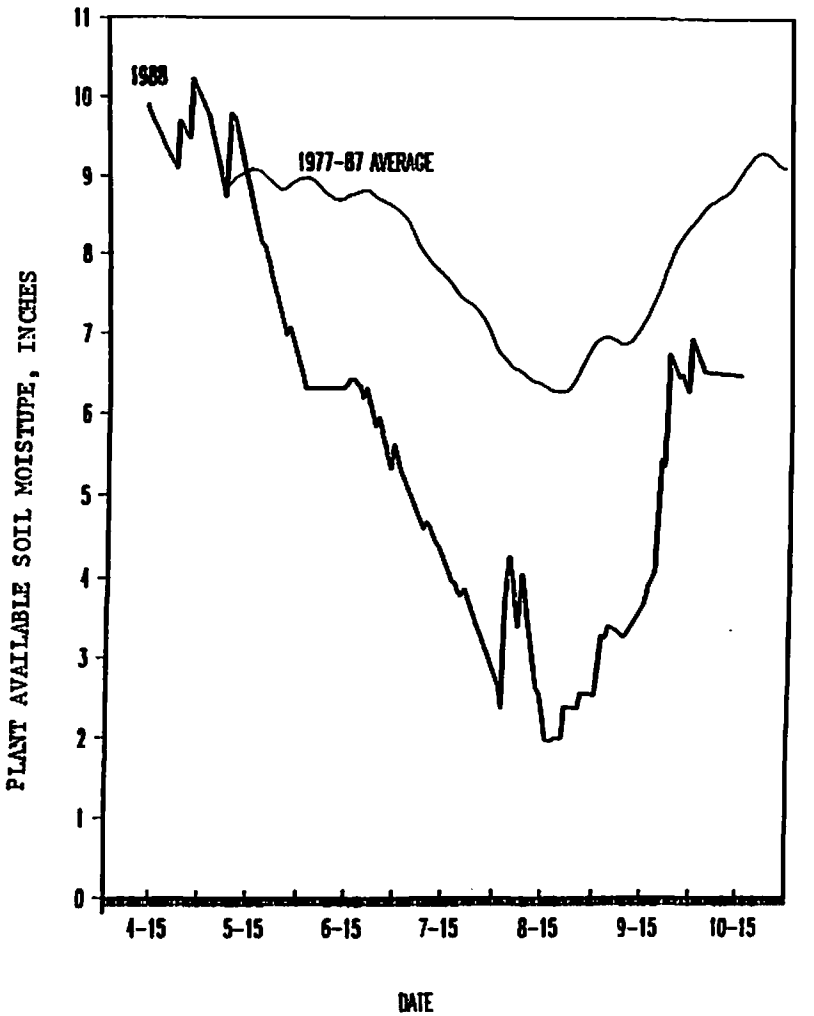

Fig. 6. Total plant available soil water in soil planted to corn at the Southern Agricultural Experiment Station. The 1977-1987 average values are shown along with the 1988 growing season values.

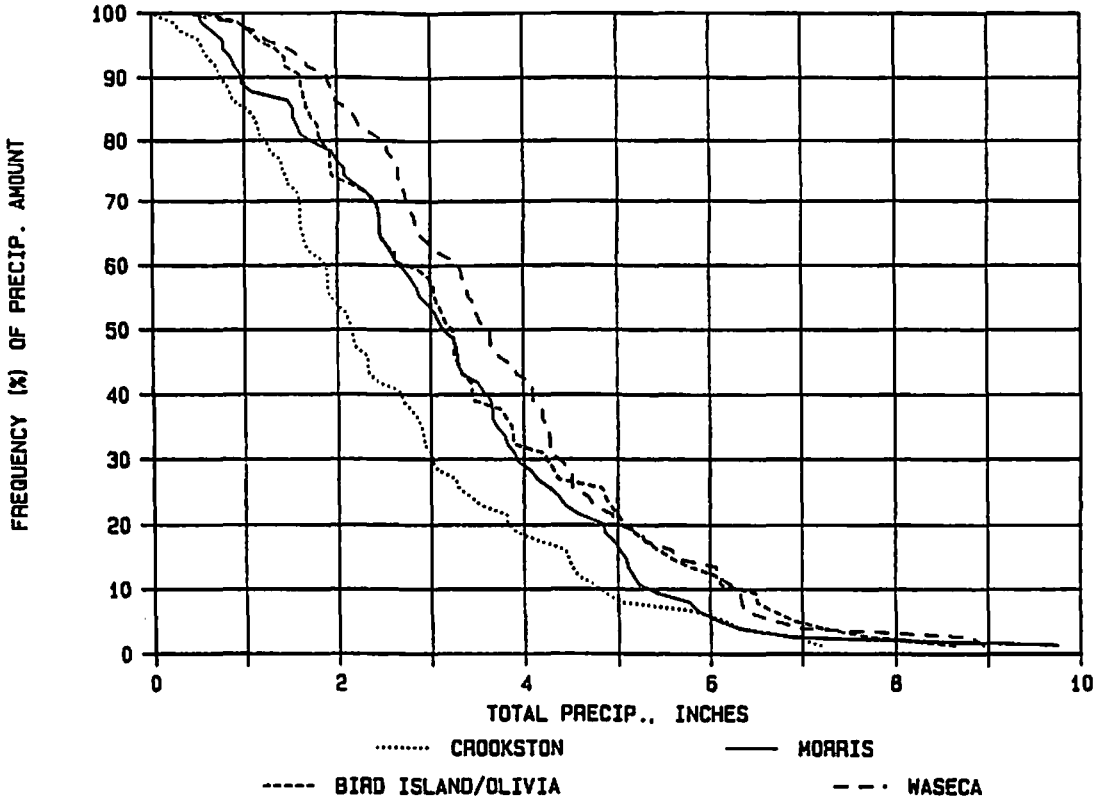

Fig. 7. Cumulative probability of precipitation occurrence between April 5 - May 15 at four Minnesota stations.

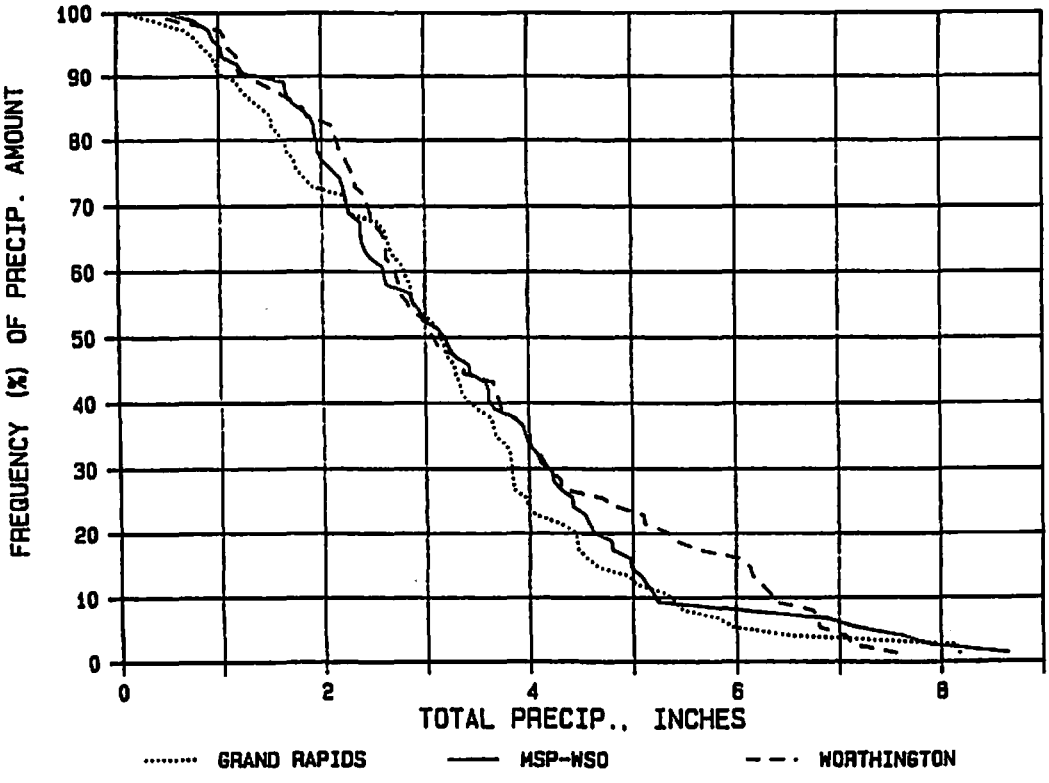

Fig. 8. Cumulative probability of precipitation occurrence between April 5 - May 15 at three Minnesota stations.

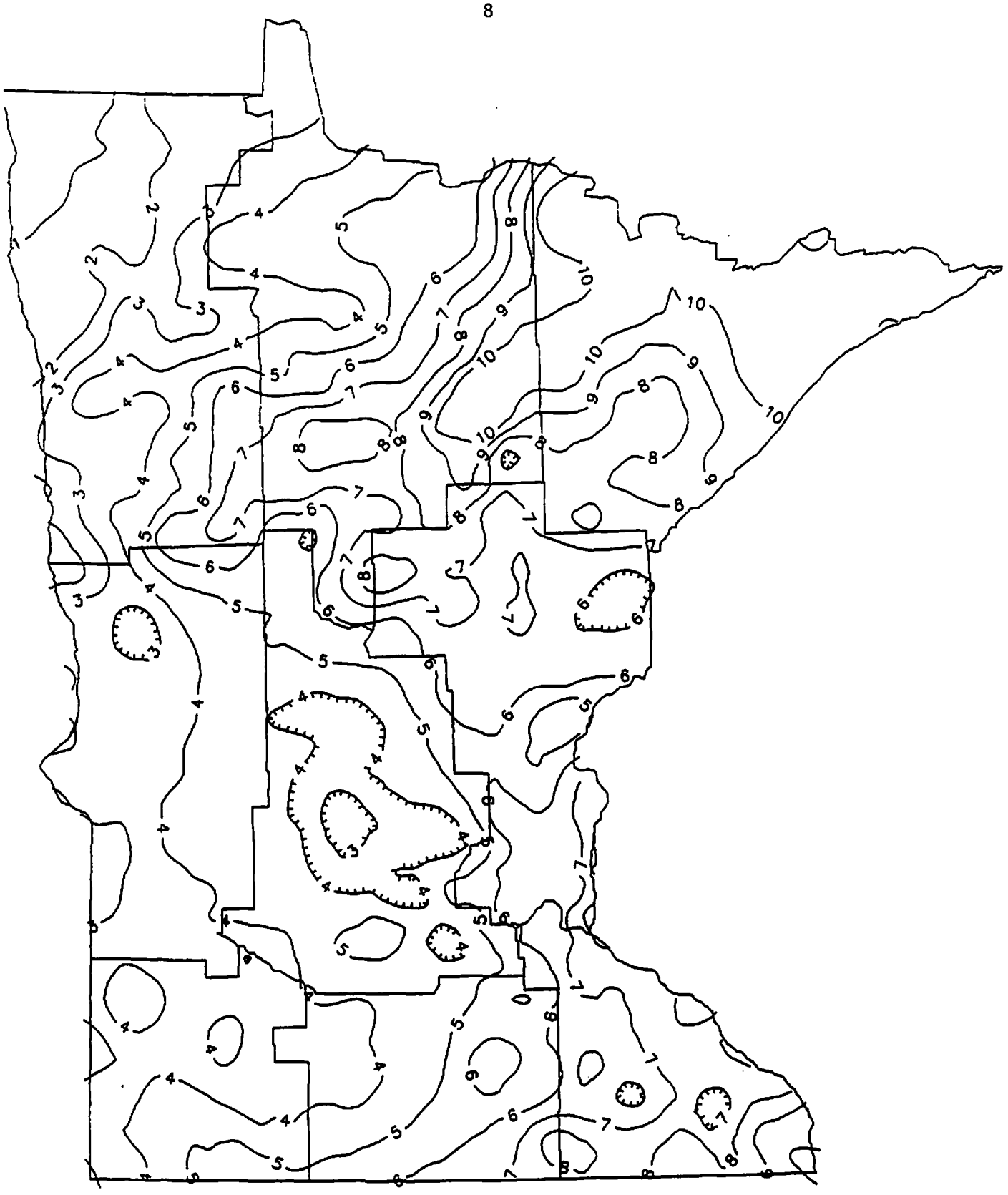

Fig. 9. Estimated plant available soil water (inches) in a soil column 5 feet deep under corn. The estimates are based upon a hypothetical soil of medium texture capable of holding 10 inches of plant available water.

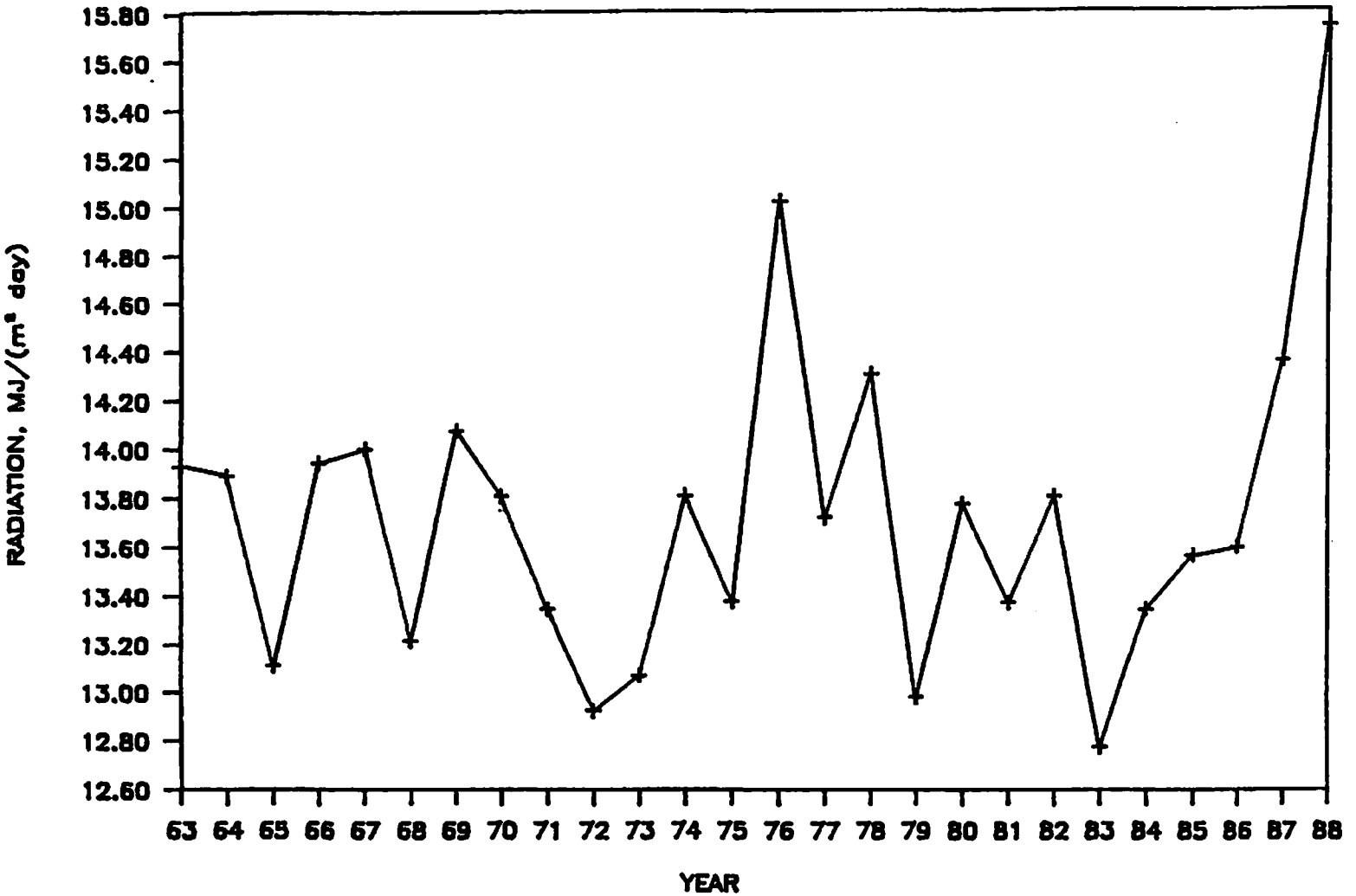

Fig. 10. Measured solar radiation incident on a horizontal surface at St. Paul, MN, 1963-1988.

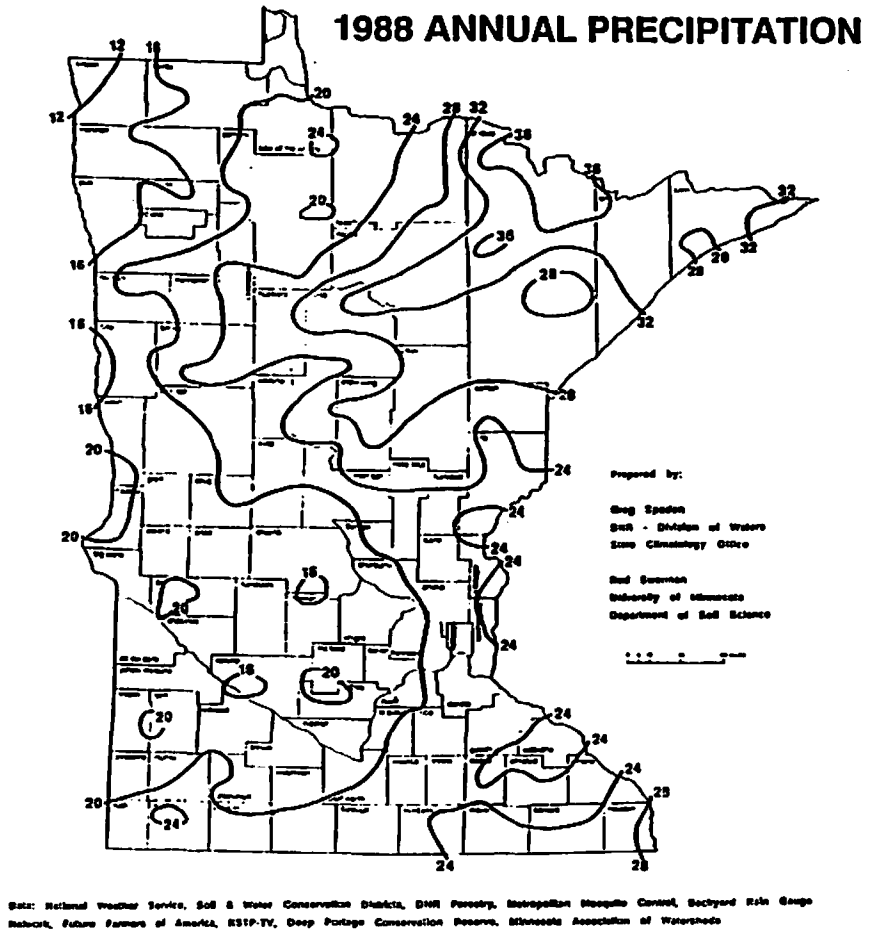

Fig. 11. Total annual precipitation in inches received in Minnesota, 1988.

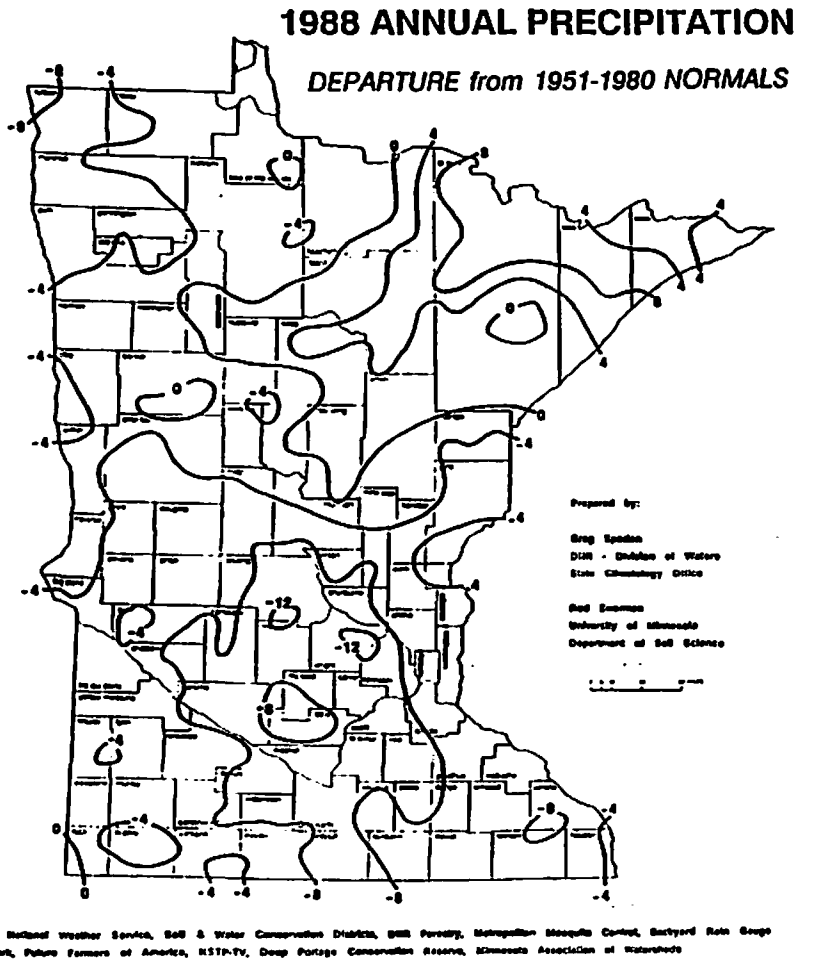

Fig. 12. Departure in inches of the 1988 total annual precipitation in Minnesota from the 1951-80 normals.

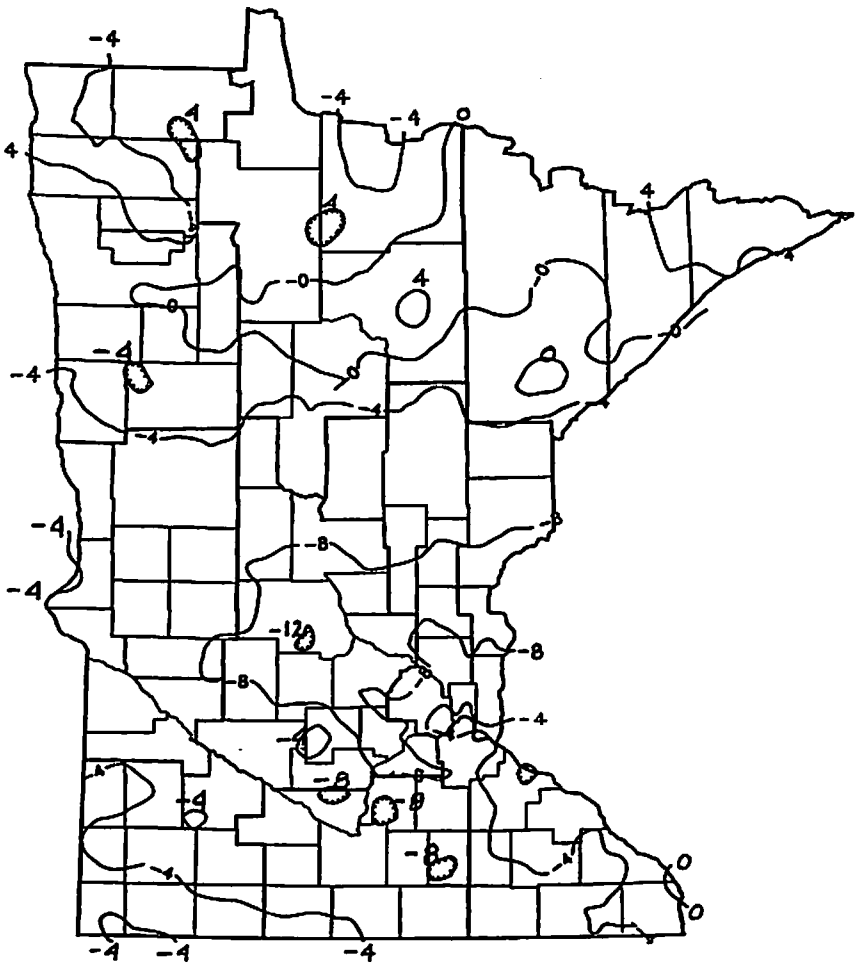

Fig. 13. Average departure in inches of the October 1986 - September 1988 hydrologic years precipitation from the 1951-1980 normal.

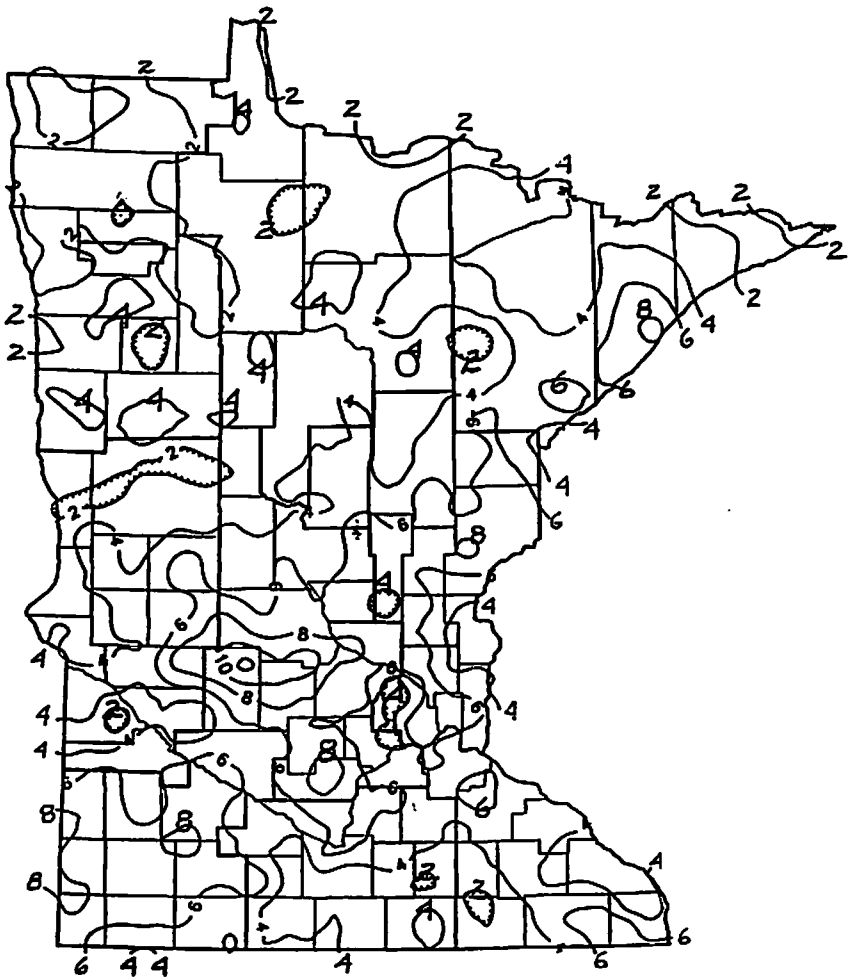

Fig. 14. Average departure in inches of the October 1982 - September 1986 (hydrologic years) precipitation from the 1951-1980 normal.

NITROGEN AND BORON UTILIZATION BY POTATO: EFFECTS ON TUBER QUALITY AND IMPLICATIONS FOR GROUNDWATER QUALITY[1]

Carl J. Rosen and Florian Lauer[2]

ABSTRACT: Under the conditions of this experiment, addition of boron fertilizer had no effect on potato yield or on hollow heart or brown center incidence. Apparently, sufficient boron was mineralized from the soil organic matter to meet crop requirements. Nitrogen fertilizer significantly increased vine yields but had variable effects on tuber yields. In Russet Burbank, tuber yield was depressed at the highest (280 lbs N/A) nitrogen rate. Presumably, this was due to continued growth of the vine at the expense of the tuber. In Reddale, where vines died back by the second harvest, tuber yields increased with increasing nitrogen. Potatoes killed early that have been fertilized with high rates of nitrogen may yield less than those that have been fertilized with lower nitrogen rates. This relationship depends somewhat on the amount of nitrate leaching that occurs during the season. Incidence of hollow heart or brown center was greatest in the largest size tubers. Within a size category nitrogen had no effect on these disorders; however, since nitrogen promoted larger tuber size there was a greater number of tubers that exhibited hollow heart or brown center with higher nitrogen rates. Nitrogen uptake by the potato plant increased with increasing rates of nitrogen application. At the early harvest (vines killed July 27), levels in the vine ranged from 47 - 157 lb N/A while at the late harvest (vines killed August 30) levels ranged from 15 - 71 lb N/A. Levels in the tubers at the early harvest ranged from 51 - 73 lb N/A while at the late harvest levels ranged from 110 - 195 lb N/A. Reddale took up more nitrogen than Russet Burbank which corresponded to greater Reddale yields. Vines killed early may provide significant nitrogen to subsequent crops. Mineralized soil nitrogen provided 27 - 80 lb N/A for crop uptake when low rates of fertilizer nitrogen were applied. Nitrate levels in potato petiole sap monitored by quick tests generally correlated well with petiole nitrates determined by conventional laboratory procedures. Significant nitrate movement was detected at the 280 lb N/A rate compared to the 70 and 140 lb N/A rates.

The first aspect of this research dealt with nutritional factors affecting potato tuber quality. Preharvest internal tuber quality disorders such as brown center and hollow heart continue to be of great concern to potato growers. In some, but not all cases, brown center may precede hollow heart development. Susceptibility to these disorders has been related to interactions among environmental conditions, cultural practices, and potato cultivar; although the precise cause is still unknown. Cool soil temperatures and high soil moisture during tuber initiation tend to promote brown center. Conditions that promote large tubers such as wide plant spacing and high nitrogen fertilizer rates also appear to promote hollow heart. High potassium rates tend to decrease hollow heart incidence. In a year when hollow heart and/or brown center incidence were high in Russet Burbank and Reddale, there was virtually no sign of these disorders in Krantz. Reddale has a high degree of resistance to Verticillium wilt which would make this cultivar desirable to grow if the brown center problem could be alleviated. Because the sandy soils of central Minnesota usually test low in boron, the role of this element in brown center/hollow heart development was investigated. Nitrogen was also included in the study to determine whether tuber size could be regulated to improve internal tuber quality.

The second aspect of this research dealt with nitrogen utilization by potato. Potatoes grown on irrigated sandy soils are usually provided with high nitrogen rates to promote growth and yield. Recent concern

[1] Support for this project was provided by Old Dutch Foods Research Fund and The Center for Water Quality. A special thanks is extended to Glenn Titrud for assistance in plot maintenance.

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about groundwater quality has raised questions about the fate of nitrogen applied to potatoes on irrigated soils. In part, this concern is due to the fact that potatoes have a relatively shallow root system, yet require high levels of nutrition to maintain high yields. To obtain background information needed to assess whether significant nitrate leaching is occurring during potato production, we: 1) characterized nitrogen response by Russet Burbank and Reddale potato, and 2) monitored nitrogen in the soil and the plant over the growing season.

The overall objectives, therefore, were to: 1) determine the effects of boron and nitrogen nutrition on yield and preharvest tuber quality of Reddale and Russet Burbank potatoes 2) characterize nitrogen utilization by these cultivars over the growing season, and 3) monitor nitrate movement in the soil during the growing season. Weather conditions were abnormally hot and dry so some of the results should be interpreted with caution. Reported here is the first year of a two year study.

EXPERIMENTAL PROCEDURES

The experiment was conducted in Becker, MN at the Sand Plain Research Farm. The soil is a Hubbard loamy sand. Selected soil chemical properties prior to planting were as follows (0-6"): pH, 6.7; organic matter, 2.2%; phosphorus, 54 lb/A; potassium, 112 lb/A; boron, 0.2 ppm. Residual nitrate-N in the top 3 ft of soil was 7.0 lb/A. The previous crop grown on the field for the past 2 years was rye. Prior to planting 300 lbs/A 0-0-22 was broadcast and incorporated. Russet Burbank and Reddale "B" size potatoes were planted April 18, 1988 at a spacing of 36" between rows and 8" within the row. At planting, all treatments received 875 lb/A 8-10-30 as a band application. Treatments included 2 cultivars, Russet Burbank and Reddale; 2 boron rates, 0 and 4 lb B/A; and three nitrogen rates, 70, 140, and 280 lb N/A. Boron was applied as Solubor in 2 split applications: 2 lb B/A as a broadcast application prior to emergence and 2 lb B/A as a sidedress one week after emergence. The low nitrogen treatment (70 lb N/A) was applied as a band at planting with no further N applied. The middle and high nitrogen treatments (140 and 280 lb N/A) were applied in three split applications: 70 lb N/A at planting 35 or 105 lb N/A one week after emergence (May 25), and 35 or 105 lb N/A at hilling (June 8). Each plot consisted of four, 20 ft rows. Rainfall was supplemented with overhead irrigation to supply water needs. Monthly irrigation and rainfall through the season were as follows: April - 0.7" rainfall, no irrigation; May 2.9" rainfall, 1" irrigation; June - 0.1" rainfall, 6.5" irrigation; July - 1.2" rainfall, 9.1" irrigation; August - 4.5" rainfall, 3.3" irrigation.

Leaf tissue (leaflets + petiole) and petiole (leaflets removed) samples were collected every two weeks starting one week after hilling for total nitrogen and nitrate-N determinations. Samples were analyzed using conventional laboratory methods. Nitrate-N was also determined in petiole samples in the field using EM Quant quick nitrate strips available from BME Lab Store, 2459 University Ave. St. Paul, MN 55114, 612-646-5339. The catalog number is CMS 158-659 and the price is $33.00 per 50 strips. For the quick nitrate test, 8 petioles from the most recently matured leaf from each plot were collected in the morning. Sap from the petiole was expressed into a small plastic dish using needle-nose pliers. The nitrate indicator strips were dipped into the sap and the time (in seconds) required to turn dark purple (based on a color chart provided with the kit) was recorded. The number of seconds to turn the strip dark purple was then converted to ug nitrate per ml of sap using a formula: nitrate (ug/ml) = $10^{(4.9-1.085 \log t)}$ where t = seconds to reach dark purple. If the strip did not turn dark purple, a nitrate reading was recorded after two minutes using a color chart provided with the kit.

Soil nitrates to a depth of 3 ft at 1 ft increments were determined prior to planting, July 26, and September 2. Each sample consisted of 3 cores from an individual plot. Samples collected in July and September were obtained from both between rows and within rows. All samples were placed in plastic bags kept moist at 40°F until analyzed. Nitrate and ammonium were extracted with 2 N KCl using a 5 g moist sample to 25 ml extractant ratio. Percent moisture was determined in each sample and ppm nitrate-N or ammonium-N were calculated on a dry weight basis. All results are expressed as pounds of nitrate-N or ammonium-N using the convention ppm X 2 = lb/A for a 6" furrow slice. Bulk density of each sampling depth was not determined so that lb/A values should be considered as approximate. For the July and September samples, lb nitrate-N/A was calculated assuming half the field was 'within row' and the other half 'between row'.

Nitrates in soil water were determined in samples collected weekly from suction tubes located in the row at a depth of 2 ft. Due to the dry weather conditions, these tubes were often dry. Vines were cut and removed at two harvest dates: July 25 and August 30. Potatoes were mechanically harvested August 2 and September 6. Subsamples of vines and tubers were collected to determine nitrogen uptake and to evaluate tuber quality.

RESULTS AND DISCUSSION

Tuber and Vine Yields. Boron applications had no effect on total tuber yield or tuber size distribution (Table 1). In contrast, nitrogen rate had significant effects on tuber yield and size distribution at both harvest dates. At the early harvest (August 3), tuber yields decreased with increasing N rate for both cultivars. Most growth at the high N rates was still in the vine rather than the tuber. At the late harvest (September 6), the trend was the same for Russet Burbank, but Reddale yields increased with N rate. Most of this increase in Reddale yield was due to an increase in the larger size tubers. Differences in response to nitrogen by these two cultivars can be explained by their vine growth (Tables 2 and 3). Nitrogen fertilizer dramatically increased vine yield of both cultivars at both harvest dates. Vines remained greener later in the season with the highest nitrogen rate, although Russet Burbank vines were slower to die back than Reddale. Thus, at the time of the second harvest, Russet Burbank potatoes supplied with 280 lb N/A were delayed in maturity and translocation from the vines to the tubers was not complete. Had the second harvest been delayed by two or three weeks, Russet Burbank yields may have increased at the higher N rate. Reddale seems to be an earlier maturing cultivar than Russet Burbank. As with tuber yields, boron applications had no effect on vine yields.

Tuber Quality. Effects of boron and nitrogen on tuber quality are presented in Table 4 for Reddale and Table 5 for Russet Burbank. Reddale had a higher incidence of tuber disorders than Russet Burbank. Regardless of fertilizer treatment or cultivar, greatest incidence of hollow heart and brown center occurred as tuber size increased. Boron applications had no effect on tuber quality in either cultivar or at either planting date. Under conditions of this experiment, boron does not appear to alleviate brown center or hollow heart disorders in potato. At the early harvest, nitrogen fertilizer did not affect incidence of hollow heart or brown center in either cultivar. At the late harvest, nitrogen had no effect on these disorders in Russet Burbank, but surprisingly tended to decrease incidence in Reddale by 20% in the greater than 14 oz category and by 9% in the 7 - 14 oz category. However, since nitrogen rate increased the largest size tubers by 50%, there was actually a greater absolute number of tubers that exhibited the disorders when nitrogen was used.

Nutrient Concentrations and Uptake. Slight symptoms of boron toxicity were observed one week after the second boron application. Older leaves exhibited a scorching and upward curling of the margins. This condition was only temporary as younger leaves appeared healthy and plant growth appeared normal within one week after symptoms were observed. Concentrations of boron in leaves sampled June 25 averaged 29 ppm in the control and 58 ppm in the treated plots (Table 6). Concentrations of boron in tubers increased with boron application at both harvest dates but to a much lower degree than in the leaves (Tables 7 and 8). The lack of boron accumulation in the tuber reflects the immobility of this element in the plant. As expected total nitrogen concentrations in leaves sampled June 25 and in tubers sampled at both harvest dates increased with increasing nitrogen application. Signs of nitrogen deficiency (general plant yellowing) were apparent at the lowest nitrogen rate toward the end of July. Otherwise, plants appeared very healthy at this point.

Boron applications increased leaf concentrations of nitrogen and phosphorus (Table 6), but had no effect on concentrations of elements in the tuber except for boron (Tables 7 and 8). Nitrogen fertilizer significantly increased leaf concentrations of phosphorus, iron, and zinc, but decreased concentrations of boron. Tuber concentrations of calcium, and zinc increased with nitrogen fertilizer at both harvests. Tuber magnesium decreased with increasing nitrogen at the early harvest. Reddale leaves sampled June 25 had higher concentrations of phosphorus, iron, and zinc but lower concentrations of calcium and magnesium. Reddale tubers had higher concentrations of nitrogen, phosphorus, magnesium, iron, zinc, copper, and boron, but lower concentrations of calcium at both harvest dates. Lower calcium levels in the Reddale tuber may be associated with the higher incidence of brown center in this cultivar.

Nutrient uptake by vines at each harvest is presented in Tables 2 and 3. Boron applications increased boron uptake by vines, but had little effect on uptake of other nutrients. At the early harvest, Reddale accumulated more phosphorus, calcium, iron, and manganese, but less magnesium than Russet Burbank. At the later harvest, vine nutrient accumulation was greatest in Russet Burbank due to the fact that these vines were still growing whereas Reddale vines had been in a rapid state of decline. Due to the increase in vine growth with nitrogen fertilizer, uptake of nitrogen and other nutrients increased with nitrogen application at both harvests.

Nutrient uptake by tubers is presented in Tables 10 and 11. Boron applications increased boron uptake at the late harvest, but had no effect on uptake of other nutrients at either harvest date. Reddale accumulated greater quantities of nitrogen, phosphorus, magnesium, zinc, copper, and boron, but lower quantities of calcium at both harvests. At the early harvest, nitrogen uptake was not affected by nitrogen fertilizer due to depressed yields at the high nitrogen rates. Phosphorus, potassium, and magnesium uptake were actually lower at the high nitrogen rates compared to the lower rates. At the later harvest date only nitrogen and zinc uptake increased with nitrogen rate.

A summary of total nitrogen uptake by vines and tubers at both harvest dates (averaged over boron rates) is presented in Table 11. Total nitrogen uptake increased as nitrogen fertilizer increased. For Russet Burbank, there was little uptake after the first harvest. In other words, most of the nitrogen had already been absorbed by July 27. Less than 20 lb N/A was absorbed by Russet Burbank during the month of August. Slightly higher amounts were absorbed by Reddale. Another interesting point to note is that potatoes grown at the 70 and 140 lb N/A rate took up more nitrogen than was actually applied. This indicates that under the conditions of the experiment, significant nitrogen was mineralized from the soil. As much as 60-80 lb N/A over the growing season was mineralized. In contrast, at the highest nitrogen rate, 25-65 lb N/A of fertilizer nitrogen remained in the soil and was not taken up by the vines or tubers. Increased nitrogen rate also increased nitrogen content of the vines. If high rates of nitrogen are used and the vines are killed early, there could be a significant contribution of nitrogen to the following crop.

Leaf and Petiole Total Nitrogen and Nitrate-N Concentrations.
Nitrogen status of the plant every two weeks starting one week after hilling as measured by various procedures is presented in Table 12. Total nitrogen in the leaf tissue was nearly twice as great as corresponding nitrogen in the petiole (leaflets removed). This difference became larger as the season progressed. In contrast, nitrate-N was 4-5 times higher in petiole tissue compared to leaf (leaflets + petiole) tissue. These results indicate that different sets of values would need to be used depending upon the tissue that was analyzed. One of the problems with tissue analysis in general is that it often takes several days to a week before results can be obtained. A quick test for nitrate would be desirable so that decisions about fertilizer need could be made without waiting. Quick test indicator strips for nitrate have been on the market for many years; however, even a potato plant deficient in nitrate will have enough nitrate in the petiole to cause the reading to be off scale. One way to circumvent this problem is to time how long it takes for the petiole sap to turn the indicator strip to a particular color. Using a formula (see procedures section), nitrate in the petiole sap can be calculated from the number of seconds to turn color. Figure 1 shows the relationship between the conventional petiole nitrate test with the quick test. There was a relatively good correlation ($r^2 = 0.95$) between the two methods. One of the problems with the quick test is that when tissue nitrate concentrations are high, the amount of time it takes to turn the appropriate color may be only 10 seconds. In this range only a few seconds can make a big difference in the nitrate-N calculation. There is also some subjectivity in the reading - one person may see the end point differently than another. An additional problem is that nitrate-N can vary with time of day and with environmental conditions. Readings should therefore be taken in the morning if possible. Despite some of these cautions, with some practice a grower or consultant could monitor nitrate in the sap to determine nitrogen status of the plant without having to wait for a laboratory test. Another year of data is needed to calibrate the quick test with the conventional laboratory test.

Soil and Water Nitrate Levels Through the Growing Season. As expected, variability in the soil nitrate levels was high particularly at the higher nitrogen rate (Table 13). However, mean concentrations seemed to generally follow nitrogen application rates. Soil nitrate-N concentrations were highest in samples

collected within the row compared to samples collected between the rows. There was little difference between soil nitrate levels in the 70 and 140 lb N/A plots. However, at the 280 lb N/A rate, significant residual nitrate remained in the field. Similar trends were also observed in the water samples collected at the two foot depth (Figure 2). Nitrate levels were generally low for the 70 and 140 lb N/A rates; however, for the 280 lb N/A rate levels were extremely high. In August nitrate levels were lower, presumably due to leaching when 3-4 inches of rain occurred the second and third weeks of the month. In future studies, suction tubes will be placed at two or three additional depths to enable better monitoring of nitrate through the profile.

Table 1. Yield of Russet Burbank and Reddale potatoes at two harvest dates as affected by nitrogen and boron.

			Harvest Date									
			August 3					September 6				
			Tuber Size				Total	Tuber Size				Total
Cultivar	B rate	N rate	<4 oz	4-7 oz	7-14 oz	>14 oz	yield (Cwt/A)	<4 oz	4-7 oz	7-14 oz	>14 oz	yield (Cwt/A)
	lb B/A	lb N/A										
Russet B	0	70	38.5	256.6	30.8	0.0	326.0	37.2	295.7	210.7	7.0	550.7
	0	140	37.8	222.2	28.9	0.0	288.9	36.1	261.6	219.4	0.0	517.1
	0	280	48.8	183.6	21.5	0.0	253.9	33.1	218.8	225.2	1.7	478.8
	4	70	33.6	242.6	40.8	0.0	317.1	39.1	283.8	205.9	0.0	528.8
	4	140	38.3	238.3	34.6	0.0	311.3	32.3	272.3	343.4	1.4	549.4
	4	280	63.6	161.8	21.9	0.0	247.3	30.7	239.1	219.7	11.7	501.2
Reddale	0	70	6.9	118.3	240.1	18.3	383.6	7.6	103.3	372.3	115.3	598.6
	0	140	8.3	127.9	250.9	40.1	427.2	9.7	83.8	379.5	156.2	629.2
	0	280	9.9	127.2	175.2	35.7	348.1	15.2	105.4	335.3	208.1	664.1
	4	70	8.8	117.6	248.2	23.9	398.5	8.9	105.6	344.6	102.8	562.0
	4	140	9.8	115.1	198.1	30.1	353.0	13.1	94.6	368.6	167.6	643.9
	4	280	11.0	118.2	192.6	25.2	346.9	11.0	102.0	351.9	182.9	647.9
Analysis of Variance												
Cultivar (C)												
	Russet B		43.5	217.5	29.8	0.0	290.8	34.8	261.9	220.7	3.6	521.0
	Reddale		9.1	120.7	217.5	28.9	376.2	11.0	99.1	358.7	155.5	624.3
Signif.			**	**	**	**	**	**	**	**	**	**
B rate (B)												
	0		25.1	172.7	124.6	15.7	338.0	23.2	178.1	290.4	81.4	573.0
	4		27.5	165.6	122.7	13.2	329.0	22.5	182.9	289.0	77.7	572.2
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N rate (N)												
	70		22.0	183.8	140.0	10.6	356.3	23.2	197.1	283.4	56.3	560.0
	140		23.6	175.9	128.1	17.5	345.1	22.8	178.0	302.7	81.3	584.9
	280		33.6	147.7	102.8	15.2	299.0	22.5	166.4	283.1	101.1	573.0
Signif.			**	**	**	NS	**	NS	NS	NS	*	NS
Linear			**	**	**	--	**	--	--	--	**	--
Quad.			NS	NS	NS	--	NS	--	--	--	NS	--
Interactions												
C X B			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X N			**	**	NS	NS	NS	*	*	NS	**	**
B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X B X N			NS	NS	NS	NS	*	NS	NS	NS	NS	NS

NS = Not Significant, * = Significant at 5%, ** = Significant at 1%.

Table 2. Vine yield and nutrient uptake as affected by boron and nitrogen - early harvest (vines killed August 25).

Cultivar	B rate	N rate	F.W. Yield	Nutrient N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb B/A	lb N/A	T/A	lb/A							oz/A		
Russet B	0	70	13.62	67.9	5.1	115.9	54.3	31.0	6.8	14.7	2.8	1.00	1.44
	0	140	18.48	98.7	6.2	132.2	56.6	39.1	8.8	10.7	2.2	0.60	1.60
	0	280	22.33	131.7	7.6	164.7	54.1	46.7	7.4	12.8	3.2	1.16	1.56
	4	70	14.99	71.9	5.3	127.0	55.2	34.9	7.1	14.4	2.8	1.28	2.56
	4	140	18.24	108.0	7.4	160.0	61.2	41.6	11.1	13.7	3.2	0.72	2.92
	4	280	21.80	134.0	8.3	174.4	55.4	42.8	10.1	13.9	2.6	0.64	2.32
Reddale	0	70	12.43	47.0	5.2	92.4	47.2	18.4	6.4	11.8	2.0	0.92	1.24
	0	140	17.84	85.6	7.0	142.6	57.7	30.0	8.0	12.6	2.2	0.48	1.56
	0	280	23.90	157.1	9.9	175.7	77.3	48.3	17.8	21.3	3.7	1.24	2.08
	4	70	14.30	55.9	5.7	114.7	49.7	21.3	7.0	14.6	2.7	0.88	2.12
	4	140	19.24	96.9	8.2	155.1	65.5	34.3	9.5	10.5	2.1	0.60	3.00
	4	280	22.81	142.2	9.6	169.9	68.9	40.8	18.5	20.3	2.8	1.40	3.16
Analysis of Variance													
Cultivar (C)													
	Russet B		18.24	102.0	6.6	145.7	56.1	39.3	8.6	13.4	2.8	0.90	2.07
	Reddale		18.42	97.4	7.6	141.7	61.0	32.1	11.2	15.2	2.6	0.92	2.19
Signif.			NS	NS	**	NS	*	**	*	NS	NS	NS	NS
B rate (B)													
	0		18.10	98.0	6.8	137.3	57.9	35.6	9.2	14.0	2.68	0.90	1.58
	4		18.56	101.5	7.4	150.2	59.3	35.9	10.6	14.6	2.71	0.92	2.68
Signif.			NS	NS	NS	*	NS	NS	NS	NS	NS	NS	**
N rate (N)													
	70		13.83	60.7	5.3	112.5	51.6	26.4	6.8	13.9	2.6	1.02	1.84
	140		18.45	97.2	7.2	147.5	60.3	36.2	9.3	11.9	2.4	0.60	2.27
	280		22.71	141.2	8.9	171.2	63.9	44.7	13.5	17.0	3.1	1.11	2.28
Signif.			**	**	**	**	**	**	*	NS	NS	NS	NS
Linear			**	*	**	**	**	**	**	NS	NS	NS	NS
			NS	NS	*	*	NS	*	NS	NS	NS	NS	NS
Interactions													
C X B			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X N			NS	**	NS	NS	NS	**	**	**	NS	NS	**
B X N			NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
C X B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 3. Vine yield and nutrient uptake as affected by boron and nitrogen - late harvest (vines killed August 30).

Cultivar	B rate	N rate	F.W. Yield	Nutrient									
				N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb B/A	lb N/A	T/A	lb/A					oz/A				
Russet B	0	70	6.73	20.8	1.8	50.8	33.2	19.3	7.6	3.0	1.2	0.56	0.80
	0	140	10.89	38.2	2.8	71.3	39.8	28.7	10.5	3.9	1.6	0.44	1.20
	0	280	17.02	67.5	4.6	88.5	46.5	41.5	10.5	5.7	2.4	0.60	1.50
	4	70	8.51	28.0	2.3	69.5	41.8	23.6	14.0	3.7	1.4	0.84	1.40
	4	140	10.13	33.2	2.5	62.6	39.8	27.9	8.0	4.4	1.6	0.40	1.40
	4	280	17.48	70.9	4.6	106.3	45.1	37.4	12.0	6.6	2.8	0.48	1.72
Reddale	0	70	3.49	15.4	1.8	34.3	27.8	11.2	11.6	4.6	1.4	0.88	0.56
	0	140	6.86	22.0	2.7	55.5	36.9	22.7	11.6	4.6	1.2	0.56	0.80
	0	280	9.61	47.6	3.5	63.4	46.7	29.2	14.4	9.0	1.8	0.48	1.04
	4	70	4.17	15.3	1.9	39.2	29.1	15.0	11.6	4.1	1.6	0.88	0.84
	4	140	8.22	26.0	2.9	57.3	38.6	20.6	14.4	6.8	2.1	1.24	1.12
	4	280	11.27	55.5	4.1	69.8	50.2	36.0	16.9	10.0	2.2	0.52	1.48
Analysis of Variance													
Cultivar (C)													
	Russet B		11.79	43.1	3.1	74.8	41.1	29.7	10.4	4.5	1.8	0.56	1.32
	Reddale		7.27	30.3	2.8	53.2	38.2	22.4	13.4	6.5	1.7	0.76	0.97
Signif.			**	**	NS	**	NS	**	NS	**	NS	NS	**
B rate (B)													
	0		9.10	35.2	2.9	60.7	38.5	25.4	11.0	5.1	1.6	0.59	0.98
	4		9.96	38.1	3.1	67.5	40.8	26.8	12.8	5.9	1.9	0.73	1.32
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
N rate (N)													
	70		5.73	19.9	2.0	48.5	33.0	17.3	11.2	3.8	1.4	0.79	0.90
	140		9.02	29.9	2.7	66.7	38.8	25.0	11.1	4.9	1.6	0.66	1.12
	280		13.84	60.4	4.2	82.0	47.2	36.0	13.4	7.8	2.3	0.52	1.43
Signif.			**	**	**	**	**	**	NS	NS	*	NS	**
Linear			**	**	**	**	**	**	NS	*	**	NS	**
Quad.			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions													
C X B			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X N			**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 4. Incidence of brown center and/or hollow heart in Reddale potatoes at early and late harvests as affected by nitrogen and boron.

		Harvest Date					
		August 3			September 6		
		Tuber Size					
		4-7 oz	7-14 oz	> 14 oz	4-7 oz	7-14 oz	> 14 oz
B rate	N rate						
lb B/A	lb N/A	% Incidence					
0	70	1.0	5.0	61.6	0.0	17.0	56.8
0	140	0.0	10.6	71.6	0.0	14.0	54.0
0	280	0.0	4.2	70.8	0.0	3.0	30.0
4	70	0.0	3.2	64.2	0.0	13.0	54.1
4	140	1.0	5.3	55.3	1.0	14.0	54.5
4	280	0.0	10.6	65.0	0.0	10.0	31.1
B rate (B)							
	0	0.3	6.6	68.0	0.0	11.3	47.0
	4	0.3	6.4	61.5	0.3	12.3	46.6
Signif.		NS	NS	NS	NS	NS	NS
N rate (N)							
	70	0.5	4.1	62.9	0.0	15.0	55.5
	140	0.5	8.0	63.4	0.5	14.0	54.2
	280	0.0	7.4	67.9	0.0	6.5	30.5
Signif.		NS	NS	NS	NS	NS	*
Linear		NS	NS	NS	NS	*	**
Quad.		NS	NS	NS	NS	NS	NS
Interaction							
B X N		NS	NS	NS	NS	NS	NS

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

Table 5. Incidence of brown center and/or hollow heart in Russet Burbank potatoes at early and late harvests as affected by nitrogen and boron.

		Harvest Date					
		August 3			September 6		
		Tuber Size					
		4-7 oz	7-14 oz	> 14 oz	4-7 oz	7-14 oz	> 14 oz
B rate lb B/A	N rate lb N/A	% Incidence					
0	70	2.0	0.0	0.0	1.0	15.0	75.0
0	140	0.0	0.0	0.0	0.0	12.0	0.0
0	280	0.0	0.0	0.0	1.0	8.0	25.0
4	70	0.0	0.0	0.0	0.0	5.0	0.0
4	140	0.0	0.0	0.0	0.0	11.0	0.0
4	280	3.4	0.0	0.0	2.0	12.0	37.5
B rate (B)							
	0	0.7	0.0	0.0	0.7	11.7	33.3
	4	1.1	0.0	0.0	0.7	9.3	12.5
Signif.		NS	NS	NS	NS	NS	NS
N rate (N)							
	70	1.0	0.0	0.0	0.5	10.0	37.5
	140	0.0	0.0	0.0	0.0	11.5	0.0
	280	1.7	0.0	0.0	1.5	10.0	31.3
Signif.		NS	NS	NS	NS	NS	NS
Linear		NS	NS	NS	NS	NS	NS
Quad.		NS	NS	NS	NS	NS	NS
Interaction							
B X N		NS	NS	NS	NS	NS	**

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

Table 6. Effect of nitrogen and boron on nutrient concentration, in recently matured leaves sampled June 27 (70 days after planting).

Cultivar	B rate lb B/A	N rate lb N/A	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			Nutrient									
			%					ppm				
Russet B	0	70	3.74	0.26	3.92	0.90	0.64	93	79	17	30	27
	0	140	4.65	0.29	3.77	0.96	0.73	102	84	18	54	25
	0	280	5.16	0.30	3.81	1.07	0.76	99	105	23	155	27
	4	70	4.10	0.28	3.71	0.96	0.73	97	81	18	63	72
	4	140	4.40	0.30	3.57	0.94	0.72	94	76	20	23	56
	4	280	5.28	0.32	4.08	0.96	0.67	100	110	21	114	43
Reddale	0	70	3.74	0.38	3.93	0.73	0.41	93	73	20	94	34
	0	140	4.41	0.40	3.53	0.82	0.47	108	67	21	13	30
	0	280	5.06	0.40	3.34	0.73	0.42	111	101	29	69	29
	4	70	3.83	0.40	4.15	0.78	0.45	99	77	20	23	73
	4	140	4.80	0.40	3.80	0.81	0.51	116	63	23	31	60
	4	280	5.22	0.46	3.41	0.65	0.41	108	85	31	20	44
Analysis of Variance												
Cultivar (C)												
	Russet B		4.58	0.29	3.81	0.96	0.71	98	89	19	73	42
	Reddale		4.51	0.41	3.69	0.75	0.44	106	78	24	42	45
Signif.			NS	**	NS	**	**	**	NS	**	NS	NS
B rate (B)												
	0		4.46	0.34	3.72	0.87	0.57	101	85	21	69	29
	4		4.63	0.36	3.79	0.85	0.58	103	82	22	46	58
Signif.			*	**	NS	NS	NS	NS	NS	NS	NS	**
N rate (N)												
	70		3.83	0.33	3.93	0.84	0.55	96	77	19	53	52
	140		4.57	0.35	3.67	0.88	0.61	105	73	21	30	43
	280		5.18	0.37	3.66	0.85	0.57	104	100	26	90	36
Signif.			**	*	NS	NS	NS	*	NS	**	NS	**
Linear			**	**	NS	NS	NS	*	NS	**	NS	**
Quad.			**	NS	NS	NS	NS	*	NS	NS	NS	NS
Interactions												
C X B			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X N			NS	NS	**	NS	NS	NS	NS	NS	NS	NS
B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	*
C X B X N			*	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 7. Nutrient concentrations in tubers as affected by N rate and boron - early harvest (Aug. 3).

Cultivar	B rate lb B/A	N rate lb N/A	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			Nutrient									
			%					ppm				
Russet B	0	70	0.94	0.23	2.18	389	1006	100	13	13	3.5	4.6
	0	140	1.03	0.25	2.23	359	1021	124	13	15	4.0	5.7
	0	280	1.36	0.22	2.23	493	974	163	19	19	3.9	4.9
	4	70	1.01	0.23	2.16	367	1012	123	15	15	4.0	5.4
	4	140	1.09	0.22	2.09	379	964	111	14	16	3.4	5.9
	4	280	1.28	0.23	2.29	465	960	118	14	19	3.6	6.4
Reddale	0	70	1.00	0.29	2.23	248	1107	130	11	16	5.3	7.6
	0	140	1.16	0.28	2.12	287	1054	173	13	20	5.7	6.9
	0	280	1.60	0.28	2.21	325	1086	170	13	22	5.6	7.0
	4	70	1.08	0.27	2.18	301	1074	151	13	19	5.1	6.9
	4	140	1.29	0.30	2.24	290	1155	132	12	20	5.7	7.9
	4	280	1.60	0.30	2.23	346	1159	166	14	23	5.5	8.4
Analysis of Variance												
Cultivar (C)												
	Russet B		1.12	0.23	2.20	409	989	123	14	16	3.8	5.5
	Reddale		1.29	0.29	2.20	300	1105	154	13	20	5.5	7.4
Signif.			**	**	NS	**	**	*	NS	**	**	**
B rate (B)												
	0		1.18	0.26	2.20	350	1041	143	14	18	4.7	6.1
	4		1.22	0.26	2.20	358	1054	134	14	18	4.6	6.8
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	*
N rate (N)												
	70		1.01	0.26	2.19	326	1050	126	13	16	4.5	6.1
	140		1.14	0.26	2.18	329	1048	135	13	18	4.7	6.6
	280		1.46	0.26	2.24	407	1045	154	15	21	4.7	6.7
Signif.			**	NS	NS	**	NS	NS	NS	**	NS	NS
Linear			**	NS	NS	**	NS	NS	NS	**	NS	NS
Quad.			NS	NS	NS	*	NS	NS	NS	NS	NS	NS
Interactions												
C X B			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X N			*	NS	NS	NS	NS	NS	NS	NS	NS	NS
B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 8. Nutrient concentrations in tubers as affected by N rate and boron - late harvest (Sept 6).

Cultivar	B rate lb B/A	N rate lb N/A	Nutrient N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			%					ppm				
Russet B	0	70	0.98	0.18	1.76	299	963	93	13	12	3.7	3.3
	0	140	1.22	0.22	1.90	341	1054	112	16	16	3.7	3.5
	0	280	1.38	0.21	1.80	327	940	100	14	18	4.0	3.6
	4	70	0.98	0.22	1.90	329	1058	116	15	13	3.6	4.4
	4	140	1.12	0.20	1.79	295	988	86	12	15	3.3	4.8
	4	280	1.36	0.22	1.81	314	965	105	15	19	4.4	4.7
Reddale	0	70	1.37	0.29	2.09	223	1196	82	11	18	6.0	7.0
	0	140	1.49	0.28	2.00	211	1136	86	10	18	5.0	6.5
	0	280	1.94	0.26	1.92	251	1125	103	14	24	6.0	6.5
	4	70	1.38	0.29	2.11	226	1219	84	12	18	5.8	7.8
	4	140	1.44	0.28	2.00	234	1159	86	12	19	5.5	7.0
	4	280	1.86	0.27	1.96	264	1124	99	13	22	5.3	7.4
Analysis of Variance												
Cultivar (C)												
	Russet B		1.17	0.21	1.83	317	994	102	14	15	3.8	4.0
	Reddale		1.58	0.28	2.01	234	1160	90	12	19	5.6	7.0
Signif.			**	**	**	**	*	*	**	**	**	**
B rate (B)												
	0		1.40	0.24	1.91	275	1069	96	13	18	4.7	5.1
	4		1.36	0.25	1.93	277	1086	96	13	18	4.6	6.0
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	**
N rate (N)												
	70		1.18	0.25	1.96	269	1108	93	13	15	4.8	5.6
	140		1.32	0.25	1.92	270	1084	93	13	17	4.4	5.4
	280		1.64	0.24	1.87	289	1038	102	14	21	4.9	5.6
Signif.			**	NS	NS	NS	*	NS	NS	**	NS	NS
Linear			**	NS	NS	*	*	NS	NS	**	NS	NS
Quad.			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions												
C X B			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X N			*	NS	NS	NS	NS	NS	NS	*	NS	*
B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X B X N			NS	NS	NS	NS	NS	NS	**	NS	NS	NS

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

Table 9. Nutrient uptake by tubers as affected by nitrogen and boron - early harvest (August 3).

Cultivar	B rate lb B/A	N rate lb N/A	Nutrient N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			%					ppm				
Russet B	0	70	55.9	13.6	129.1	2.3	5.9	9.6	1.2	1.2	0.36	0.48
	0	140	51.9	12.5	111.7	1.8	5.2	9.9	1.0	1.3	0.36	0.52
	0	280	57.8	9.4	94.6	2.1	4.1	11.2	1.3	1.3	0.28	0.32
	4	70	57.3	13.1	123.0	2.1	5.8	11.5	1.4	1.3	0.36	0.48
	4	140	60.9	12.1	116.3	2.1	5.4	10.2	1.3	1.4	0.32	0.48
	4	280	51.0	9.0	90.6	1.8	3.8	7.3	0.9	1.2	0.20	0.40
Reddale	0	70	54.2	15.7	119.3	1.3	6.0	11.1	1.0	1.4	0.44	0.72
	0	140	68.4	16.2	124.8	1.7	6.2	16.2	1.3	1.9	0.56	0.64
	0	280	72.9	12.7	99.7	1.5	4.9	12.0	1.0	1.6	0.40	0.52
	4	70	60.8	14.9	121.7	1.7	6.0	13.4	1.3	1.6	0.44	0.64
	4	140	60.4	13.8	103.9	1.3	5.4	10.0	0.9	1.4	0.44	0.60
	4	280	71.4	13.2	99.7	1.5	5.2	11.7	1.0	1.6	0.40	0.60
Analysis of Variance												
Cultivar (C)												
	Russet B		55.8	11.6	110.9	2.0	5.0	9.9	1.2	1.3	0.31	0.44
	Reddale		64.7	14.4	111.5	1.5	5.6	12.4	1.1	1.6	0.45	0.61
Signif.			**	**	NS	**	*	*	NS	**	**	**
B rate (B)												
	0		60.2	13.4	113.2	1.8	5.4	11.6	1.1	1.4	0.40	0.53
	4		60.3	12.7	109.2	1.8	5.3	10.7	1.1	1.4	0.36	0.53
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N rate (N)												
	70		57.1	14.3	123.3	1.9	5.9	11.4	1.2	1.4	0.40	0.57
	140		60.4	13.6	114.2	1.7	5.3	11.6	1.1	1.5	0.42	0.56
	280		63.3	11.1	96.1	1.7	4.5	10.5	1.1	1.4	0.32	0.46
Signif.			NS	**	**	NS	*	NS	NS	NS	NS	NS
Linear			NS	**	**	NS	**	NS	NS	NS	NS	NS
Quad.			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions												
C X B			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X B X N			NS	NS	NS	**	NS	NS	NS	NS	NS	NS

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

Table 10. Nutrient uptake by tubers as affected by nitrogen and boron - late harvest (September 6).

Cultivar	B rate lb B/A	N rate lb N/A	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			Nutrient									
			%					ppm				
Russet B	0	70	117.6	23.7	210.3	3.6	11.5	17.9	2.4	2.2	0.68	0.68
	0	140	129.5	23.7	202.0	3.6	11.2	19.0	2.7	2.7	0.64	0.60
	0	280	137.7	21.0	179.0	3.2	9.4	15.8	2.3	2.8	0.64	0.56
	4	70	109.8	24.3	212.2	3.7	11.8	20.6	2.8	2.3	0.64	0.76
	4	140	132.9	24.1	213.5	3.5	11.8	16.5	2.4	3.0	0.64	0.92
	4	280	150.6	23.8	198.7	3.4	10.6	18.2	2.7	3.3	0.76	0.80
Reddale	0	70	142.1	29.6	215.8	2.3	12.3	13.5	1.9	3.0	1.00	1.12
	0	140	164.8	30.8	220.1	2.3	12.5	15.7	1.8	3.1	0.88	1.12
	0	280	215.0	28.9	213.0	2.8	12.5	18.3	2.4	4.2	1.04	1.16
	4	70	129.6	27.3	198.4	2.1	11.4	12.8	1.9	2.7	0.92	1.16
	4	140	161.6	30.8	222.8	2.6	12.9	15.2	2.1	3.4	1.00	1.24
	4	280	194.8	28.2	201.6	2.7	11.7	16.3	2.1	3.7	0.84	1.28
Analysis of Variance												
Cultivar (C)												
	Russet B		129.7	23.5	202.6	3.5	11.1	18.0	2.5	2.7	0.67	0.72
	Reddale		168.0	29.3	212.0	2.5	12.2	15.3	2.0	3.4	0.95	1.18
Signif.			**	**	NS	**	**	**	**	**	**	**
B rate (B)												
	0		151.1	26.3	206.7	3.0	11.6	16.7	2.3	3.0	0.81	0.87
	4		146.6	26.4	207.9	3.0	11.7	16.6	2.3	3.1	0.80	1.03
Signif.			NS	NS	NS	NS	NS	NS	NS	NS	NS	**
N rate (N)												
	70		124.8	26.2	209.2	2.9	11.8	16.2	2.2	2.6	0.81	0.93
	140		147.2	27.4	214.6	3.0	12.1	16.6	2.2	3.1	0.79	0.97
	280		174.5	25.5	198.1	3.0	11.0	17.2	2.4	3.5	0.82	0.95
Signif.			*	NS	NS	NS	NS	NS	NS	**	NS	NS
Linear			**	NS	NS	NS	NS	NS	NS	**	NS	NS
Quad.			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions												
C X B			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X N			*	NS	NS	**	NS	**	NS	NS	NS	NS
B X N			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C X B X N			NS	NS	NS	NS	NS	NS	*	NS	NS	NS

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

Table 11. Summary of nitrogen uptake by vines and tubers as affected by nitrogen fertilizer at early and late harvests.

Cultivar	N rate lb N/A	Early Harvest Vines	Early Harvest Tubers	Early Harvest Total	Late Harvest Vines	Late Harvest Tubers	Late Harvest Total
		lb N/A			lb N/A		
Russet B	70	69.9	56.6	126.5	24.4	113.7	138.1
	140	103.3	56.4	159.7	35.7	131.2	166.9
	280	132.8	54.4	187.2	69.2	144.2	213.4
Reddale	70	51.5	57.5	109.0	15.4	135.8	151.2
	140	91.2	64.4	155.6	24.0	163.2	187.2
	280	149.6	72.1	221.7	51.5	204.9	256.4
Analysis of Variance							
Cultivar (C)							
	Russet B	102.0	55.8	157.8	43.1	129.7	172.8
	Reddale	97.4	64.7	162.1	30.3	168.0	198.3
Signif.		NS	**	NS	**	**	**
N rate (N)							
	70	60.7	57.1	117.8	19.9	124.8	144.7
	140	97.2	60.4	156.7	29.9	147.2	177.1
	280	141.2	63.3	204.5	60.4	174.5	234.9
Signif.		**	NS	**	**	*	**
Linear		*	NS	**	**	**	**
Quad.		NS	NS	NS	NS	NS	NS
Interaction							
C X N		**	*	**	NS	*	NS

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

Table 12. Comparison of nitrogen and nitrate-N concentration in leaves (leaflet + petiole), petioles, and petiole sap at six sampling dates.

		Sampling Date														
		June 13 (56 DAP[1])					June 27 (74 DAP)					July 11 (84 DAP)				
		Kjeldahl N		Water extractable NO_3-N		Quick test Sap NO_3-N	Kjeldahl N		Water extractable NO_3-N		Quick test Sap NO_3-N	Kjeldahl N		Water extractable NO_3-N		Quick test Sap NO_3-N
Cultivar	N rate	Leaf	Petiole	Leaf	Petiole	Petiole	Leaf	Petiole	Leaf	Petiole	Petiole	Leaf	Petiole	Leaf	Petiole	Petiole
lb N/A		---- % -----		--- ug/g ---		- ug/ml -	---- % -----		--- ug/g ---		- ug/ml -	----- % ----		--- ug/g ---		- ug/ml -
Russet B	70	5.48	3.43	4685	21839	2190	3.89	2.23	1476	6902	877	3.56	1.84	953	1155	234
	140	5.62	3.47	5913	21824	2002	4.53	2.74	3969	17364	1648	4.03	2.47	1263	6320	1070
	280	6.01	3.55	7211	21890	2415	5.22	3.28	6527	21309	2241	4.85	3.25	3768	17715	2392
Reddale	70	5.61	3.76	5539	20346	1742	3.78	2.39	2014	8252	550	3.63	1.64	1611	2497	308
	140	5.34	4.00	6831	23806	1813	4.61	3.21	4361	18821	1335	4.08	2.44	1240	9601	823
	280	6.27	4.01	7610	23247	2060	5.14	3.60	4397	23724	1627	4.91	3.43	3899	21671	1899
Analysis of Variance																
Cultivar (C)																
Russet B		5.71	3.48	5936	21851	2203	4.58	2.74	4054	15264	1589	4.17	2.52	1995	8397	1232
Reddale		5.74	3.92	6660	22467	1871	4.51	3.07	3687	17318	1171	4.21	2.50	2250	11257	1010
Signif.		NS	**	**	NS	**	NS	*	NS	NS	**	NS	NS	NS	**	NS
N rate (N)	70	5.55	3.59	5112	21093	1966	3.83	2.31	1745	7577	713	3.60	1.74	1282	1826	271
	140	5.48	3.74	6372	22816	1908	4.57	2.97	4165	18092	1492	4.05	2.46	1252	7901	946
	280	6.14	3.78	7411	22569	2238	5.18	3.44	5463	22517	1934	4.88	3.34	3834	19693	2144
Signif.		NS	**	**	NS	NS	**	**	**	**	**	**	**	*	**	**
Linear		NS	**	**	NS	NS	**	**	**	**	**	**	**	*	**	**
Quad.		NS	NS	NS	NS	NS	**	NS	NS	**	*	NS	NS	NS	NS	NS
Interaction																
C X N		NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	*	NS	NS	NS

NS = not significant, * = significant at 5%, ** = significant at 1%,
[1]DAP = Days after planting

Table 12. Con't.

Cultivar	N rate (lb N/A)	July 25 (98 DAP) Kjeldahl N Leaf (%)	July 25 Kjeldahl N Petiole (%)	July 25 Water extractable NO_3-N Leaf (ug/g)	July 25 Water extractable NO_3-N Petiole (ug/g)	July 25 Quick test Sap NO_3-N Petiole (ug/ml)	August 8 (112 DAP) Kjeldahl N Leaf (%)	August 8 Kjeldahl N Petiole (%)	August 8 Water extractable NO_3-N Leaf (ug/g)	August 8 Water extractable NO_3-N Petiole (ug/g)	August 8 Quick test Sap NO_3-N Petiole (ug/ml)	August 22 (126 DAP) Kjeldahl N Leaf (%)	August 22 Kjeldahl N Petiole (%)	August 22 Water extractable NO_3-N Leaf (ug/g)	August 22 Water extractable NO_3-N Petiole (ug/g)	August 22 Quick test Sap NO_3-N Petiole (ug/ml)
Russet B	70	2.88	1.16	53	1687	29	2.76	1.40	63	1128	19	2.96	1.34	105	725	106
	140	3.28	1.36	151	1756	126	3.50	1.53	891	2429	259	3.82	1.82	341	1848	112
	280	4.63	2.30	3279	10442	1237	4.25	2.47	3013	8548	883	4.88	2.25	1406	6491	73
Reddale	70	3.10	1.07	112	235	2	2.53	1.23	129	387	25	2.69	1.18	359	318	28
	140	3.51	1.27	271	2440	37	3.19	1.32	397	1066	98	3.21	1.32	337	2099	89
	280	4.39	2.21	2827	13591	1205	4.23	2.22	2244	10145	670	3.97	2.32	1831	8836	786
Analysis of Variance																
Cultivar (C)																
Russet B		3.63	1.60	1161	4629	464	3.53	1.80	1322	4035	387	3.93	1.80	617	664	317
Reddale		3.66	1.52	1071	5423	415	3.32	1.58	923	3866	266	3.29	1.61	842	948	301
Signif.		NS	NS	NS	NS	NS	NS	**	NS	NS	*	**	NS	NS	NS	NS
N rate (N)																
	70	3.00	1.11	83	999	15	2.63	1.32	96	758	22	2.82	1.26	232	522	67
	140	3.40	1.31	211	2128	81	3.35	1.42	644	1766	179	3.52	1.57	339	1973	100
	280	4.51	2.25	3053	12054	1221	4.24	2.34	2628	9347	779	4.43	2.28	1618	7663	760
Signif.		**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Linear		**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Quad.		NS	NS	**	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction																
C X N		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 13. Soil nitrate-N concentrations at the early (July 27) and late (Aug. 30) harvest.

N rate	Depth	Sampling Date			
		July 27		August 30	
lb/A	Ft.	In Row	Betwn Row	In Row	Betwn Row
		lb NO_3-N/A			
70	0-1	5.7 ± 2.7	3.6 ± 1.1	4.9 ± 2.9	3.4 ± 1.6
	1-2	2.2 ± 1.2	1.0 ± 0.6	1.9 ± 1.0	0.6 ± 0.4
	2-3	1.2 ± 0.7	1.6 ± 1.6	0.9 ± 0.8	0.3 ± 0.3
	Total	9.1 ± 4.1	6.2 ± 3.1	7.7 ± 3.9	4.3 ± 1.8
	Total in field	15.3 ± 6.4		12.0 ± 5.7	
140	0-1	6.3 ± 2.7	4.0 ± 1.4	5.0 ± 2.5	2.6 ± 1.4
	1-2	2.6 ± 1.9	1.1 ± 0.4	1.5 ± 0.8	0.9 ± 0.4
	2-3	2.7 ± 0.9	1.3 ± 0.7	1.0 ± 0.6	0.4 ± 0.4
	Total	11.6 ± 3.9	6.4 ± 2.2	7.5 ± 3.3	3.9 ± 2.0
	Total in field	18.0 ± 5.7		11.4 ± 4.1	
280	0-1	37.5 ± 38.0	5.5 ± 1.8	8.5 ± 5.7	4.5 ± 2.7
	1-2	48.1 ± 39.5	1.8 ± 1.0	10.2 ± 12.3	1.3 ± 0.7
	2-3	15.9 ± 12.5	1.4 ± 0.9	5.4 ± 3.7	0.7 ± 0.3
	Total	101.5 ± 81.6	8.7 ± 3.2	24.1 ± 15.9	6.5 ± 3.1
	Total in field	110.0 ± 82.9		30.7 ± 16.3	

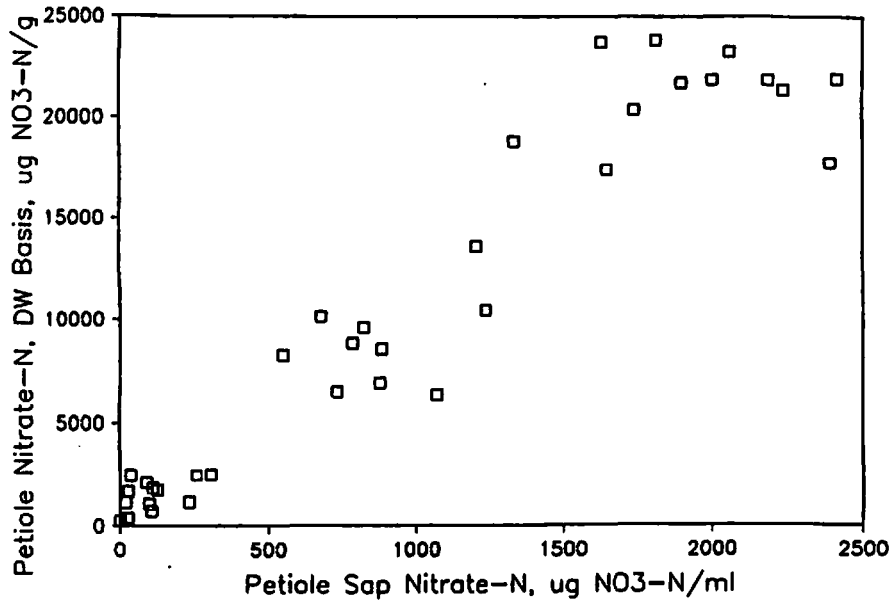

Figure 1. Correlation between the petiole sap nitrate quick test and the conventional petiole nitrate laboratory test. $r^2 = 0.95$, $y = 10.056x + 662.8$.

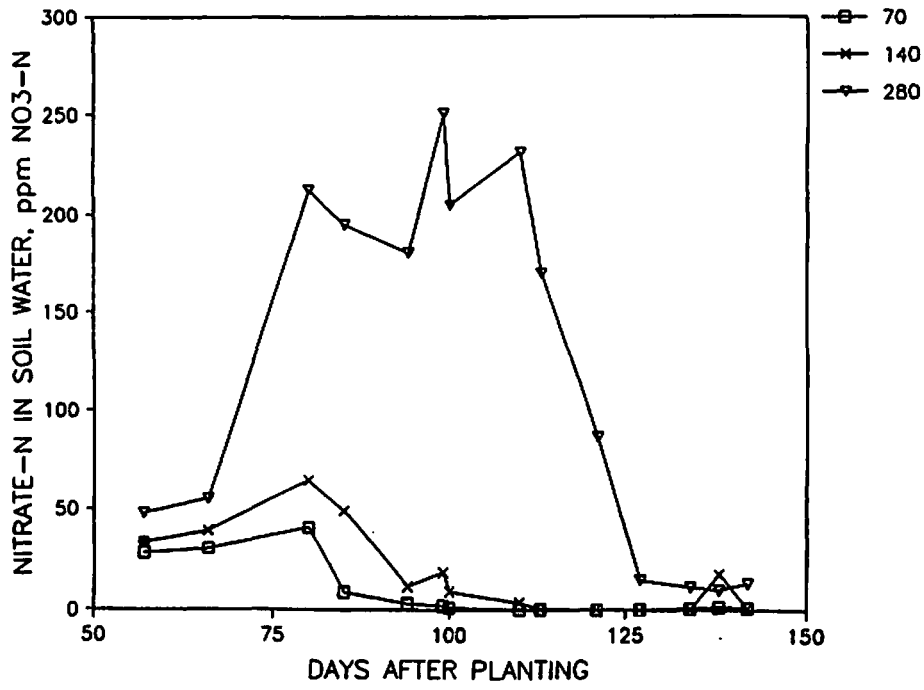

Figure 2. Seasonal nitrate-N levels in soil water at a depth of 2 feet below the row as affected by N fertilizer rate.

1988 WEATHER DATA
NORTHWEST EXPERIMENT STATION, CROOKSTON, MN

T.E. Cymbaluk[1]

"DRY" is the word for 1988. Eight of the twelve months were below normal in precipitation. The five months that deviated the most in precipitation were April, May, June, July, and August; the five most crucial months for agricultural crops in the Red River Valley. The 1988 precipitation was 6.49 inches less than the 90-year average. The amount of precipitation for the small grain crops (May 1 - July 31) was 4.82 inches, 4.44 inches below the 90-year average. The amount of precipitation for the sugarbeet season (May 1 - September 30) was 9.36 inches, 4.97 inches below the 90-year average. The longest period without rain was 39 days, from March 28 to May 5. There was no precipitation in April, only once has this happened in the month of April (April, 1980). There have been only 8 months that received no precipation since 1890. The greatest amount of precipitation that occurred in a single day in 1988 was received on September 18, accummulating 1.44 inches of rain.

The temperature for 1988 was slightly warmer when compared with the 90-year average. Eight of the 12 months were above normal in regard to temperature, accounting for the average annual temperature to be 1.5 degrees above normal. March, April, May, June, July, and August were above normal in temperature. The highest temperature for 1988 occurred on July 5 at 104° F. The lowest temperature for 1988 occurred on January 5 and February 9 at -29° F.

The last frost for the spring of 1988 was May 12 (28° F) which initiated a 143-day frost-free period ending October 3 (22° F). The ground frost reached a maximum depth of 35 inches by March 18. Surface thaw had begun by March 25. By April 26, the ground frost was gone.

With a mild winter, early warm spring temperatures made it possible for an early planting season in 1988. The soil moisture content was low, there was no rain in April with little rain in May, and strong winds made it difficult for crops to be established. Due to the lack of moisture, there was little tillering in the small grain crops. Even with precipitation becoming normal in the fall, the soil moisture content was low at the end of 1988.

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

[1] Junior Scientist, Northwest Experiment Station, University of Minnesota, Crookston, MN.

Table 1. Weather summary for 1988 with 90-year averages for precipitation and mean temperatures.

Month	Precipitation 1988	Precipitation 1890-1979	Mean Temperatures 1988	Mean Temperatures 1890-1979
	------- inches -------		---------- °F ---------	
January	0.87	0.56	2.6	3.7
Febuary	0.20	0.59	6.8	8.1
March	1.66	0.84	27.3	22.9
April	0	1.57	43.0	41.4
May	1.61	2.59	62.0	54.6
June	1.52	3.56	71.9	64.4
July	1.69	3.09	73.0	69.6
August	1.56	2.90	70.1	67.4
September	2.98	2.16	56.3	57.5
October	0.67	1.43	40.0	45.3
November	0.83	0.78	25.7	26.7
December	0.59	0.60	11.8	11.5
Total	14.18	20.67	Mean 40.9	39.4

Table 2. Records broken or matched at the Northwest Experiment Station, Crookston, MN in 1988.

Highest Maximum Temperature			Highest Minimum Temperature		
Date	Old Record	New (1988)	Date	Old Record	New (1988)
	-------- °F ----------			--------- °F ----------	
March 5	47 (1925)	48	April 7	44 (1963)	46
April 16	77 (1913)	77	May 1	59 (1955)	62
June 4	92 (1968)	93	May 30	64 (1919)	71
June 5	93 (1939)	94	June 4	66 (1963)	69
June 11	94 (1956)	95	June 5	65 (1932)	65
July 5	93 (1940)	104	July 4	70 (1938)	73
July 6	100 (1936)	100	July 5	71 (1910)	71
July 27	101 (1941)	101	August 6	72 (1941)	74
August 10	92 (1958)	97	August 1	70 (1947)	70
August 11	94 (1969)	95			

TIMING OF NITROGEN APPLICATION ON SUGARBEET[1]

John A. Lamb[2]

ABSTRACT: A four-year field study examining the effect of split applications of N fertilizer on sugarbeet yield and quality was conducted in 1988. Recommended amounts of N fertilizer were applied in one, two, or four way splits as a four-inch deep band. The four application times include preplant, 4-leaf stage, 4-leaf + 3 weeks, and 4-leaf + 6 weeks. Any application after the 4-leaf stage tended to reduce yield, recoverable sugar, and sugar concentration. The impurity index tended to increase with the last application.

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

MATERIALS AND METHODS: This study was conducted from 1985 to 1988 with four experiments located at the Northwest Experiment Station and two in the Southern Minnesota Beet Sugar Cooperative area (Table 1). The treatments were nitrogen fertilizer (anhydrous ammonia in 1985 and UAN 28% in 1986 to 1988) injected four inches deep with shanks spaced 22 inches apart at four different application times. These applications involved applying the recommended amount according to a 0-2 foot nitrate-N soil test, 150 lb N/A in 1985 and 120 lb N/A in 1986 to 1988. Table 2 contains a list of application times. The first time was preplant in the spring. The second occurred at the four true leaf stage with the third and fourth times occurring three and six weeks after the second treatment, respectively. The SoMN 1987 location applications were delayed considerably by rain. The plots were 6 rows and 4 rows wide at NWES and Southern Minnesota, respectively and 35 feet in length. Four replications of Hilleshog Dippe II in 1985 and 1986 and KW 3265 in 1987 and 1988 were planted with a John Deere 71 flex unit. Populations were thinned to 125 plants per 100 feet of row. The quality data was determined at the American Crystal Sugar Tare Lab in East Grand Forks, MN.

RESULTS AND DISCUSSION: Southern Minnesota - 1988 - Table 3 lists results from 1988. The only parameter that was affected by the N treatment was amino-N in the root. The treated sugarbeets were not different from the check so no conclusion as to the effect of timing of N application on amino-N can be drawn. The rest of the parameters were not affected by the treatment. This lack of difference occurred because of the drought conditions that occurred during the growing season. Fertilizer N was not used by the plant because water was limiting plant growth more than nitrogen availability.

NWES - 1988 - The data in Table 4 indicates that yield, sugar content, recoverable sugar per ton, amino-N and impurity index were affected by the addition of N. Yield, amino-N, and impurity index were increased by nitrogen application but no set of application treatments consistently increase any parameter. Sugar content and recoverable sugar per ton were decreased by nitrogen application. Again no trend was apparent.

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

1 Funding by Sugarbeet Research and Education Board of Minnesota and North Dakota.

2 Assistant Professor of Soil Science, Northwest Experiment Station, University of Minnesota, Crookston, MN.

Overall Analysis - 1985 to 1988 - In the overall analyses, the Southern Minnesota locations were dropped out because of lack of response to nitrogen application in 1988 and the late application of treatments in 1987. This leaves the NWES locations 1985-1988. The means and statistical analyses for these locations are listed in Table 5. The addition of nitrogen significantly increased root yield, recoverable sugar per acre, Na, amino-N and the impurity index. This was expected. The object of this study was to explore the possibility of using split applications and changing the time of application to minimize the increase in impurities and maximize the root growth. In comparing application effects on root yield and recoverable sugar per acre, there were no significant differences between treatments. There was a trend towards greater yields and recoverable sugar per acre with the preplant and the four leaf time of application when compared with the last two application times. The later application time tended to decrease sugar content and increase the impurity index. The impurity index was affected by increases in Na and amino-N. Root K concentrations were not effected by N application.

Table 1. Description of experimental sites, 1985 - 1988.

Location	Year	Variety	Planting Date	Harvest Date	NO_3^--N 0-2'
					lbs/A
NWES	1985	Dippe II	4/25	9/20	28
NWES	1986	Dippe II	5/22*	9/25	41
NWES	1987	KW 3265	4/28	9/24	41
SoMN	1984+	KW 3265	5/5	9/22	43
NWES	1988	KW 3265	4/19	9/28	70
SoMN	1988++	KW 3265	5/2	9/4	71

* Replanted because of crust.
\+ Located at Mike Schjeken Farm.
++ Located at Mike Holein Farm.

Table 2. Application treatments for N timing study, 1985 to 1988.

Treatment	Preplant	4-Leaf	4-Leaf +3 Weeks	4-Leaf +6 Weeks
1	0	0	0	0
2	1/4X	1/4X	1/4X	1/4X
3	1/2X	1/2X	0	0
4	1/2X	0	1/2X	0
5	1/2X	0	0	1/2X
6	0	1/2X	1/2X	0
7	0	1/2X	0	1/2X
8	0	0	1/2X	1/2X
9	X	0	0	0
10	0	X	0	0
11	0	0	X	0
12	0	0	0	X

X=120 lb N/A in 1985
80 lb N/A in 1986
80 lb N/A in 1987
50 lb N/A in 1988

Table 3. Treatment means and statistical analyses for Southern Minnesota location, 1988.

Treatment				Yield	Sugar	Recoverable Sugar		Na	K	Amino-N	Index
				T/A	%	lb/A	lb/Ton	-------ppm-----			
0	0	0	0	13.2	16.6	3988	299	120	1948	571	653
12.5	12.5	12.5	12.5	13.3	16.0	3822	286	142	1969	648	725
25	25	0	0	14.7	16.1	4278	288	164	1950	629	714
25	0	25	0	15.7	16.6	4718	298	131	1967	626	685
25	0	0	25	13.7	16.5	4108	298	145	1913	547	640
0	25	25	0	13.8	16.3	4080	294	127	1932	581	663
0	25	0	25	12.4	15.9	3637	286	135	1941	552	675
0	0	25	25	15.0	16.1	4321	289	196	1992	580	693
50	0	0	0	13.4	15.8	3815	284	167	1851	608	696
0	50	0	0	14.7	16.7	4510	304	142	1920	506	604
0	0	50	0	14.2	16.4	4203	294	138	1963	606	683
0	0	0	50	13.4	16.0	3849	286	176	2050	570	700
Treatment				NS	NS	NS	NS	NS	NS	*	NS
Check vs Rest				NS	NS	NS	NS	NS	NS	NS	NS
C.V.%				17.0	4.4	19.3	5.1	32.6	7.2	8.5	8.9
LSD.05				3.4	1.0	1140	21	40	203	72	87

*, is the 0.05 significance level.

Table 4. Treatment means and statistical analyses for NWES location, 1988.

Treatment				Yield	Sugar	Recoverable Sugar		Na	K	Amino-N	Index
				T/A	%	lb/A	lb/Ton	-------ppm-----			
Check				13.2	17.6	4337	328	173	1806	301	454
12.5	12.5	12.5	12.5	13.8	17.0	4324	312	163	1844	426	545
25	25	0	0	13.1	17.3	4223	321	147	1761	356	481
25	0	25	0	14.3	17.0	4455	195	195	1879	431	560
25	0	0	25	15.5	17.4	4987	321	174	1834	410	523
0	25	25	0	14.7	17.1	4621	314	146	1862	430	542
0	25	0	25	14.2	17.5	4616	324	151	1862	388	507
0	0	25	25	14.4	17.3	4630	321	137	1760	335	468
50	0	0	0	15.9	17.5	5099	321	171	1872	451	551
0	50	0	0	13.6	17.2	4328	318	161	1885	387	520
0	0	50	0	12.8	17.3	4096	319	154	1801	395	510
0	0	0	50	14.2	17.1	4481	314	152	1924	409	541
Fall 50				13.7	17.0	4275	312	155	1841	449	554
Treatment				*	NS	++	NS	NS	NS	++	NS
Check vs Rest				.12	++	NS	++	NS	NS	**	*
C.V.%				8.3	2.4	9.5	3.3	22.3	7.5	16.2	12.7
LSD.05				1.7	0.6	610	15	51	199	92	95

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

Table 5. Treatment means and statistical analyses for the four NWES locations, 1985 to 1988.

Treatment				Yield	Sugar	Recoverable Sugar			Na	K	Amino-N	Index	Loss to Molasses
				T/A	%	lb/A	lb/Ton	%	------ppm----				%
0	0	0	0	14.8	17.4	4769	322	93	212	1881	311	486	1.14
1/4X	1/4X	1/4X	1/4X	17.2	16.9	5300	308	91	289	1809	438	579	1.32
1/2X	1/2X	0	0	17.6	17.2	5546	315	92	224	1833	434	556	1.29
1/2X	0	1/2X	0	17.1	17.1	5366	313	91	249	1924	439	579	1.34
1/2X	0	0	1/2X	17.2	16.7	5231	303	91	279	1944	454	617	1.38
0	1/2X	1/2X	0	17.4	17.0	5423	311	91	233	1925	432	577	1.31
0	1/2X	0	1/2X	16.6	16.9	5123	309	91	267	1856	428	575	1.32
0	0	1/2X	1/2X	16.9	16.6	5149	303	91	280	1902	442	606	1.36
X	0	0	0	17.7	17.0	5470	309	91	260	1926	472	605	1.39
0	X	0	0	17.6	17.0	5467	311	92	250	1827	387	548	1.26
0	0	X	0	16.7	17.0	5228	312	92	256	1895	394	555	1.28
0	0	0	X	17.1	16.8	5248	306	91	268	1902	420	583	1.31
Site				**	**	**	**	**	**	**	**	**	**
Treatment				*	*	NS	*	**	NS	NS	**	**	**
Check vs Rest				**	**	**	**	**	*	NS	**	**	**
Site * Treatment				NS	NS	NS	NS	NS	NS	NS	**	NS	NS
C.V.%				12.6	3.5	13.1	4.5	1.2	29.2	7.3	16.7	12.9	10.3
LSD.05				1.5	0.4	485	9.8	.008	52	96	49	51	0.09

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

FOLIAR NITROGEN APPLICATION ON SUGARBEET - TIMING AND RATE[1]

John A. Lamb and John T. Moraghan[2]

ABSTRACT: A three-year study examining the effects of late season topdress N on sugarbeet that were either fertilized preplant with the recommended amount of N or no preplant N was finished in 1988. The use of preplant N with no late application of N was superior to any late season topdress treatment in this study. Application of N to a sugarbeet crop after July 1 will not effect root yield and will decrease sugar content and recoverable sugar per ton.

OBJECTIVE: In recent years a growing concern among producers has been the premature yellowing or N deficiency, of sugarbeet fields. Many questions have arisen concerning the use of a foliar N application to correct this situation. Because of the possible detrimental effects on sugarbeet quality, a cooperative study was started with the objective of determining the effects of foliar N application on sugarbeet yield and quality after early yellowing under optimum fertilizer application and inadequate N conditions. In 1988 another condition was tested; the effect of foliar N on a sugarbeet crop under drought stress.

PROCEDURE: The third and final year of this study was established at the Northwest Experiment Station, on a soil NO_3^--N test, 0-2 ft, of 70 pounds/Acre. Table 1 lists the soil and foliar N treatments. The soil N treatments were applied fall 1987 as Urea and incorporated. Six replications of ACH 164 were planted April 19 in a randomized complete block design. The plots were overplanted and thinned to 125 plants per 100 feet of row. The foliar treatments were applied as Urea-ammonium nitrate solution (UAN 28% N) in 20 pound N/Acre increments on June 30, July 18, and July 29.

Petiole and blade samples were taken 7 to 10 days after each foliar treatment and analyzed for total N and NO_3^--N. Because of drought damage, only five replications were hand harvested September 29. The quality was determined by American Crystal Sugar quality lab at East Grand Forks, MN. Brei samples were taken and N was determined on them at J.T. Moraghan's lab at NDSU.

RESULTS AND DISCUSSION: 1988 The results from 1988 add information about the response to late N application under drought stress conditions. Many locations in the Red River Valley and Renville area had sugarbeets under drought stress to the point they stopped growing. Many producers were asking if an application of N would help get the plants growing again. Table 2 lists the root and top yield, sugar content, recoverable sugar per acre, and recoverable sugar per ton. Only sugar concentration and recoverable sugar per ton were affected by the use of nitrogen either soil or foliar applied. The addition of soil and foliar N decreased sugar concentration by 0.3% and 0.5%, respectively. Decreases in recoverable sugar per ton were 8 and 14 lb per ton for soil and foliar applications, respectively. The foliar treatments did cause a larger reduction in sugar production because the application occurred later in the growing season. The increase in amino N concentration (Table 3) was the main impurity parameter affected by the foliar treatments.

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

[1] Funding provided by Sugarbeet Research and Education Board of Minnesota and North Dakota.

[2] Assistant Professor of Soil Science, Northwest Experiment Station, University of Minnesota, Crookston, MN and Professor of Soil Science, North Dakota State University, Fargo, ND.

Table 1. Treatments for foliar N trial, NWES 1988.

Treatment	Soil Preplant lb N/A	Foliar 6/30	Foliar 7/15	Foliar 7/30	Total
		------ lb 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	70**	0	0	0	0
6	70	0	0	20	20
7	70	0	20	20	40
8	70	20	20	20	60

* Soil test was 40, 40, and 70 lb NO_3^--N/A 0-2 ft. in 1986, 1987, and 1988, respectively.

** 100 lb N/A applied 1986 and 1987 to bring soil test 0-2' + fertilizer N = 140 lb N/A.

Table 2. Sugarbeet root and top yield, sugar content, recoverable sugar per ton, and recoverable sugar per acre, NWES 1988.

Soil N	Foliar	Yield	Sugar	Recoverable Sugar		Top Yield
lb N/A	lb N/A	T/A	%	lb/A	lb/Ton	lb/A
0	0	11.9	18.6	3821	347	2778
0	20	11.7	18.0	3892	333	2750
0	40	12.5	18.2	4176	335	3037
0	60	11.9	17.6	3821	321	3182
70	0	12.3	17.8	4030	328	3154
70	20	11.2	17.9	3665	329	2927
70	40	11.8	17.7	3835	325	3185
70	60	12.3	17.8	4004	325	3267
	0	11.6	18.2	3925	337	2966
	20	11.4	18.0	3778	331	2839
	40	12.2	17.9	4005	330	3111
	60	12.1	17.7	3913	323	3225
0		11.8	18.1	3927	334	2937
70		11.9	17.8	3883	326	3113
Soil N		NS	*	NS	*	NS
Foliar N		NS	++	NS	++	NS
S x F		NS	NS	NS	NS	NS
C.V.%		16.0	2.6	16.4	10.3	15.2

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

Table 3. Treatment means and statistical analyses for impurity parameters for foliar N study at NWES in 1988.

Soil N	Foliar	Na	K	Amino-N	Index
lb N/A	lb N/A	---------ppm--------			
0	0	154	1754	366	452
0	20	165	1771	456	519
0	40	160	1703	488	525
0	60	217	1809	532	487
70	0	185	1862	462	544
70	20	176	1783	513	555
70	40	168	1699	495	540
70	60	186	1714	550	573
	0	169	1808	414	498
	20	170	1777	485	537
	40	164	1701	492	532
	60	202	1761	541	580
0		174	1759	460	521
70		179	1764	505	553
Soil N		NS	NS	++	NS
Foliar N		NS	NS	*	++
S x F		NS	NS	NS	NS
C.V.%		22.7	7.3	17.4	12.8

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

The use of late season N applications did not stimulate plant growth and actually was detrimental to sugar production in 1988.

1986 to 1988: This year, 1988, was the last of the three-year study on late season N application. For this information to be useful to producers in making production decisions, the information must be summarized and results generalized. This study was conducted in three very different production years. In 1986 the study was replanted because of crust formation which hurt emergence. The best sugarbeet production on record in the Red River Valley occurred in 1987. An early planting date coupled with an optimum growing season produced large sugar yields. Drought is the best way to summarize 1988. At NWES the subsoil moisture was depleted to 30% of field capacity in 1987 and not recharged before planting in 1988.

Only 9.3 inches of precipitation occurred during the 1988 growing season, compared to a 90-year-average of 14.2 inches. In the overall statistical analyses, Table 4, the year effect was highly significant for all parameters except the impurity index. This occurred because of the difference in growing seasons discussed above. The statistics that are important for summarizing and applying the results to the real world are the year x soil, year x foliar, and year x foliar x soil interactions. If these statistics are significant, it indicates the treatment responses were different each year. For this study the year x soil N interactions were significant for only root yield, recoverable sugar per acre, Na, amino N, and the impurity index. Table 5 lists the means for the significant year x soil N interactions.

In 1986 and 1987 the root yield was increased 0.9 and 2.6 tons per acre with the addition of preplant N. In 1988 no yield increase occurred. The lack of increase can be attributed to drought and a reasonable amount of N mineralized from organic matter during the growing season.

Sugar content and recoverable sugar per ton were not affected by the year the study was conducted, Table 4. Both were significantly decreased by soil and foliar N applications. The sugar content decrease was 0.5 and 0.4% for soil and foliar applications, respectively (Table 7).

The recoverable sugar per acre was increased by soil N in 1986 and 1987 and a small decrease in 1988. The 1986 increase was only 120 lb sugar/A. This increase was reduced compared to the potential yield increase because of the late planting date. In 1987, a large increase occurred of 764 lb sugar/A. The drought of 1988 caused a small decrease of 44 lb sugar/A.

Sugar impurities of K and amino N were affected differently by soil N application. In 1986 and 1987, K concentration was decreased dramatically with the addition of soil N. In the drought year, 1988, the K concentration was not affected. The decreases were caused by dilution of K in the root by the yield increases that resulted. The use of foliar N applications did not affect root K concentrations. Soil N application increased amino N concentrations every year of the study. Amino N was also increased with the foliar N application in all years (Table 6). The sodium (Na) concentration was increased by both soil and foliar N applications, Table 7. Because the amino-N concentration is the major impurity measured, the impurity index is affected by the nitrogen applications the same as amino-N. In all years of the study, the addition of soil N increased the index. The index increases were different for each year ranging from 105 in 1986 to 32 units in 1988.

In summary, the use of preplant soil application at amounts recommended by a NO_3^--N soil test was superior to a foliar N application later in the season for sugar production. The combined data suggests that applying foliar N to an unfertilized crop will not increase root yield and will decrease sugar content and recoverable sugar.

Because of the N mineralization potential of the soils in the sugarbeet production areas of Minnesota and North Dakota, adequate N is supplied the sugarbeet after July 1 during the growing season. This data also substantiates that sugarbeet yield response to fertilizer N occurs earlier in the growing season mainly through the stimulation of a faster canopy establishment.

Table 4. Overall statistical analyses of foliar N study, 1986 to 1988 at NWES.

	Root		Recoverable Sugar				Amino	Impurity
	Yield	Sugar	lb/A	lb/Ton	Na	K	N	Index
Year	**	**	**	**	**	**	**	NS
Soil N	**	**	**	**	**	**	**	**
Foliar N	NS	**	**	**	**	NS	**	**
Soil x Foliar	NS	NS	NS	NS	NS	NS	NS	NS
Year * Soil	**	NS	**	NS	NS	*	**	**
Year * Foliar	NS	NS	NS	NS	NS	NS	NS	NS
Year * Soil * Foliar	NS	NS	NS	NS	NS	NS	NS	NS
C.V.%	12.4	2.6	12.7	3.2	26.0	5.9	15.5	10.7

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

Table 5. Soil N by year interaction means for root yield, recoverable sugar (lb/A), K, amino N, and purity index at NWES, 1986-1988.

Year	Soil N	Root Yield	Recoverable Sugar	K	Amino-N	Index
	lb N/A	Ton/A	lb/A	----------ppm----------		
1986	0	13.4	4814	2190	251	445
	100	14.3	4934	2069	448	550
1987	0	15.6	5540	1943	362	480
	100	18.2	6324	1850	450	529
1988	0	11.8	3927	1759	460	521
	70	11.9	3883	1764	505	553

Table 6. Overall foliar N treatment means for amino N and impurity index at NWES, 1986-1988.

Foliar	Amino N	Index
lb N/A	ppm	
0	363	476
20	406	509
40	433	525
60	449	540

Table 7. Overall treatment means for sugar concentration, recoverable sugar (lb/Ton), and Na at NWES, 1986-1988.

Soil N	Foliar	Sugar	Recoverable Sugar	Na
lb N/A	lb N/A	%	lb/Ton	ppm
0	0	19.1	356	186
0	20	18.9	351	191
0	40	18.9	350	229
0	60	18.6	343	235
100	0	18.8	347	222
100	20	18.5	341	257
100	40	18.4	338	253
100	60	18.4	336	281

PHOSPHORUS FERTILIZATION ON SUGARBEET - 1988[1]

John A. Lamb[2]

OBJECTIVE: In recent years a concern has arisen among producers about the use of phosphorus. Historically sugarbeet ground has been overfertilized with phosphorus. In the last 15 years the phosphorus recommendations have been reduced to the point that very little has been applied. The objective of this study is to reevaluate the phosphorus recommendations for sugarbeet under improved production practices.

PROCEDURE: Five rates of phosphorus (0, 20, 40, 60, and 80 pounds P_2O_5/A) as triple superphosphate (0-44-0) were applied in the fall of 1987 on a Wheatville loam at the Northwest Experiment Station, Crookston, MN. The sodium bicarbonate soil test for 0-6 in depth was 9 lb/A. Sugarbeet variety KW 3265 was planted April 19, 1988 and thinned back to a stand of 125 plants per 100 feet of row. The study was harvested September 28, 1988 and quality determined at the American Crystal Quality Lab, East Grand Forks, MN.

RESULTS AND DISCUSSION: Table 1 lists the yield and quality results from 1988. The only parameter effected by phosphorus application was sodium. Sodium decreased as the amount of phosphorus increased. This decrease was probably caused by the small increase in root size and thus diluted the Na concentration in the root. The lack of root yield and recoverable sugar response was not expected because of the low soil test P value of 9 lb/A.

Table 1. Treatment means and statistical analyses for yield and quality parameters, NWES, 1988.

P_2O_5	Yield	Sugar	Recoverable Sugar		Na	K	Amino-N	Index
lb/A	T/A	%	lb/A	lb/Ton	--------ppm-------			
0	12.7	17.5	4088	322	186	2005	388	535
20	13.4	17.5	4345	323	201	1912	382	522
40	14.4	17.6	4673	324	184	1981	409	541
60	14.0	17.7	4604	328	146	1929	336	483
80	13.0	17.8	4273	330	129	1877	338	472
P Rate	NS	NS	NS	NS	*	NS	NS	NS
Linear	NS	NS	NS	NS	**	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS
C.V.	13.9	3.3	15.8	4.1	18.5	6.7	15.4	11.8

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

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

1 Funding provided by Sugarbeet Research and Education Board of Minnesota and North Dakota.

2 Asisstant Professor of Soil Science, Northwest Experiment Station, University of Minnesota, Crookston, MN.

THE EFFECTS OF SULFUR APPLICATION ON SUGARBEET IN MINNESOTA AND NORTH DAKOTA[1]

John A. Lamb[2]

OBJECTIVE: Because changes in the environment (less contaminants in air) and sugarbeet cultural practices (varieties, soil fertility, planting dates) many questions have arisen with regard to the need of sulfur application on heavy textured soils in Minnesota and North Dakota. About 20 years ago research at the Northwest Experiment Station led to the conclusion that sulfur was not needed for efficient sugarbeet production. In view of the above mentioned change, it was felt a study to update the information about sulfur was needed.

PROCEDURE: From 1986 to 1988, five studies were conducted with 3 sulfur rates of 0, 25, and 50 lb S/A as elemental sulfur (98% S). Three of the locations were at the Northwest Experiment Station and two were located in the Southern Minnesota Beet Sugar Cooperative area. The soil parameters are listed in Table 1. Sulfur values are not available for the NWES1 and NWES2 sites, but traditionally this area has tested low and have sulfur soil test values similar to NWES3. Maribo 403 was overplanted and thinned back to a population of 125 plants per 100 feet of row. All sites were mechanically harvested and both yield and quality were determined. Quality analyses were done at the American Crystal Sugar Quality Lab, East Grand Forks, MN.

RESULTS AND DISCUSSION: The root yield and quality results for five locations from 1986 to 1988 are presented in Table 2. The locations were chosen to be on loam to clay loam soils in the Southern Beet Sugar Cooperative Area and Crookston, MN. The results from each location were significantly different for all parameters measured. The overall statistical analyses indicate that the crop nonresponse to sulfur was the same at each location. The lack of response suggests that sulfur fertilization is not needed for maximum economic sugar production even though the sulfur soil test is low. On finer textured soils the sulfur soil test is not accurate. The organic matter in these soils will, during the growing season, mineralize enough sulfur to meet the needs of the sugarbeet plant. The sulfate-S soil test does not measure the ability of the soil to mineralize sulfur. Another consideration is most soils in Northwest Minnesota on which sugarbeets are grown are underlain with gypsum ($CaSO_4$) which is a source of sulfur for the plant. These results concur with results from studies conducted at Crookston over 20 years ago. If a producer is raising sugarbeets on a soil that is a sandy loam or sandier and low in organic matter (less than 2%), then a soil test would be recommended. If the result is in the low category (less than 6 ppm 0-6"), then it is advised the producer should apply a test strip of sulfur and observe if a response occurs.

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

1 Funded by Sugarbeet Research and Education Board of Minnesota and North Dakota.

2 Assistant Professor of Soil Science, Northwest Experiment Station, University of Minnesota, Crookston, MN.

Table 1. Soil characteristics for sulfur study.

	Depth (Inches)	NWES 1986	NWES 1987	SoMN 1987	NWES 1988	SoMN 1988
NO_3^--N, lb/A	0-24	41	40	43	70	71
$NaHCO_3$ P, lb/A	0-6	7	9	18	9	15
K, lb/A	0-6	220	250	473	230	370
SO_4^--S, ppm	0-6	NA	NA	16	2	14
pH	0-6	7.9	8.1	7.8	8.0	7.6

Table 2. Location and sulfur rate means and statistical analyses for sugarbeet yield and quality over 5 locations from 1986 to 1988.

Location	Yield	Sugar	Recoverable Sugar		Na	K	Amino-N	Index	Loss to Molasses
	T/A	%	lb/A	lb/Ton	------ppm-----				---%----
Crox 1986	20.0	18.4	6722	336	379	2145	367	556	1.39
Crox 1987	17.0	17.8	5565	327	319	2100	326	533	1.29
Crox 1988	12.5	18.2	4219	337	210	1858	380	496	1.23
SoMN 1987	19.2	16.0	5440	284	372	2237	537	751	1.64
SoMN 1988	11.5	16.1	3344	291	149	2046	525	660	1.44
S Rate									
0	16.2	17.5	5180	318	284	2108	419	594	1.40
25	16.1	17.2	5039	313	297	2049	423	600	1.39
50	15.8	17.2	4956	314	276	2075	438	604	1.42
Statistical Analysis									
Location	**	**	**	**	**	**	**	**	**
S Rate	NS	NS	NS	NS	NS	NS	NS	NS	NS
Lin	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad	NS	NS	NS	NS	NS	NS	NS	NS	NS
Loc x S Rate	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.	11.7	3.0	10.4	3.9	23.2	7.0	15.0	12.0	10.6

** is 0.01 significant level.
NS = not significant.

RESPONSE OF RUSSET BURBANK POTATO TO FOLIAR RATES OF 20-0-0-3

Russ Severson, Duane Preston, John Lamb[1]

ABSTRACT: Foliar nitrogen applications on potatoes and wheat have been tried on an experimental basis by growers in the Red River Valley the past two years. This study addresses the early application of liquified urea on Russet Burbank potatoe yields. Results of this one-year study indicate no significant response to added foliar nitrogen. Adverse environmental conditions during 1988 may account for the lack of response. This trial will be repeated and expanded for the next two years if a pending grant is funded.

BACKGROUND AND JUSTIFICATION: The excess supply of low quality urea fertilizer over the past few years has created an opportunity for liquid fertilizer dealers to fluidize urea for foliar applications. Nysul, 20-0-0-3, has been applied as foliar feeding for wheat and potatoes the past two years in the Red River Valley on an experimental basis by some growers. Foliar feeding of potatoes on the lighter textured beach ridge soils seems to be an economical and environmental alternative to conventional practices. The total nutritional need would not have to be applied prior to planting but could be applied as the crop requires nutrition.

EXPERIMENTAL PROCEDURE: This study was conducted on a potato production field at the Paul Hoff farm, Louisville Township Section 30, in West Polk County during 1988. The sandy loam soil had the following chemical properties prior to planting (0-6"): pH, 8.2; P_2O_5, 25 lbs/A; K_2O, 210 lbs/A; and NO_3^--N (0-24") 34 lbs/A. The previous crop was barley. Prior to planting, an in-row application of 400 lbs/A of 10-20-40 plus 10 gal/A 10-34-0 were applied with a six-row row marker machine.

A randomized complete block design with four replications was used in this trial. The nitrogen rates consisted of 0, 15, 30, 45 and 60 lb/A. All treatments were applied on July 11, with a CO_2 backpack sprayer at 30 PSI, 15 GPA with 8003 flat fan nozzles. The potato stage of growth was tuber initiation and petiole leaf analysis indicated a slight nitrogen deficiency with a level of 3.9 ppm Nitrogen. The plots were treated as part of the production field for weed, insect and disease control practices.

Yield measurements were taken on September 30, harvesting the two center rows of the four-row plot with a one-row Grimme potato plot harvester supplied by the Red River Valley Potato Research Farm, Grand Forks, ND. The resulting yields are listed in Table 1.

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

[1] Extension Agent/Agriculture, West Polk County, Crookston, MN; Area Agent/Potatoes, East Grand Forks, MN; Assistant Professor, Soil Science, Northwest Experiment Station, University of Minnesota, Crookston, MN.

Table 1. Effect of foliar nitrogen on tuber yield in 1988 at Crookston.

Treatment	Yield
Rate lbs/A	CWT
Control	201.6
15	199.5
30	191.7
45	194.7
60	199.0
Significance	NS

RESULTS AND DISCUSSION: There were no significant differences between any of the treatments with respect to total tuber yield. With the above normal temperatures and below normal precipitation yield potentials were reduced and the soil-applied fertilizer apparently supplied adequate nutrition for this particular growing season.

CONCLUSION: The results from this study are from only one year. Climatic conditions have a major influence on plant response and soil interactions.

To determine if foliar application and rate of nitrogen would be economically beneficial, more sites and environments need to be evaluated. Quality may also be a parameter which should be measured in future trials.

CHLORIDE FOR SPRING WHEAT

J. A. Lamb and C. E. Windels[1]

ABSTRACT: Information was collected to determine if chloride fertilizer is needed in northwest Minnesota. Two locations in 1988 did not have spring wheat grain yield responses to Cl fertilizer even with a soil test that indicates a possibility.

OBJECTIVE: In 1988 two sites were selected to gather information on the effect of chloride application on spring wheat in northwest Minnesota. The sites were located in Clay and Mahnomen Counties. Soil test information is listed in Table 1.

Table 1. Soil Test Information for Chloride Study - 1988

		Clay County	Mahnomen County
NO3-- N lb/A	0-2'	215	50
P lb/A	0-6"	48	7
K lb/A	0-6"	820	210
pH	0-6"	7.4	8.0
Chloride lb/A	0-2'	47	28

Best fertilizer and weed control practices were practiced with these plots. Two sources of chloride (KCl and $CaCl_2$) were applied and incorporated at five rates (0, 12, 24, 36, and 48 lb Cl^-/A) before planting Marshall wheat with a double disk press wheel drill. The row spacing was 6 inches with plot sizes of 8 by 30 foot. Whole plant samples were taken for chloride determination at softdough. Also at this time root rot ratings were determined. The plots were harvested with a small plot combine the last week of July and first week of August.

Clay County 1988: Table 2 lists the 1988 grain yield results corrected to 13.5 % moisture. Chloride caused a small, but significant decrease in grain yield at the Clay County site. There was no affect of source which indicates it was the chloride causing this effect. According to research in South Dakota, the soil test of 47 lb Cl^-/A 0-2' would indicate that a response was probable and 12 lbs/A of chloride should be applied.

Mahnomen County 1988: This location had a 28 lb Cl^-/A 0-2' soil test. Grain yield was not affected by chloride fertilization. The dry conditions plus low grain yields could be the cause of this nonresponse.

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

[1] Assistant professors of Soil Science and Plant Pathology, respectively, Northwest Experiment Station, University of Minnesota, Crookston, MN.

Table 2. Effect of Chloride Fertilization on Spring Wheat Grain Yields - 1988.

Source	Cl^- Rate	Grain Yield	
		Clay County	Mahnomen County
	lb/A	----------bu/A----------	
KCl	0	49.6	18.1
KCl	12	51.8	18.9
KCl	24	46.7	21.0
KCl	36	38.0	19.1
KCl	48	44.3	19.1
$CaCl_2$	0	45.2	17.9
$CaCl_2$	12	49.5	21.8
$CaCl_2$	24	46.0	17.9
$CaCl_2$	36	42.9	20.6
$CaCl_2$	48	46.3	19.5
	0	47.4	18.0
	12	50.7	20.3
	24	46.4	19.4
	36	40.5	19.8
	48	45.3	19.3
KCl		45.2	19.5
$CaCl_2$		46.2	19.9

RESIDUAL NITROGEN STUDY AT LAMBERTON[1]

D.J. Fuchs, J.A. Staricka and W.W. Nelson[2]

Abstract: Corn and soybean yields are usually greater in a rotation than in a monoculture system. This study was conducted to determine the nitrogen-rate response of corn and the ensuing year effect of residual nitrogen on soybean yields. The effect of 6 N-rates (0 - 400 lbs/ac) were examined in a corn-soybean rotation on a Normania loam, clay loam. In 1988, there was no N-rate response for corn nor soybeans, because of inadequate precipitation. In the past 3 years, N-rate response was noted for corn but not for soybeans.

(Annual report of this experiment has been included in last year's University of Minnesota, Soil Science Department 1988 "Blue Book", and much of the previous data will not be repeated here.)

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

Results: Yields are given in Tables 2 and 3.

A regression analysis technique was used to determine if there was a significant effect of nitrogen rate on corn and soybean yields. There was no significant ($p = 0.05$) nitrogen-rate response for corn nor soybeans. The drought had a major effect on crop growth and development. In the past, corn had a significant response to nitrogen each year. Also the N-rate at which maximum yield was reached decreased each year. The reason for this has not been determined. In soybeans, there has not been a response to nitrogen any of the 4 years.

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[1] Funding provided by the Agricultural Experiment Station.

[2] Junior Scientist, Graduate Student and Superintendent - University of Minnesota, Southwest Experiment Station, Lamberton, MN 56152, respectively.

Table 1. Corn and Soybean Management Information.

Item		Corn	Soybean
1987 Fall Primary Tillage:		Soil Saver	Soil Saver
Secondary Tillage	Type:	Disk Twice	Disk Twice
	Date:	3 May	11 May
Seed	Hybrid/Variety:	P 3732	Hardin
	Rate:	26,000 ppa	
	Date:	5 May	12 May
Herbicide	Brand:	Eradicane-Bladex	Treflan-Amiben
	Rate:	2.5 & 1.5 #/ac	3/4 & 2.5 #/ac
	Date:	3 May	11 May

Table 2. Corn Yields (Note: 2 samples per rep).

N-Rate	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Avg.
(lbs/ac)	----------	----------	Bu/Ac	----------	----------
0	56.7	46.7	58.8	60.5	55.8
	67.7	58.6	48.6	64.4	
50	56.5	47.9	52.1	56.1	54.1
	55.8	53.9	55.8	54.4	
100	58.9	63.8	52.2	51.4	56.8
	56.3	60.4	59.2	52.1	
150	50.7	53.9	54.8	58.0	55.2
	58.8	53.3	60.1	51.6	
200	48.9	56.8	66.9	54.7	58.3
	53.3	59.7	52.8	72.9	
400	59.8	65.9	51.9	56.6	56.9
	56.1	59.9	53.8	50.5	

P-value = 0.31

Table 3. Soybean Yields (Note: 2 samples per rep).

Residual N-Rate	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Avg.
(lbs/ac)	----------	----------	Bu/Ac	----------	----------
0	25.8	27.5	28.6	29.3	27.0
	24.2	25.1	25.8	29.5	
50	34.4	26.0	30.1	22.1	27.6
	32.3	25.3	25.8	24.1	
100	24.9	33.2	27.5	29.8	30.1
	30.7	33.6	27.5	33.5	
150	26.1	30.8	31.3	29.9	29.1
	27.4	29.1	30.7	27.4	
200	27.6	30.8	31.3	29.9	30.3
	27.3	30.2	34.9	30.5	
400	30.6	28.9	31.4	31.4	30.2
	28.8	28.5	30.9	30.5	

P-value = 0.093