A Report on Field Research in Soils

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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

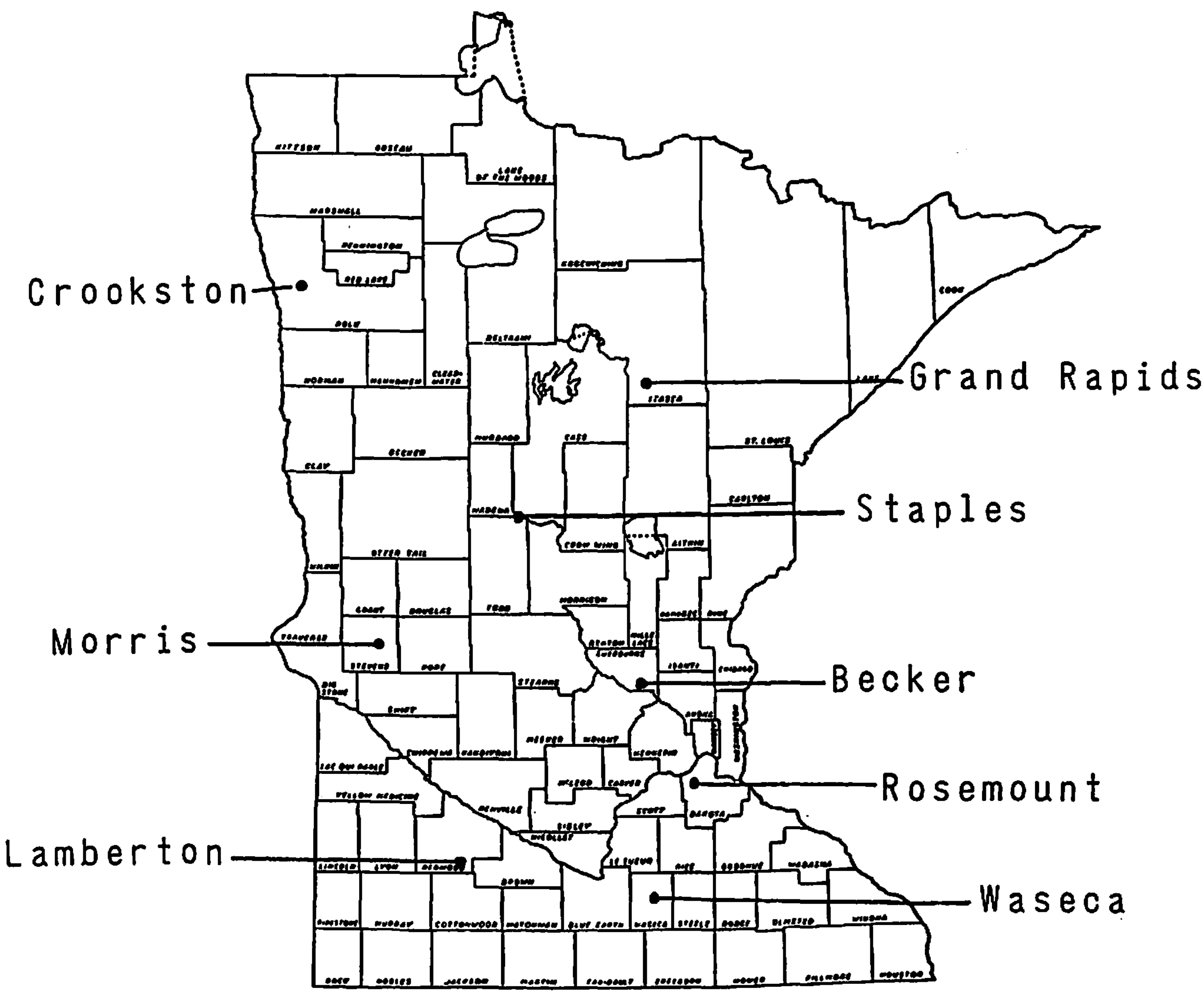

Table of Contents

Morris, continued

Staples

Waseca

Westport

Off Station Research

Corn

Soybeans

Potatoes

Fertilizer Placement

Tillage

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.

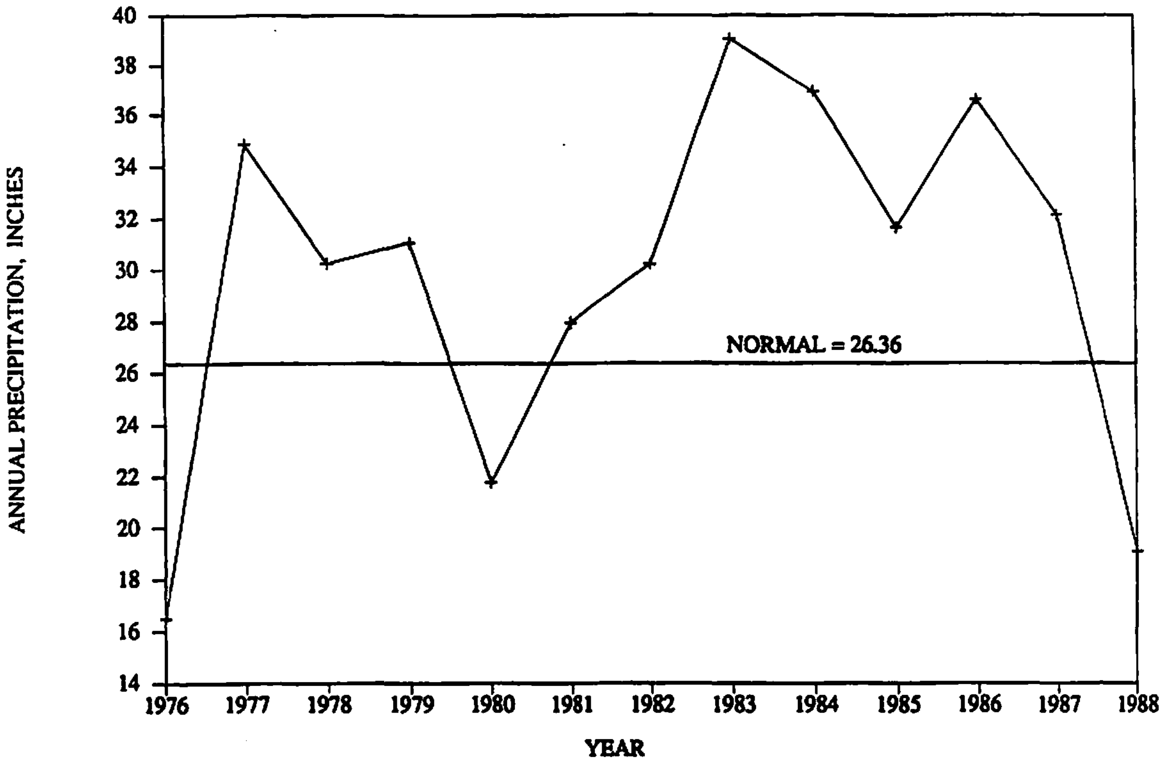

Fig. 1. Annual total precipitation at Minneapolis - St. Paul, 1976-1988.

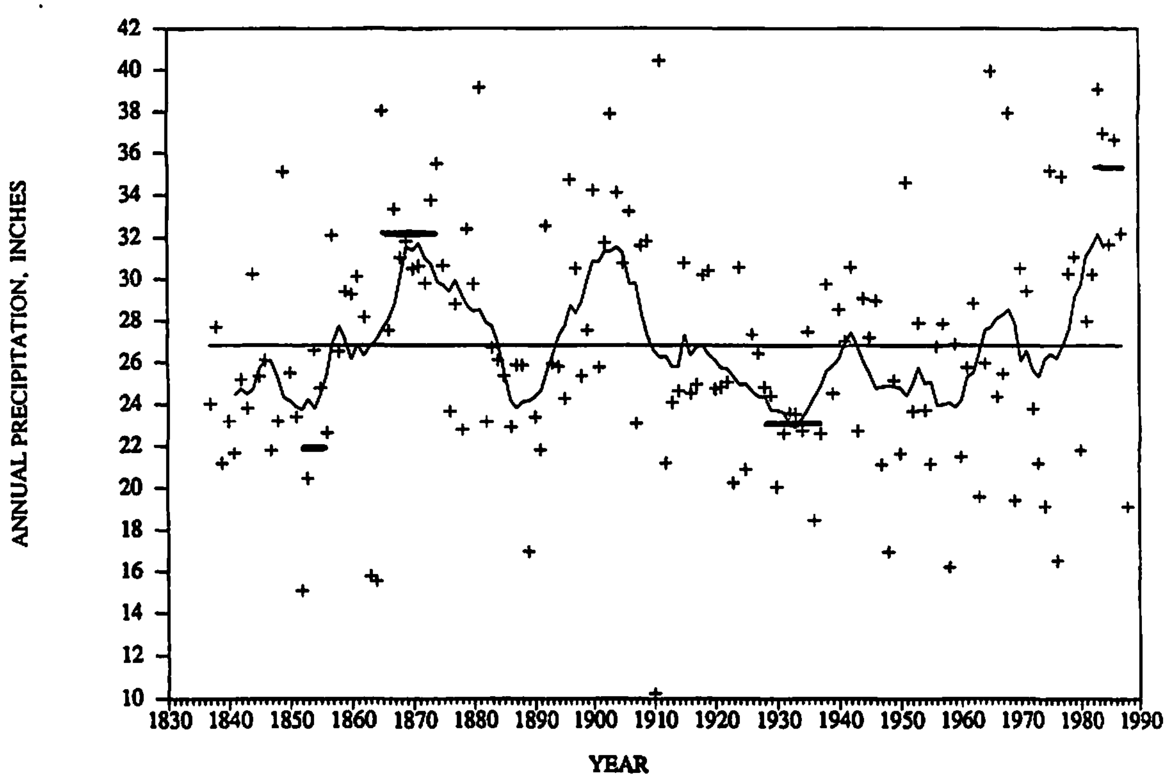

Fig. 2. The 1837-1988 annual total precipitation at Minneapolis - St. Paul. The crosses indicate the value for each individual year, the horizontal line shows the overall mean of 26.78 in., and the other line is the smoothed annual values so a trend (if any) can be seen. The horizontal bars show the 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).

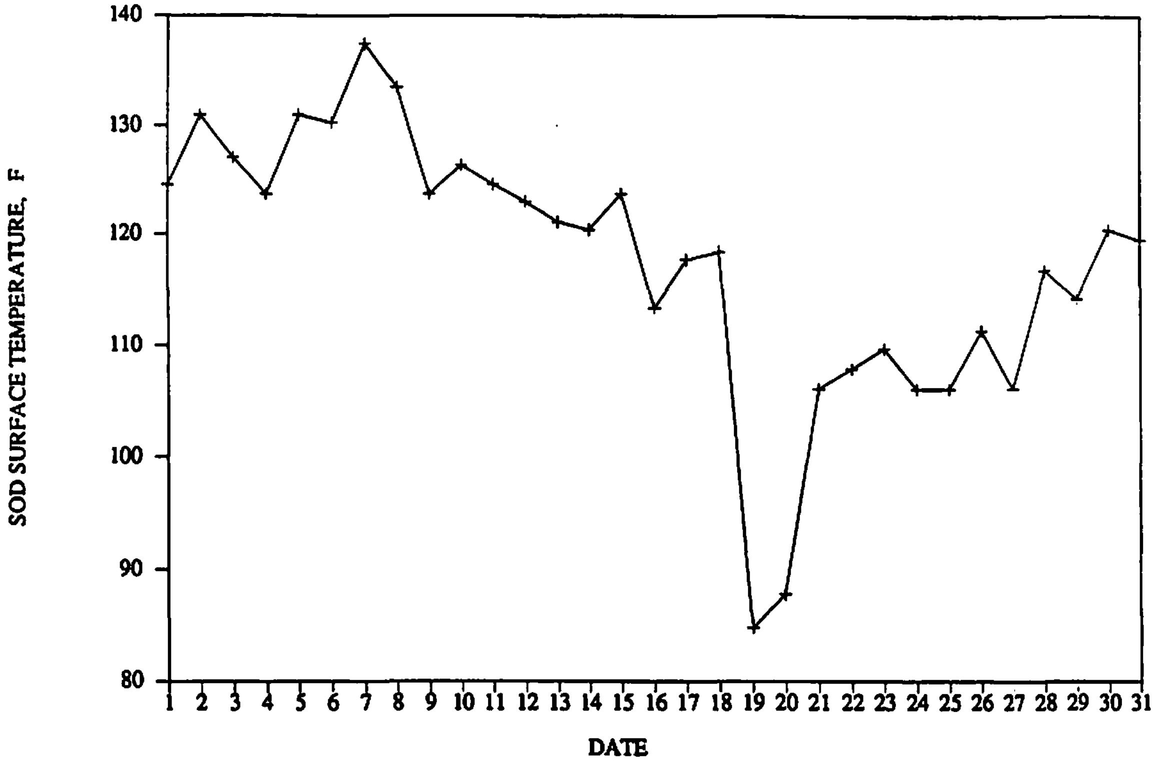

Fig. 3. Daily maximum sod surface temperatures measured at the U. of MN. climatological observatory, St. Paul, July, 1988.

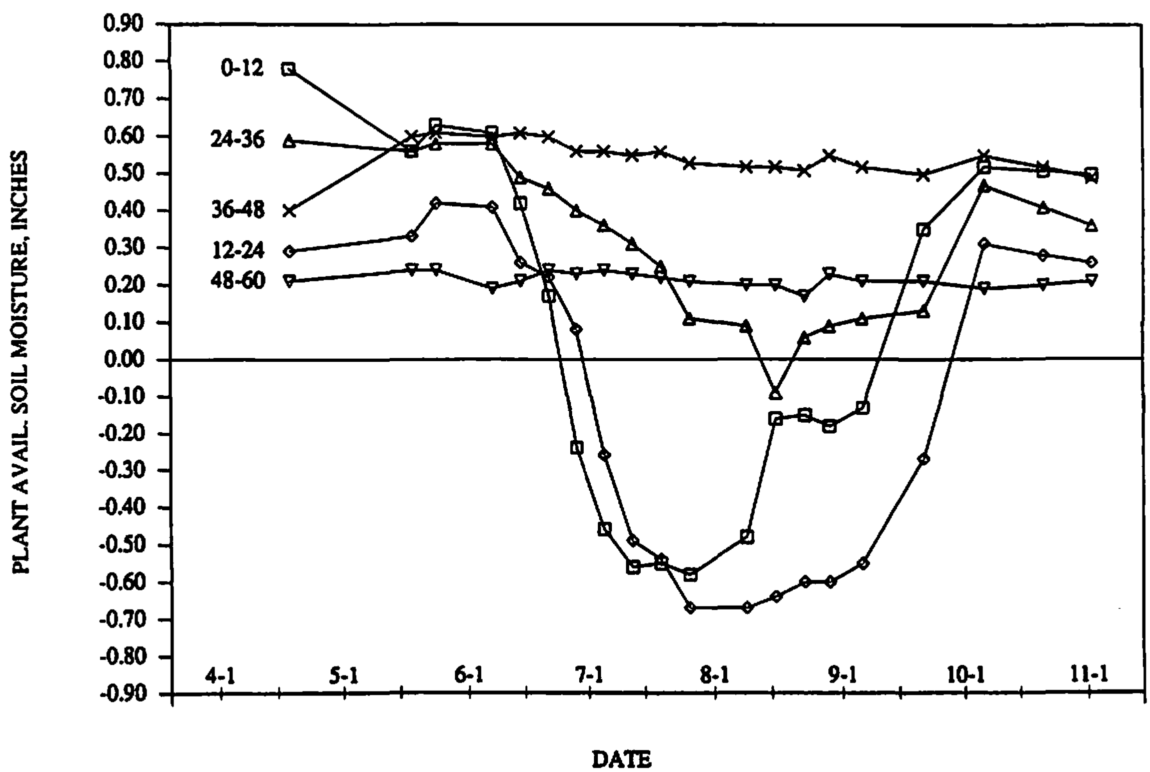

Fig. 4. Water content of each foot of soil (1-5 feet in depth) in a Tara silt loam soil planted to corn at the West Central Agricultural Experiment Station, Morris, MN, 1988.

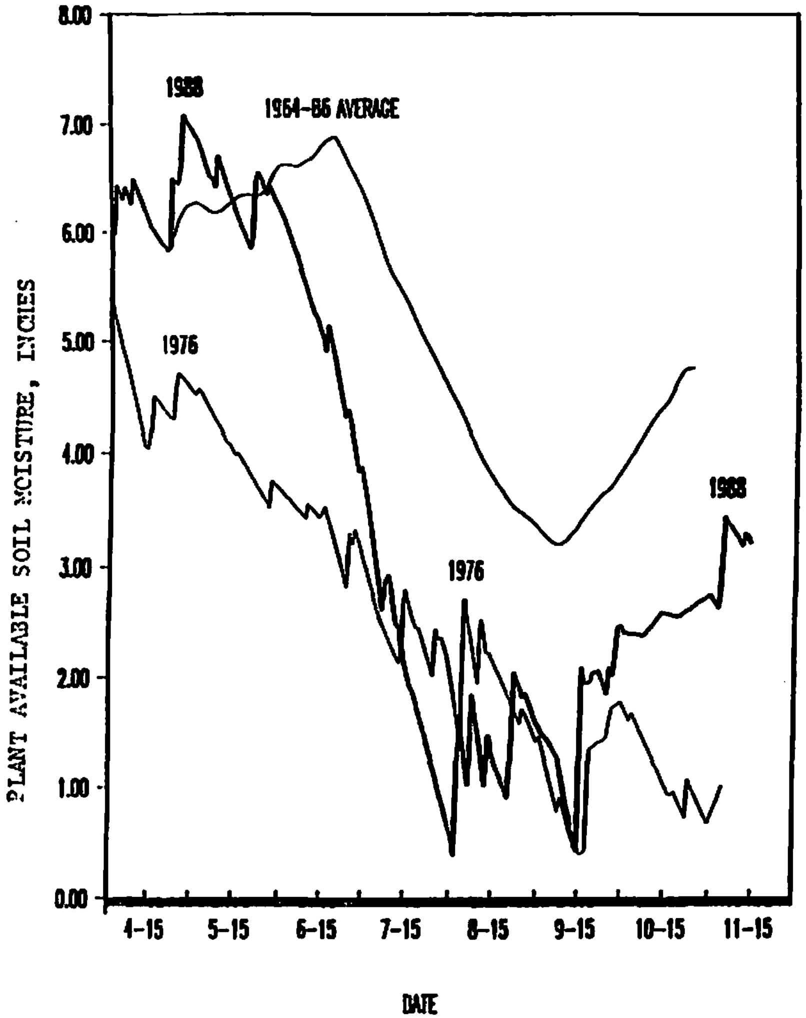

Fig. 5. Total plant available soil water in Webster silty clay loam planted to corn at the Southwest Agricultural Experiment Station. The 1964-1986 average values are shown along with the 1976 and 1988 growing season values.

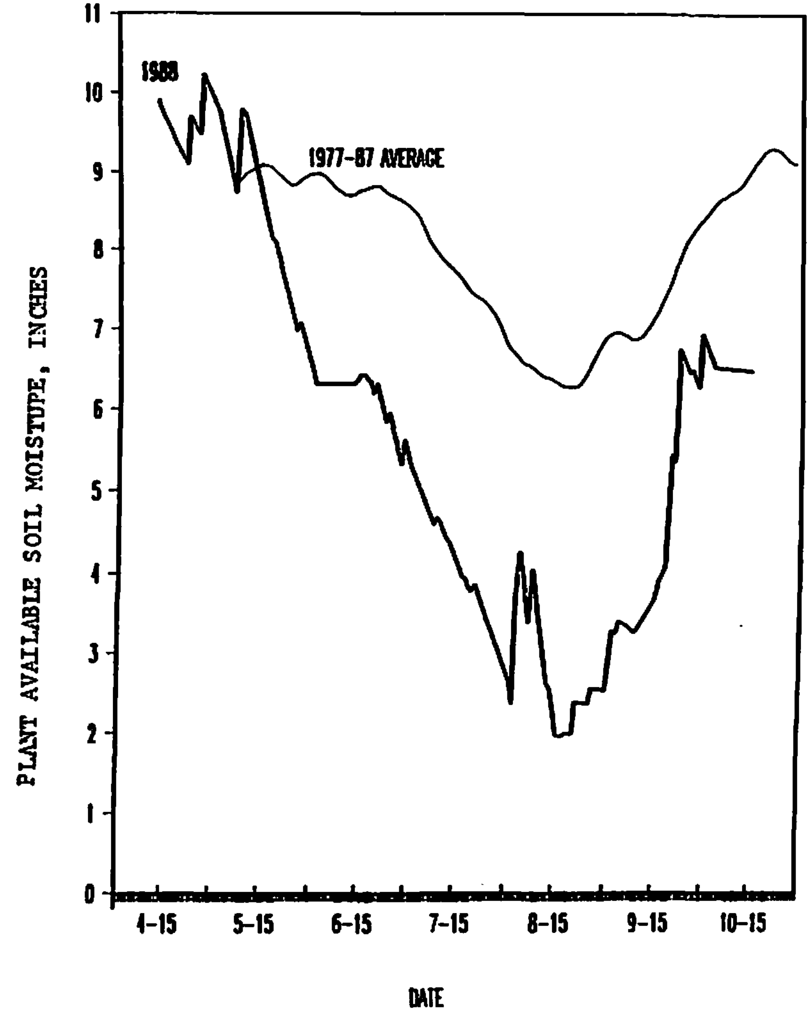

Fig. 6. Total plant available soil water in soil planted to corn at the Southern Agricultural Experiment Station. The 1977-1987 average values are shown along with the 1988 growing season values.

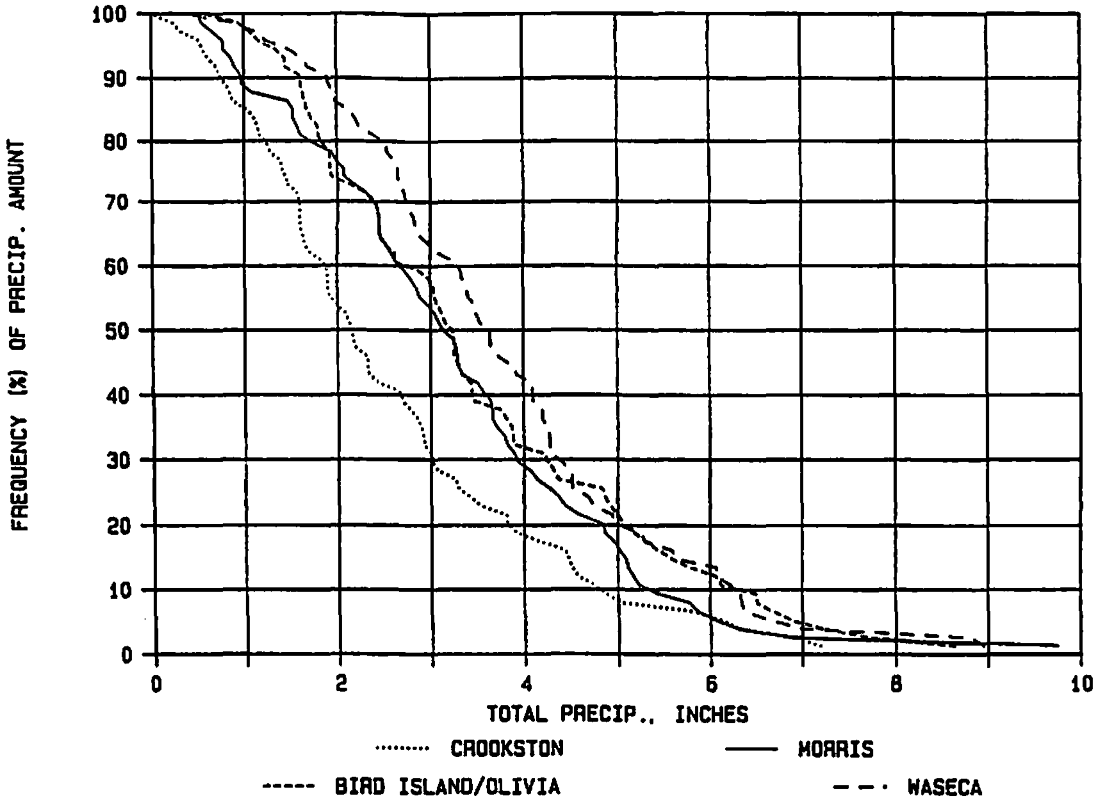

Fig. 7. Cumulative probability of precipitation occurrence between April 5 - May 15 at four Minnesota stations.

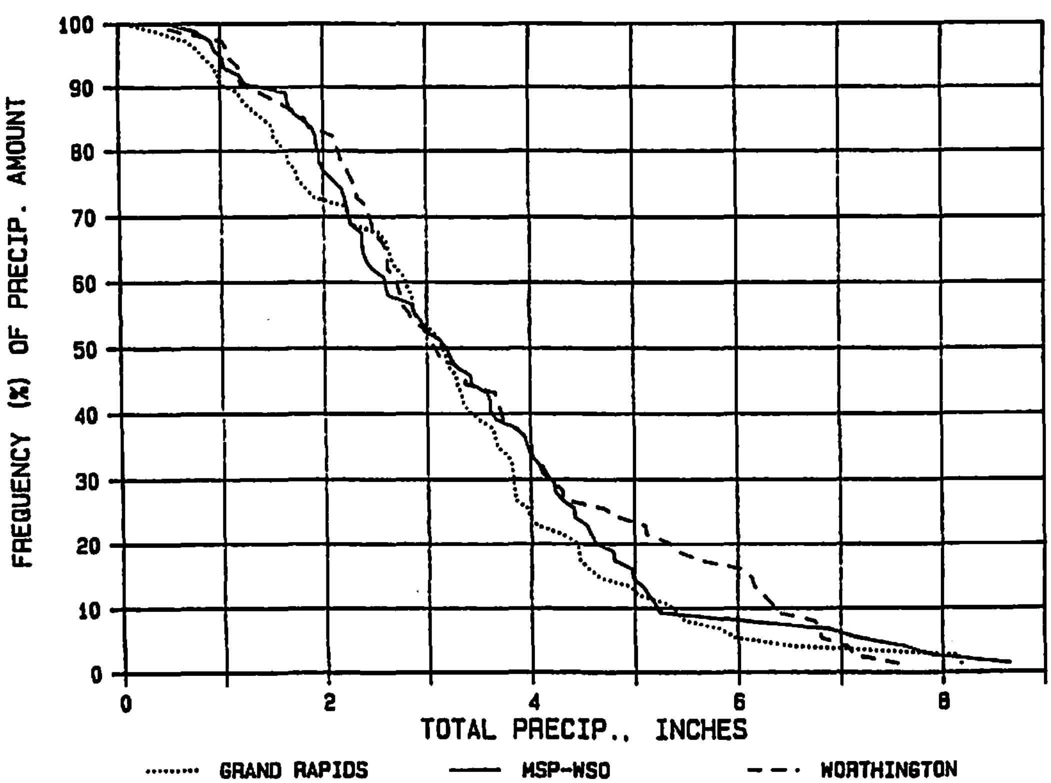

Fig. 8. Cumulative probability of precipitation occurrence between April 5 - May 15 at three Minnesota stations.

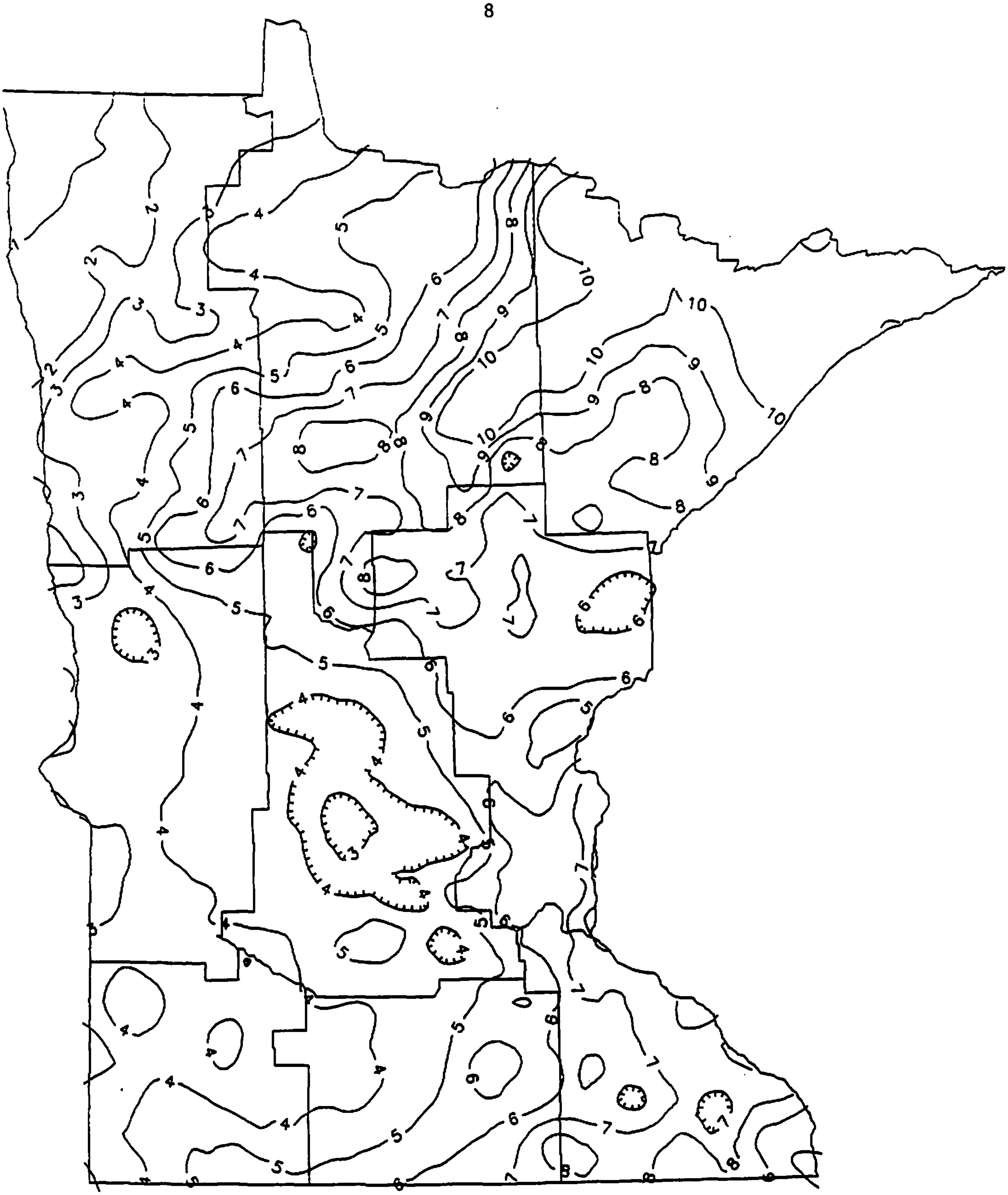

Fig. 9. Estimated plant available soil water (inches) in a soil column 5 feet deep under corn. The estimates are based upon a hypothetical soil of medium texture capable of holding 10 inches of plant available water.

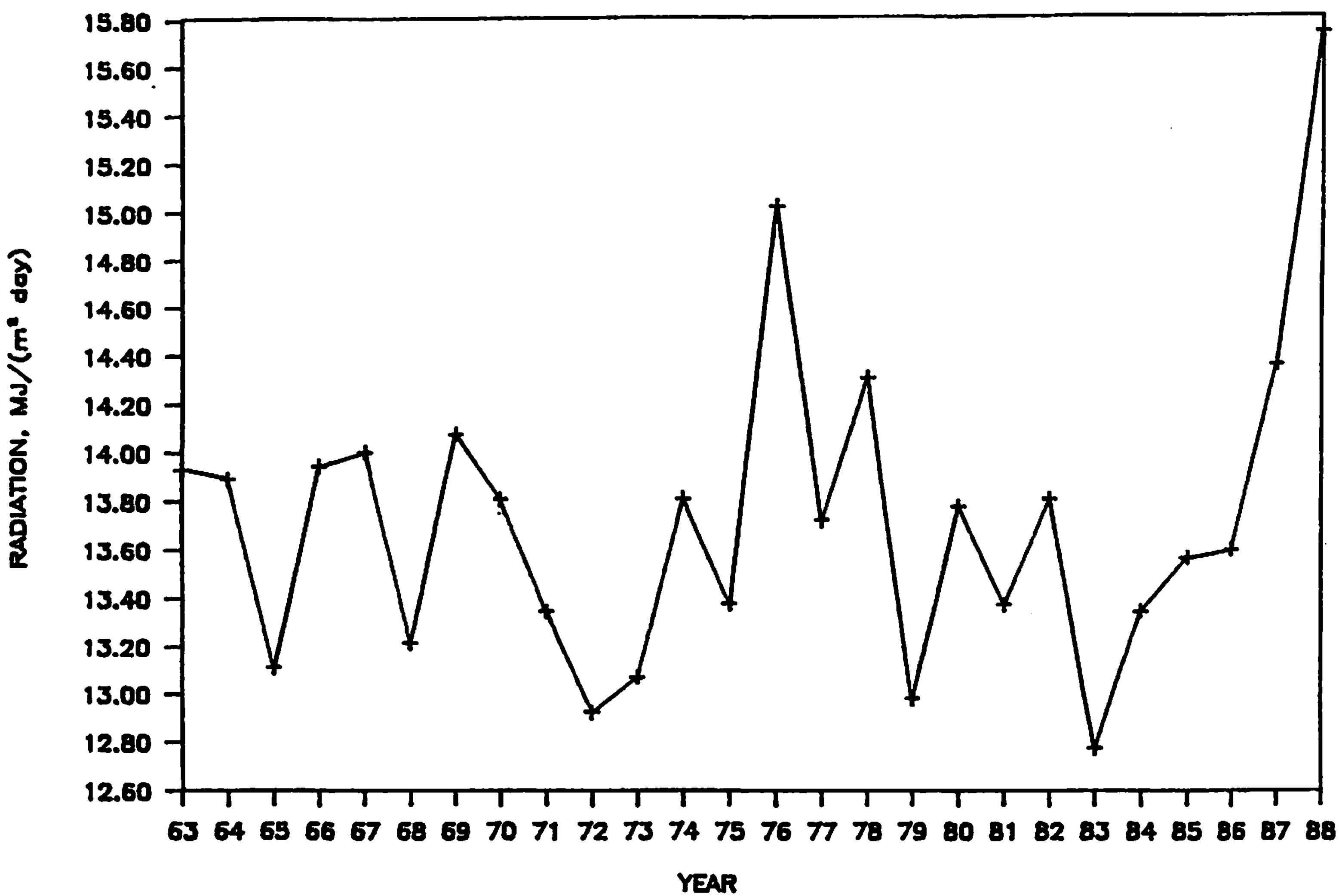

Fig. 10. Measured solar radiation incident on a horizontal surface at St. Paul, MN, 1963-1988.

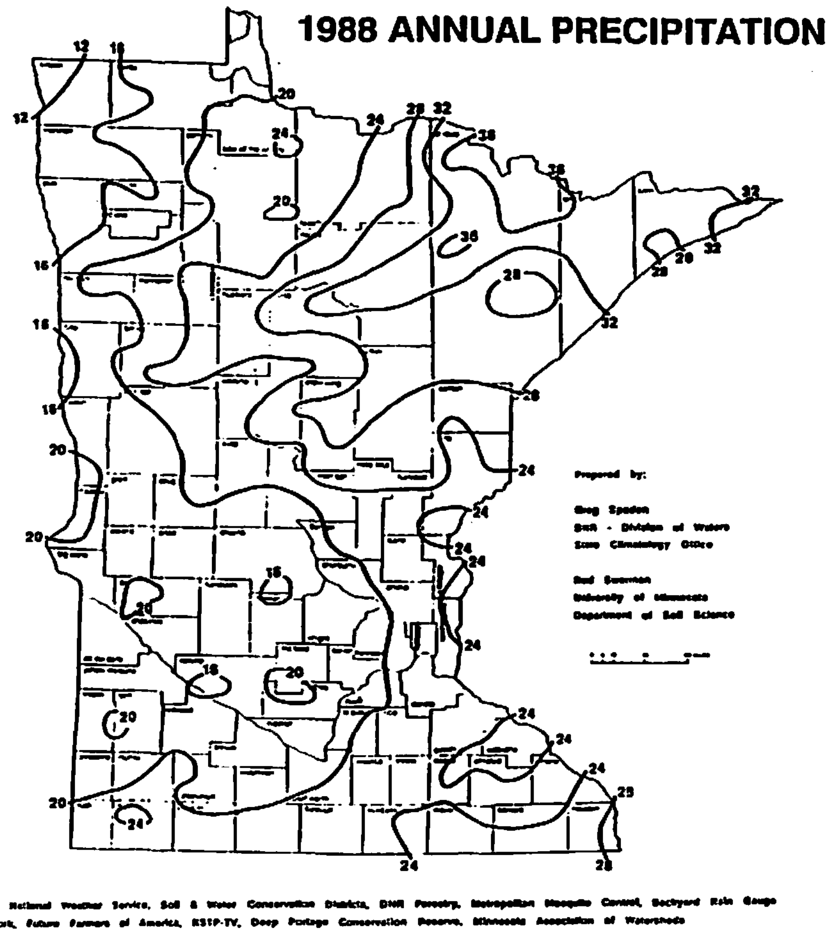

Fig. 11. Total annual precipitation in inches received in Minnesota, 1988.

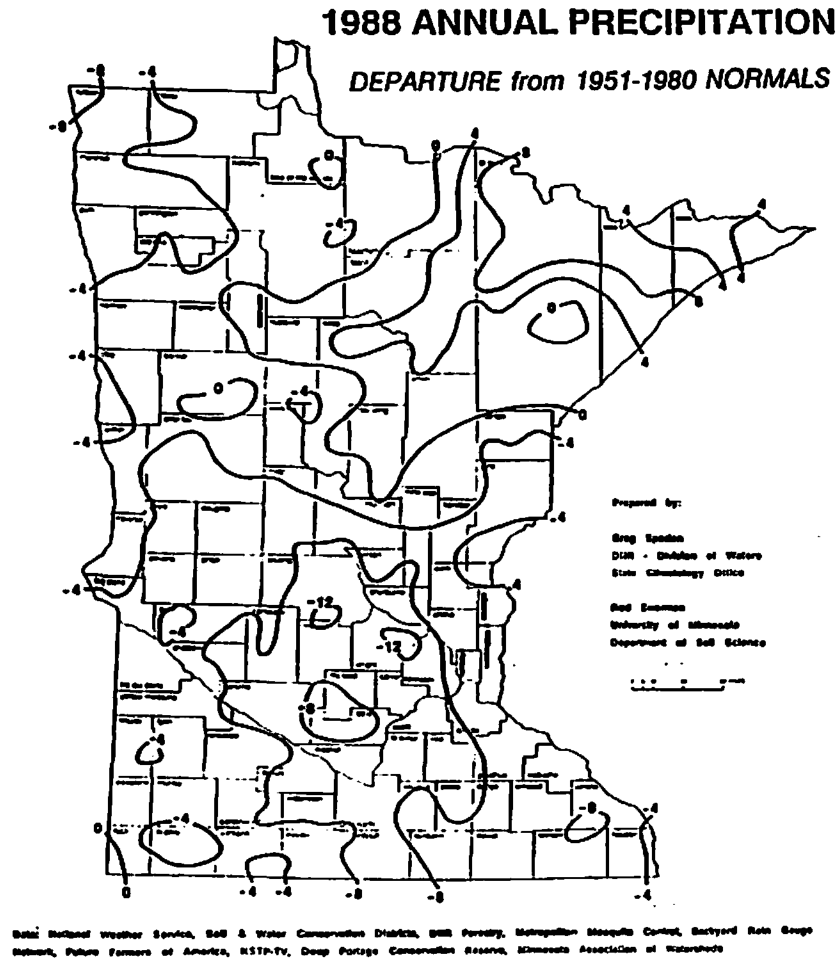

Fig. 12. Departure in inches of the 1988 total annual precipitation in Minnesota from the 1951-80 normals.

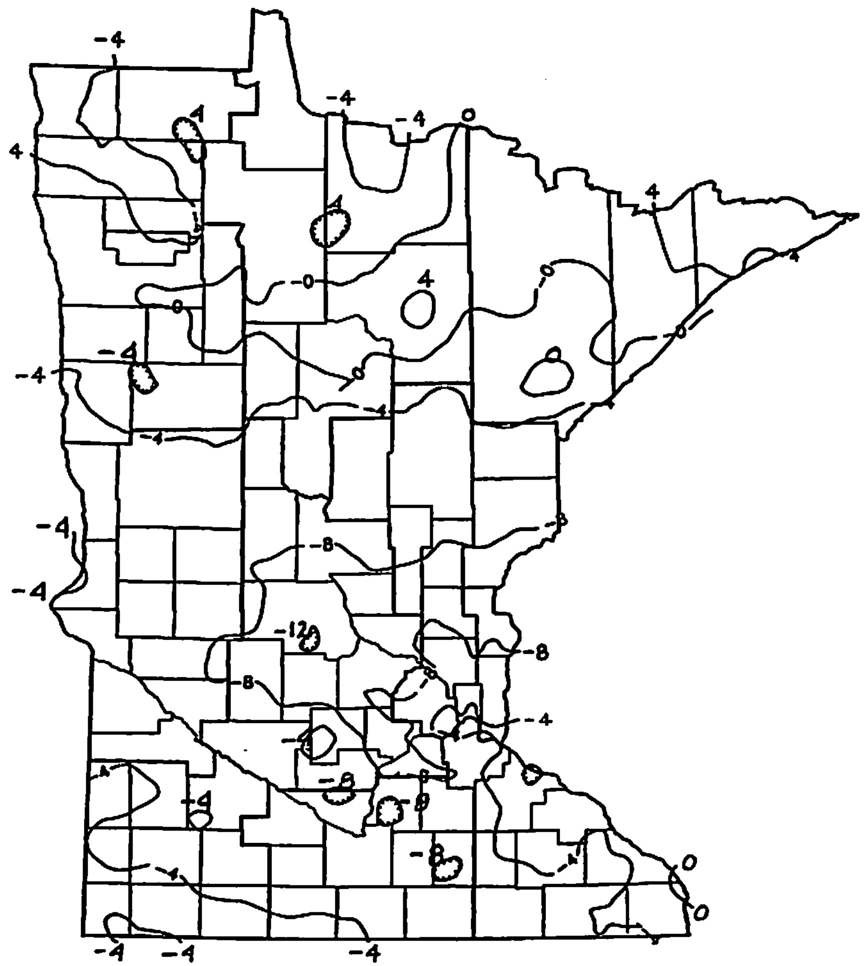

Fig. 13. Average departure in inches of the October 1986 - September 1988 hydrologic years precipitation from the 1951-1980 normal.

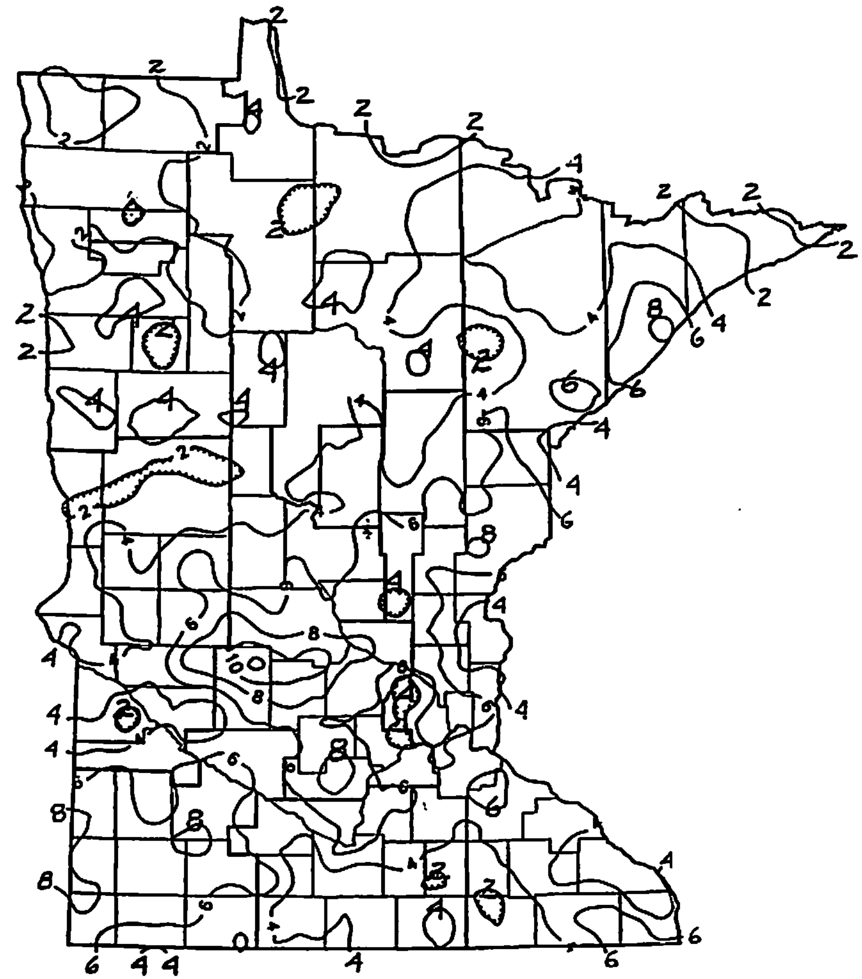

Fig. 14. Average departure in inches of the October 1982 - September 1986 (hydrologic years) precipitation from the 1951-1980 normal.

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

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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.

Cultivar	B rate lb B/A	N rate lb N/A	Harvest Date: August 3, Tuber Size <4 oz	4-7 oz	7-14 oz	>14 oz	Total yield (Cwt/A)	Harvest Date: September 6, Tuber Size <4 oz	4-7 oz	7-14 oz	>14 oz	Total yield (Cwt/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 lb B/A	N rate lb N/A	F.W. Yield T/A	N (lb/A)	P (lb/A)	K (lb/A)	Ca (lb/A)	Mg (lb/A)	Fe (oz/A)	Mn (oz/A)	Zn (oz/A)	Cu (oz/A)	B (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 lb B/A	N rate lb N/A	F.W. Yield T/A	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
				Nutrient									
				------------ 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 lb B/A	N rate 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					
B rate lb B/A	N rate lb N/A	4-7 oz	7-14 oz	> 14 oz	4-7 oz	7-14 oz	> 14 oz
		% 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
			------	%	------			------	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	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	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			Nutrient									
			%					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
			%					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					
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 lb N/A	Leaf	Petiole	Leaf	Petiole	Petiole	Leaf	Petiole	Leaf	Petiole	Petiole	Leaf	Petiole	Leaf	Petiole	Petiole
		---- % -----		--- 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.

		Sampling Date														
		July 25 (98 DAP)					August 8 (112 DAP)					August 22 (126 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 lb N/A	Leaf	Petiole	Leaf	Petiole	Petiole	Leaf	Petiole	Leaf	Petiole	Petiole	Leaf	Petiole	Leaf	Petiole	Petiole
		---- % -----		--- ug/g ---		- ug/ml -	---- % -----		--- ug/g ---		- ug/ml -	----- % ----		--- ug/g ---		- 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	

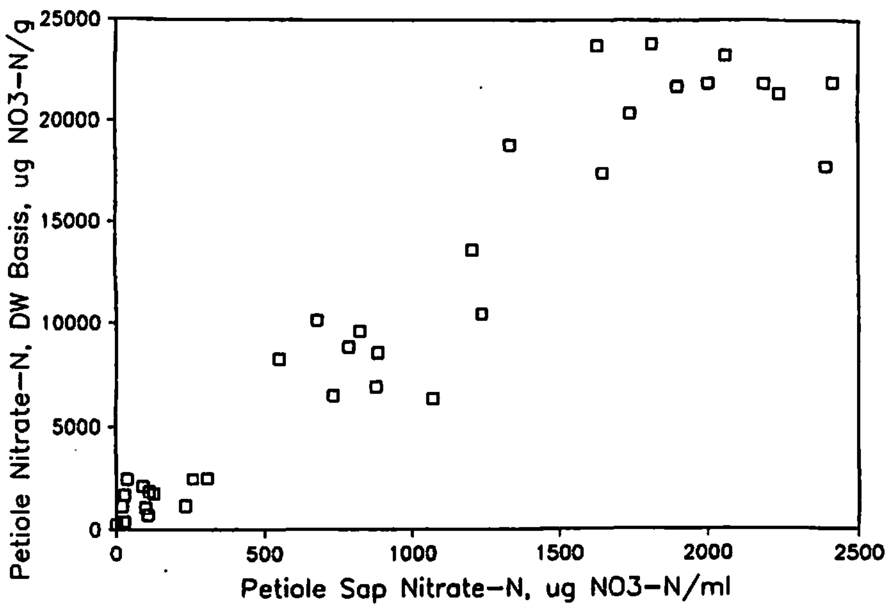

Figure 1. Correlation between the petiole sap nitrate quick test and the conventional petiole nitrate laboratory test. $r^2 = 0.95$, $y = 10.056x + 662.8$.

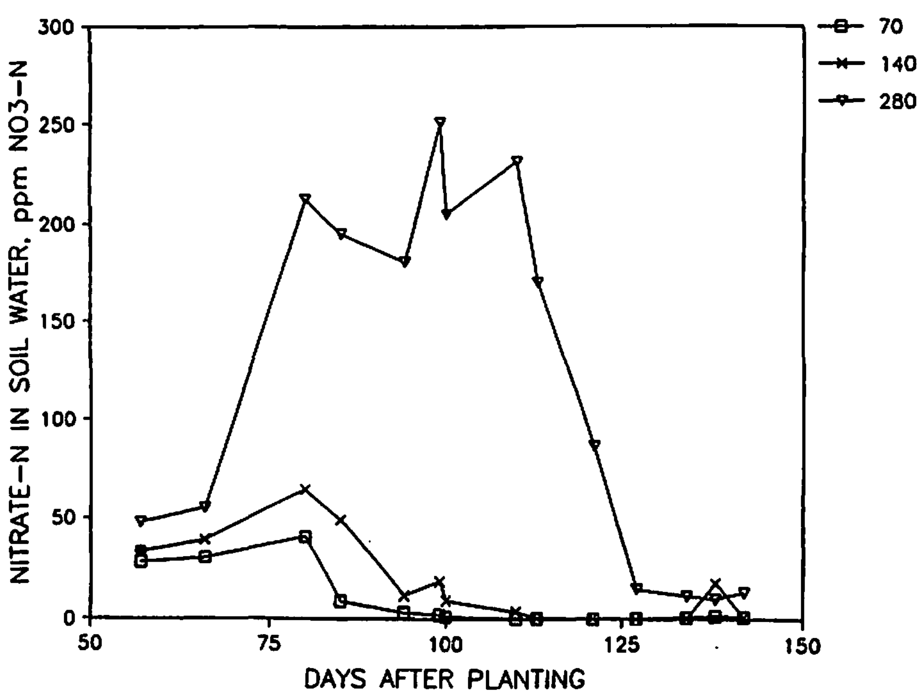

Figure 2. Seasonal nitrate-N levels in soil water at a depth of 2 feet below the row as affected by N fertilizer rate.

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.

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

	Precipitation		Mean Temperatures	
Month	1988	1890-1979	1988	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.

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[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.

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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.

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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.

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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.

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[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 Rate lbs/A	Yield 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.

[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

TWENTY-NINE YEARS OF FIELD EXPERIMENTATION WITH NITROGEN SOURCE, PLACEMENT, AND TIME OF APPLICATION TO A WEBSTER LOAM AT THE SOUTHWEST EXPERIMENT STATION LAMBERTON, MN[1]

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

Abstract: Corn yields may be affected by different nitrogen management systems. This study was conducted to determine if differences exist between nitrogen forms (urea or ammonium nitrate), amounts ranging from 0 to 160 pounds N/Ac, and their time of application (fall or spring) and placement (surface, moldboard plow incorporation or sidedress) on corn yields. The effects were examined on continuous corn with 30-inch rows in a Webster clay loam. In 1988, there was little difference between the various treatments because of the drought. When precipitation is not limiting, corn yields respond the greatest to N rate with a slight advantage to spring application with little difference between N forms.

(Annual reports of this experiment have been included in most of the University of Minnesota Soil Science Department "Blue Books" and much of this information will not be included here).

The fertilizer treatments have now been applied annually to the same plot area for 29 years. Each plot is 20' by 77.5' with the four replications arranged in a randomized block. After ear corn removal and stalk cutting, the fall treatments are broadcast on their respective plots and the entire area is then moldboard plowed to approximately 12 inches deep. The fall surface treatments are then broadcast with no further working of the plow area. Spring treatments are broadcast before seedbed preparations in late April or early May. The corn is planted in 30-inch rows at a plant population of 26,000 plants/A, using a band starter fertilizer of 8-24-12 at a rate of 180#/A over the entire experimental area, thus supplying an additional 14 #N/A to all plots. Sidedress treatments are broadcast in June and incorporated during cultivation.

<u>1988 results:</u> The 1988 yields from this experiment are given in Table 1. The one-way analysis of variance (Table 2) indicates a no significant treatment effect. The Tukey HSD for yield (p = 0.05) is 29.5 bu/ac. Last year the LSD (p = 0.05) was 12.7 bu/ac. The drought dramatically increased the variability of the treatments.

Also included in Table 1 are the 28-yr averages. (In 1976, no yields were obtained due to drought, thus only 28 years of data exist). Figure 1 provides a 3 dimensional perspective of the 28-yr average yields versus time of application and N-rate. (Note: Missing 3-D bars are because of incomplete experiment design, not because of obscurity). The results of 1988 do not follow previous 28 year average trends, where greatest yield response is to increasing N-rates, because of the drought. There is a moderate response to delayed application time, with the exception of the fall surface treatments. Normally, there is little difference in yield between ammonium nitrate and urea treatments.

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[1] Funding provided by Agricultural Experiment Station

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

Table 1. Influence of nitrogen form, rate, and time of application on grain yield on a Webster loam, Southwest Experiment Station, Lamberton, MN 1988.

------ Nitrogen Treatment ------			------------------ 1988 ------------------					
Rate	Form	Time	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Avg.	28 yr. Avg.
#N/Ac			------------- Bu/Ac @ 15.5 % moisture -------------					
--	Check	----	51.2	40.0	30.8	48.0	42.5	65.0
40	Ammonium Nitrate	Fall	71.0	54.3	72.2	58.6	64.0	83.0
40	Urea	Fall	51.3	56.5	53.0	59.9	55.2	87.0
40	Ammonium Nitrate	Fall Surface	64.4	47.4	77.8	70.2	65.0	81.0
40	Urea	Fall Surface	50.1	46.5	54.4	67.1	54.5	86.0
80	Ammonium Nitrate	Fall	48.6	65.3	63.6	35.1	53.2	103.0
80	Urea	Fall	54.2	65.4	61.2	70.5	62.8	103.0
160	Ammonium Nitrate	Fall	48.9	61.5	90.1	45.1	61.4	110.0
160	Urea	Fall	53.4	49.4	68.9	49.9	55.4	112.0
40	Ammonium Nitrate	Spring	49.6	52.8	59.1	53.4	53.7	94.0
40	Urea	Spring	46.1	51.4	54.8	65.1	54.4	93.0
80	Ammonium Nitrate	Spring	80.6	63.9	61.2	74.3	70.0	107.0
80	Urea	Spring	65.2	73.7	54.3	81.2	68.6	108.0
40	Ammonium Nitrate	Side Dress	63.2	36.4	77.6	48.8	56.5	97.0
40	Urea	Side Dress	50.2	39.5	66.6	68.7	56.3	97.0
80	Ammonium Nitrate	Side Dress	58.4	54.2	86.1	76.0	68.7	103.0
80	Urea	Side Dress	72.3	73.2	59.2	56.7	65.4	111.0
160	Ammonium Nitrate	Side Dress	70.7	62.4	76.3	60.9	67.6	115.0
	Average						59.7	98.0
	Tukey (p = 0.05)						29.5	

Table 2. One-way analysis of variance.

Source	DF	Sum of Squares	Mean Square	F-Value	P value
Block	3	886.7	295.6	2.47	0.07241
Treatment	17	3639.0	214.0	1.79	0.05641
Error	54	4322	80.0		
Total	71	21311			

Yields From Continuous Corn Study
28-yr Averages

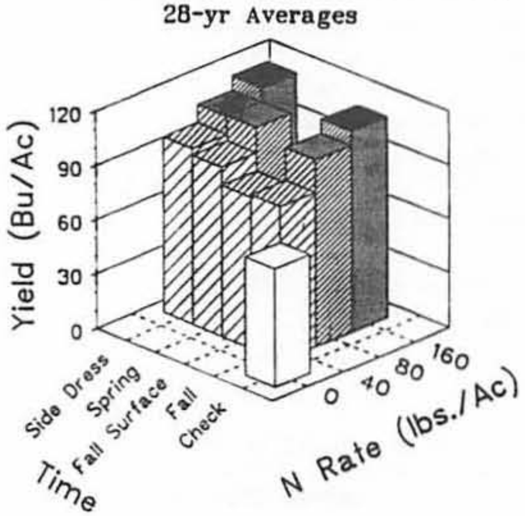

Figure 1

THE EROSION-PRODUCTIVITY STUDY AT THE SOUTHWEST EXPERIMENT STATION, LAMBERTON, MN[1]

J.A. Staricka, D.J. Fuchs, M. Lindstrom, W.W. Nelson, and J.B. Swan[2]

Abstract: Field data is needed to evaluate crop growth simulation models. The objective of this is to determine the interactive effect of tillage and soil erosion level on corn yields. Continuous corn is grown under conventional (fall moldboard plow) or ridge tillage on sites which have been slightly, moderately, or severely eroded. In 1987, neither tillage nor erosion had a significant effect on yield.In 1988, ridge tillage yields were significantly greater at p = 0.01 than conventional tillage on all various erosion classes for the first time in four years. Corn yields decrease with increasing erosion for both tillages.

Introduction: This experiment is part of RRF project NC-174, Soil Productivity and Erosion. The objectives of this study are "To asses the effect of erosion-modified soil physical properties on potential productivity of selected soils under rainfed conditions, with emphasis on evaluation of physically-based simulation models." The experiment was started in 1984. Detailed results from 1985 and 1986 were presented in the "1987 Bluebook".

Methods and Materials: Plots for this study were located in areas of a field which had been slightly (SLT), moderately (MOD), and severely (SEV) eroded. The soil type for the slight and moderately eroded areas is a Ves (fine-silty, mixed mesic Typic Hapludalf). The soil type on the severely eroded area is a Storden (fine-loamy, mixed (calcareous), mesic Typic Udorthent). Two tillage systems were used on the field: CONVentional (fall moldboard plow) and RIDGE-tillage.

The field has been in continuous corn since the experiment started. Fertilizer was applied based on the soil test of each erosion treatment. The amounts of fertilizer applied are listed in Table 1. Additional management information is given in Table 2.

Stand counts were recorded in June of both years (1987 and 1988) and are listed in Table 3. Leaf numbers for 1987, but not for 1988, and are provided in Table 4. Tasseling and silking information is provided in Table 5.

Grain yields are given in Table 6. Analysis of variance, using a spilt plot design (erosion class = whole plots, tillage = split plots) for each year is furnished in Tables 7 and 8.

Summary of results: Precipitation was the major yield limiting factor in 1988. The lack of adequate moisture resulted in significant differences in corn yields among the various erosion classes. The slightly eroded areas had greater yields than the severely eroded areas, probably because of the poor soil water holding capability and runoff potential of these soils. In 1987 there were no significant differences among the various slopes, probably because moisture was not a limiting factor. Which may also explain why there was no significant difference in tillages in 1987 also. In 1988, ridge tillage had significantly higher yields than the conventional tillage for the first time in four years.

Acknowledgements: The Southwest Experiment Station would like to thank the John Deere Company for providing the JD 7000 Conservation ridge tillage.

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[1] Funding provided by the USDA - CSRS and the Agricultural Experiment Station.

[2] Graduate Student, Junior Scientist - U of MN, Southwest Experiment Station; Soil Scientist - USDA-ARS, Morris, MN 56267; Superintendent - U of MN, Southwest Experiment Station; Professor - U of MN, Soil Science Dept., St. Paul, MN 55108, respectively.

Table 1. Applied Fertilizer.

Time	Plots[1]	N	P_2O_5	K_2O	Comments
		---- # / Ac ----			
Fall 1986	All	39	100	100	
Spring 1987	All	220	--	--	4/20/87
Spring 1987	SEV	7	20	7	(starter)
Fall 1987	SEV		75		
Spring 1988	All	150	--	--	4/29/88
Spring 1988	All	7	20	7	(starter)

1/ Erosion levels: SLT = Slight, MOD = Moderate, SEV = Severe

Table 2. Management Information.

Item	Type	Rate	Date
1987			
Secondary Tillage[1]	Disk	Twice	Spring
Insecticide	Counter	1.0 #/Ac	4/21/88
Seed	Pioneer 3732	26,000 p/Ac	" "
Herbicides	Lasso	3.0 #/Ac	4/22/87
	Bladex	2.0 #/Ac	" "
1988			
Secondary Tillage[1]	Disk/Digger		4/22/89
Insecticide	Furadan	1.0 #/Ac	4/29/88
Seed	Pioneer 3732	26,000 p/Ac	" "
Herbicides	Eradicane	2.5 #/Ac	4/22/88
	Bladex	1.5 #/Ac	" "

1/ Secondary tillage performed on conventional (moldboard plow) plots only.

Table 3. Stand Counts.[1]

Treatment[2]	1987 CONV	1987 RIDGE	1987 Avg.	1988 CONV	1988 RIDGE	1988 Avg.
	plants (thousands) / Ac					
SLT	22.9	19.0	20.9	22.9	20.8	21.9
MOD	19.2	16.1	17.6	21.6	18.9	20.3
SEV	22.0	17.9	19.9	21.9	21.8	21.9
Avg	21.4	17.7	19.5	22.1	20.5	21.4

1/ Measurements taken on 6/1/87 and 6/30/88.

2/ Erosion levels: SLT = Slight, MOD = Moderate, SEV = Severe
Tillage systems: CONV = Conventional (moldboard plow),
RIDGE = ridge tillage.

Table 4. 1987 Leaf Numbers.[1]

Treatment[2]	CONV	RIDGE	Avg.
	----- Leaf Number -----		
SLT	5.17	5.35	5.26
MOD	3.06	5.27	4.17
SEV	5.25	5.59	5.42
Avg	4.49	5.40	4.95

1/ Measurements taken on 6/1/87, no measurements for 1988.
2/ Erosion levels: SLT = Slight, MOD = Moderate, SEV = Severe
Tillage systems: CONV = Conventional (moldboard plow), RIDGE = ridge tillage.

Table 5. Phenology

	50% Tassel		50% Silk	
Erosion Class	CONV	RIDGE	CONV	RIDGE
	----------July, 1987----------			
SLT	7	4	10	6
MOD	15	7[1]	16	10[1]
SEV	9	7	10	10
	----------July, 1988----------			
SLT	8	8	12	13
MOD	7	8	12	15
SEV	7	7	12	13

1/ Dry soil conditions at planting resulted in differential emergence. Reps 1 and 2 of this treatment had a larger proportion of delayed plants.

Table 6. Grain Yield.

Treatment[1]		Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Avg.
		-------------- Bu / Ac @ 15.5% moisture ------------						
		------ 1987 ------						
SLT	CONV	134.1	146.3	137.1	148.6	---	---	141.5
SLT	RIDGE	136.6	139.2	133.2	120.1	---	---	132.3
MOD	CONV	135.3	136.9	128.0	151.6	---	---	138.0
MOD	RIDGE	129.2	109.7	129.6	119.9	---	---	122.1
SEV	CONV	121.2	121.3	159.4	119.2	---	---	130.3
SEV	RIDGE	144.1	133.8	130.9	122.4	---	---	132.8
		------ 1988 ------						
SLT	CONV	61.9	47.0	55.1	38.4	50.7	46.5	49.9
SLT	RIDGE	50.1	71.2	64.1	51.9	52.8	50.2	56.7
MOD	CONV	59.4	39.5	48.9	31.3	33.8	48.7	43.6
MOD	RIDGE	52.7	57.3	50.1	48.0	43.4	61.4	52.2
SEV	CONV	38.5	48.0	22.1	18.1	44.7	58.7	38.4
SEV	RIDGE	55.9	51.9	36.1	37.3	50.9	52.4	47.4

1/ Erosion levels: SLT = Slight, MOD = Moderate, SEV = Severe
Tillage systems: CONV = Conventional (moldboard plow), RIDGE = ridge tillage.

Table 7. Analysis of variance for 1987 yields.

Source	DF	SS	MS	F	P-value
Rep	3	131.5	43.82	0.34	0.7953
Erosion	2	208.8	104.4	0.84	0.4848
ERROR1	6	765.3	127.5	--	--
Tillage	1	339.8	339.8	2.19	0.1735
Erosion*Tillage	2	346.6	173.3	1.11	0.3695
ERROR2	9	1400	155.5	--	--

Table 8. Analysis of variance for 1988 yields.

Source	DF	SS	MS	F	P-value
Rep	5	1131.0	226.3	2.03	0.1592
Erosion	2	654.6	327.3	2.94	0.09915
ERROR1	10	1114.0	111.4	--	--
Tillage	1	595.4	595.4	10.80	0.005003
Erosion*Tillage	2	8.6	4.3	0.08	0.9253
ERROR2	9	1400	155.5	--	--

MANAGEMENT OF SLOPES USING VARIOUS TILLAGES, TILLAGE AND ROW DIRECTION AT THE SOUTHWEST EXPERIMENT STATION[1]

J.A. Staricka, D.J. Fuchs, M. Lindstrom, W.W. Nelson, and J.B. Swan[2]

Abstract: Field research is needed to evaluate soil movement under different crop production practices and its consequent effect on crop growth. This study was conducted to examine soil movement and crop yields on three different slope percentages (1%, 4%, and 8%), with various tillages (ridge tillage, moldboard plow, and chisel), and tillage and planting directions (up and down the slope, or contour to the slope) in a corn - soybean rotation. In 1988, tillage was the only significant treatment on corn yields ($p = 0.05$). In all years, slope position and/or planting direction had significant effect on yields ($p = 0.05$).

Materials: This study began in the fall of 1985 to examine soil movement on three different slope percentages (1%, 4%, and 8%), using various tillages (ridge tillage, moldboard plow, and chisel), and tillage and planting directions (up and down the slope, or contour to the slope) in a corn and soybean rotation. Yields are measured every year and soil movement is being monitored.

Fertilizer information is provided in Table 1.

Additional management information is provided in Table 2.

Results: Analysis of variance of the yields for the three years on the various slopes are provided in Tables 3-5 (1986), 9-11 (1987) and 15-17 (1988). Yield averages and standard deviations of all treatment combinations are presented after the analysis of variance tables for each respective year.

In 1988, ridge tillage treatment had significantly higher corn yields than moldboard and chisel plow on all three slope percentages (Table 15-17). Even though, early in the growing season (June and July), the ridge tillage treatments showed on the 8 percent slopes severe K deficiency and were visually underdeveloped in comparison to the other tillages. The above normal precipitation in August may have helped it through the critical growth stage more than the other tillage treatments because of its delayed growth.

In 1988, position on the 8 percent slope was also a significant factor ($p = 0.001$) with highest yields occurring on the top portion of the slope.

In 1987, the 8 percent slope position (top, middle and bottom) and its interaction with row direction were the significant treatments ($p = 0.005$). The greatest yields occurred on the top portion of the slope (summit and shoulder).

In 1986, row direction and slope position on the 8 percent slope were the only significant treatments ($p = 0.05$) with highest yields on the middle part of the slope (backslope).

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Table 1. Applied Fertilizer.

Time	Plots	N	P_2O_5	K_2O	Comments
		----	# / Ac	----	
Fall 1985				50	
Spring 1986		7	21	7	(starter)
Spring 1986		125			6/12/86 (sidedress)
(no fertilizer for 1987 growing season)					
Spring 1988		125	--	--	6/4/88 (sidedress)
Spring 1988		7	21	7	(starter)

Table 2. Management Information.

Item	Type	Rate	Date
	1986		
Secondary Tillage[1]	Digger	Twice	5/5
Seed	Pioneer 3732	26,500 ppa	5/5
Herbicides	Lasso	2.5 lbs/ac	5/7
	Bladex	1.5 lbs/ac	5/7
	1987		
Secondary Tillage[1]	Disk	Twice	4/30
Seed	Corsoy 79	160,000 ppa	5/2
Herbicides	Lasso	3.0 lbs/ac	5/4
	Amiben	2.5 lbs/ac	5/4
	1988		
Secondary Tillage[1]	Digger	Twice	4/20
Seed	Pioneer 3732	26,000 ppa	5/4
Herbicides	Lasso	3.0 lbs/ac	5/4
	Bladex	1.5 #/Ac	5/4

1/ No secondary tillage on ridge tillage plots.

Table 3. 1986 analysis of variance for the 1 percent slope. (Note: Analyzed as a randomized block design.)

Source	DF	SS	MS	F	P-value
Rep	1	4.201	4.201	(0.195)	(0.6704)
Tillage	2	1.865	0.9325	0.0445	0.9578
ERROR1	8	172.2	21.53	---	

Table 4. 1986 analysis of variance for the 4 percent slope. (Note: Analyzed as a split plot design.)

Source	DF	SS	MS	F	P-value
Rep	1	291.2	291.2	(15.55)	(0.1581)
Row[1]	1	207.7	207.7	11.09	0.1857
ERROR1	1	18.73	18.73	---	
Tillage	2	27.63	13.82	0.4858	0.7556
Row*Tillage	2	4.756	2.378	0.1300	0.8790
ERROR2	16	292.7	18.29	---	

1/ Row = Row direction (up and down, or contour to the slope).

Table 5. 1986 analysis of variance for the 8 percent slope. (Note: Analyzed as a split-split plot design.)

Source	DF	SS	MS	F	P-value
Rep	2	410.9	205.5	(8.509)	(0.1052)
Row	1	1281.0	1281.0	53.04	0.01834
ERROR1	2	48.29	24.15	---	
Tillage	2	23.74	11.87	0.1523	0.8612
Row*Tillage	2	355.1	177.6	2.279	0.1647
ERROR2	8	623.5	77.94	---	
Position[1]	2	665.2	332.6	6.302	0.002905
Row*Position	2	307.0	153.5	2.908	0.06051
Tillage*Position	4	224.8	56.2	0.0805	0.9881
Row*Tillage*Position	4	16.99	4.247	0.9881	0.08047
ERROR3	78	4117.0	52.78	---	

1/ Position = slope position (top, middle and bottom).

Table 6 (A-B). 1986 Corn Yields on the 1 Percent Slope.

6A.

	Avg	s[1]
Overall	178.8	3.8

1/ s = Standard deviation.

6B.

Tillage	Avg	s
Chisel	178.4	4.7
Moldboard	178.7	3.7
Ridge	179.3	3.0

Table 7 (A-D). 1986 Corn Yields on the 4 Percent Slope.

7A.

	Avg	s
Overall	179.3	4.9

7B.

Tillage	Avg	s
Chisel	179.6	4.3
Moldboard	180.4	4.2
Ridge	177.8	6.2

7C.

Row Dir.	Avg	s
Up & Down	182.2	4.7
Contour	176.3	5.0

7D.

Till[1]	Row Dir.	Avg	s
CH	Up & Down	183.8	5.1
CH	Contour	176.9	3.2
MP	Up & Down	182.6	3.5
MP	Contour	176.6	5.0
RT	Up & Down	180.2	5.6
RT	Contour	175.4	6.7

1/ CH = CHisel plow, MP = Moldboard Plow
RT = Ridge Tillage.

Table 8 (A-H). 1986 Corn Yields on the 8 Percent Slope.

8A.

	Avg	s
Overall	168.8	7.6

8B.

Tillage	Avg	s
Chisel	169.4	8.7
Moldboard	168.9	3.7
Ridge	168.3	6.9

8C.

Row Direction	Avg	s
Up & Down	172.3	7.8
Contour	165.4	7.4

8D.

Slope Position	Avg	s
Top	167.9	5.6
Mid	172.2	6.2
Bottom	166.4	7.6

8E.

Tillage	Row Dir.	Avg	s
Chisel	Up & Down	175.1	7.3
Chisel	Contour	163.7	10.1
Moldboard	Up & Down	172.2	8.3
Moldboard	Contour	165.5	6.0
Ridge	Up & Down	169.5	7.7
Ridge	Contour	167.0	6.1

8F.

Tillage	Slope Pos.	Avg	s
Chisel	Top	169.8	7.4
Chisel	Mid	173.4	7.0
Chisel	Bottom	165.0	7.9
Moldboard	Top	168.6	6.0
Moldboard	Mid	172.6	7.4
Moldboard	Bottom	165.6	5.1
Ridge	Top	165.5	3.3
Ridge	Mid	170.7	4.2
Ridge	Bottom	168.5	9.7

8G.

Row Dir.	Slope Pos.	Avg	s
Up & Down	Top	169.0	6.2
Up & Down	Mid	177.2	4.5
Up & Down	Bottom	170.6	8.1
Contour	Top	166.8	4.9
Contour	Mid	167.2	7.9
Contour	Bottom	162.1	7.0

8H.

Till	Row Dir.	Slope Pos.	Avg	s
CH	Up & Down	Top	173.1	8.4
CH	Up & Down	Mid	180.3	2.3
CH	Up & Down	Bottom	171.8	6.6
CH	Contour	Top	166.4	6.4
CH	Contour	Mid	166.4	11.7
CH	Contour	Bottom	158.2	9.2
MP	Up & Down	Top	169.5	6.8
MP	Up & Down	Mid	178.2	7.4
MP	Up & Down	Bottom	169.1	7.1
MP	Contour	Top	167.6	5.1
MP	Contour	Mid	167.0	7.3
MP	Contour	Bottom	162.0	3.1
RT	Up & Down	Top	164.4	3.4
RT	Up & Down	Mid	173.1	3.7
RT	Up & Down	Bottom	171.0	10.5
RT	Contour	Top	166.5	3.2
RT	Contour	Mid	168.3	4.6
RT	Contour	Bottom	166.0	8.8

Table 9. 1987 analysis of variance for the 1 percent slope. (Note: Analyzed as a randomized block design.)

Source	DF	SS	MS	F	P-value
Rep	1	0.9219	0.9219	(0.2329)	(0.6423)
Tillage	2	5.302	2.651	0.6698	0.5383
ERROR1	8	31.67	3.958		

Table 10. 1987 analysis of variance for the 4 percent slope. (Note: Analyzed as a split plot design.)

Source	DF	SS	MS	F	P-value
Rep	1	2.75	2.75	0.0663	(0.8396)
Row	1	9.305	9.305	0.2243	0.7184
ERROR1	1	41.49	41.49	---	
Tillage	2	54.78	27.39	2.715	0.09659
Row*Tillage	2	10.47	5.236	0.5189	0.6048
ERROR2	16	161.5	10.09		

Table 11. 1987 analysis of variance for the 8 percent slope. (Note: Analyzed as a split-split plot design.)

Source	DF	SS	MS	F	P-value
Rep	2	477.9	239.0	(2.528)	(0.2834)
Row	1	31.45	31.45	0.3327	0.6223
ERROR1	2	189.1	94.54	---	
Tillage	2	24.82	12.41	0.3437	0.7191
Row*Tillage	2	8.481	4.241	0.1174	0.8907
ERROR2	8	288.9	36.11	---	
Position	2	243.8	121.9	8.203	5.844e-4
Row*Position	2	171.8	85.9	5.781	4.559e-3
Tillage*Position	4	42.36	10.59	0.7127	0.5857
Row*Tillage*Position	4	35.73	8.931	0.601	0.6630
ERROR3	78	1159.0	14.86	---	

Table 12 (A-B). 1987 Soybean Yields on the 1 Percent Slope.

12A.

	Avg	s
Overall	51.3	1.9

12B.

Tillage	Avg	s
Chisel	52.0	2.2
Moldboard	50.4	2.1
Ridge	51.4	1.2

Table 13 (A-D). 1987 Soybean Yields on the 4 Percent Slope.

13A.

	Avg	s
Overall	46.2	3.5

13B.

Tillage	Avg	s
Chisel	46.7	2.1
Moldboard	44.2	3.6
Ridge	47.8	3.8

13C.

Row Dir.	Avg	s
Up & Down	46.9	3.3
Contour	45.6	3.7

13D.

Till	Row Dir.	Avg	s
CH	Up & Down	46.4	2.8
CH	Contour	47.1	1.5
MP	Up & Down	45.3	3.8
MP	Contour	43.0	3.5
RT	Up & Down	48.8	3.1
RT	Contour	46.7	4.7

Table 14 (A-H). 1987 Soybean Yields on the 8 Percent Slope.

14A.

	Avg	s
Overall	36.9	5.0

14B.

Tillage	Avg	s
Chisel	36.2	4.0
Moldboard	37.3	4.4
Ridge	37.0	6.3

14C.

Row Direction	Avg	s
Up & Down	36.3	5.3
Contour	37.4	4.7

14D.

Slope Position	Avg	s
Top	38.5	5.0
Mid	37.2	5.3
Bottom	34.9	4.0

14E.

Tillage	Row Dir.	Avg	s
Chisel	Up & Down	35.3	3.8
Chisel	Contour	37.1	4.1
Moldboard	Up & Down	36.9	4.7
Moldboard	Contour	37.7	4.2
Ridge	Up & Down	36.7	7.0
Ridge	Contour	37.4	5.8

14F.

Tillage	Slope Pos.	Avg	s
Chisel	Top	37.6	5.2
Chisel	Mid	36.3	3.8
Chisel	Bottom	34.7	2.2
Moldboard	Top	38.6	4.3
Moldboard	Mid	38.7	3.8
Moldboard	Bottom	34.6	4.1
Ridge	Top	39.3	5.7
Ridge	Mid	36.5	7.5
Ridge	Bottom	35.3	5.3

14G.

Row Dir.	Slope Pos.	Avg	s
Up & Down	Top	36.2	4.8
Up & Down	Mid	37.6	6.4
Up & Down	Bottom	35.2	4.4
Contour	Top	40.8	4.2
Contour	Mid	36.8	4.1
Contour	Bottom	34.5	3.6

14H.

Till	Row Dir.	Slope Pos.	Avg	s
CH	Up & Down	Top	34.8	4.6
CH	Up & Down	Mid	36.7	4.5
CH	Up & Down	Bottom	34.4	1.9
CH	Contour	Top	40.4	4.4
CH	Contour	Mid	36.0	3.5
CH	Contour	Bottom	35.0	2.5
MP	Up & Down	Top	37.3	4.8
MP	Up & Down	Mid	39.1	3.5
MP	Up & Down	Bottom	34.4	5.1
MP	Contour	Top	39.9	3.8
MP	Contour	Mid	38.4	4.4
MP	Contour	Bottom	34.8	3.4
RT	Up & Down	Top	36.5	5.5
RT	Up & Down	Mid	36.9	10.1
RT	Up & Down	Bottom	36.8	5.7
RT	Contour	Top	42.2	4.7
RT	Contour	Mid	36.0	4.8
RT	Contour	Bottom	33.9	4.9

Table 15. 1988 analysis of variance for the 1 percent slope. (Note: Analyzed as a randomized block design.)

Source	DF	SS	MS	F	P-value
Rep	1	294.0	294.0	(4.374)	(0.06986)
Tillage	2	830.3	415.1	6.172	0.02388
ERROR1	8	537.8	67.22	---	

Table 16. 1988 analysis of variance for the 4 percent slope. (Note: Analyzed as a split plot design.)

Source	DF	SS	MS	F	P-value
Rep	1	539.6	539.6	(1.280)	(0.4608)
Row	1	55.81	55.81	0.132	0.7779
ERROR1	1	421.7	421.7	---	
Tillage	2	2091.0	1046.0	12.83	4.73e-4
Row*Tillage	2	123.9	61.94	0.760	0.4839
ERROR2	16	1304.0	81.51	---	

Table 17. 1988 analysis of variance for the 8 percent slope. (Note: Analyzed as a split-split plot design.)

Source	DF	SS	MS	F	P-value
Rep	2	4328.0	2164.0	(3.757)	(0.2102)
Row	1	552.2	552.2	0.959	0.4308
ERROR1	2	1152.0	576.0	---	
Tillage	2	2622.0	1311.0	6.992	0.01754
Row*Tillage	2	958.8	479.4	2.557	0.1385
ERROR2	8	1500.0	187.5	---	
Position	2	6529.0	3264.0	18.174	3.318e-7
Row*Position	2	605.2	302.6	1.685	0.1922
Tillage*Position	4	785.6	196.4	1.094	0.3657
Row*Tillage*Position	4	1120.0	280.1	1.560	0.1934
ERROR3	78	14010.0	179.6	---	

Table 18 (A-B). 1988 Corn Yields on the 1 Percent Slope.

18A.

	Avg	s
Overall	36.5	12.3

18B.

Tillage	Avg	s
Chisel	36.5	7.4
Moldboard	26.4	14.3
Ridge	46.7	4.1

Table 19 (A-D). 1988 Corn Yields on the 4 Percent Slope.

19A.

	Avg	s
Overall	25.5	14.0

19B.

Tillage	Avg	s
Chisel	27.2	17.3
Moldboard	13.3	5.3
Ridge	35.9	4.8

19C.

Row Dir.	Avg	s
Up & Down	27.0	16.4
Contour	23.9	11.8

19D.

Till	Row Dir.	Avg	s
CH	Up & Down	32.0	22.4
CH	Contour	22.5	11.5
MP	Up & Down	13.1	6.9
MP	Contour	13.4	4.3
RT	Up & Down	36.0	5.9
RT	Contour	36.0	4.4

Table 20 (A-H). 1988 Corn Yields on the 8 Percent Slope.

20A.

	Avg	s
Overall	35.2	17.9

20B.

Tillage	Avg	s
Chisel	31.7	19.8
Moldboard	31.8	17.3
Ridge	42.2	14.5

20C.

Row Direction	Avg	s
Up & Down	37.5	16.9
Contour	32.9	18.7

20D.

Slope Position	Avg	s
Top	42.0	13.0
Mid	39.3	20.0
Bottom	24.3	14.8

20E.

Tillage	Row Dir.	Avg	s
Chisel	Up & Down	29.7	17.8
Chisel	Contour	33.6	21.8
Moldboard	Up & Down	36.4	13.8
Moldboard	Contour	27.1	19.5
Ridge	Up & Down	46.2	15.3
Ridge	Contour	38.1	12.9

20F.

Tillage	Slope Pos.	Avg	s
Chisel	Top	39.3	12.9
Chisel	Mid	38.1	25.5
Chisel	Bottom	17.5	9.8
Moldboard	Top	36.7	13.1
Moldboard	Mid	38.3	20.1
Moldboard	Bottom	20.3	12.8
Ridge	Top	50.0	9.8
Ridge	Mid	41.4	14.4
Ridge	Bottom	35.1	15.7

20G.

Row Dir.	Slope Pos.	Avg	s
Up & Down	Top	47.1	10.7
Up & Down	Mid	38.6	14.9
Up & Down	Bottom	26.6	18.0
Contour	Top	36.9	13.4
Contour	Mid	39.9	24.5
Contour	Bottom	22.0	10.8

20H.

Till	Row Dir.	Slope Pos.	Avg	s
CH	Up & Down	Top	45.5	5.8
CH	Up & Down	Mid	33.1	15.5
CH	Up & Down	Bottom	10.7	7.9
CH	Contour	Top	33.2	15.5
CH	Contour	Mid	43.2	33.7
CH	Contour	Bottom	24.4	5.9
MP	Up & Down	Top	41.2	11.2
MP	Up & Down	Mid	42.3	13.0
MP	Up & Down	Bottom	25.9	12.2
MP	Contour	Top	32.2	14.3
MP	Contour	Mid	34.2	26.1
MP	Contour	Bottom	14.8	11.6
RT	Up & Down	Top	54.8	10.6
RT	Up & Down	Mid	40.5	17.1
RT	Up & Down	Bottom	43.4	15.8
RT	Contour	Top	45.2	6.5
RT	Contour	Mid	42.4	12.8
RT	Contour	Bottom	26.8	11.3

WEST CENTRAL EXPERIMENT STATION
WEATHER SUMMARY - 1988

		Precipitation			Temperature			Soil Temperature (10 cm depth)	
Month	Period	1988	100-yr. av.	Dev. from av.	1988	100-yr. av.	Dev. from av.	1988	10 yr. av.
January	1-31	0.70	0.68	-0.05	5.6	8.0	+ 9.9	17.6	20.7
February	1-29	0.20	0.67	-0.35	9.2	12.8	+16.7	15.8	23.9
March	1-31	0.82	1.13	+0.44	30.1	26.7	+ 5.5	29.5	29.2
April	1-10	0.44	0.57	-0.57	45.5	38.0	+ 5.5	38.9	
	11-20	0	0.64	-0.31	36.7	44.4	+11.0	41.3	
	21-30	0.13	1.05	-0.99	44.7	48.3	+ 6.3	44.5	
Total or av.		0.57	2.26	-1.87	43.6	43.6	+ 7.6	41.5	41.4
May	1-10	0.77	0.77	-0.65	63.2	52.0	+ 8.1	57.6	
	11-20	0.06	0.95	-0.59	60.6	55.8	+ 6.9	60.8	
	21-31	0.88	1.25	+1.19	69.5	60.0	+ 0.3	67.3	
Total or av.		1.71	2.97	- .05	64.3	56.1	+ 4.9	62.1	57.1
June	1-10	T	1.29	-1.13	73.2	63.0	+ 2.4	77.3	
	11-20	0.41	1.30	+0.40	73.7	66.3	+ 5.5	71.7	
	21-30	0.08	1.37	-1.36	74.7	68.1	- 1.3	80.4	
Total or av.		0.49	3.96	-2.09	73.9	65.8	+ 2.2	77.6	69.3
July	1-10	0.39	1.44	-0.75	75.7	70.1	- 1.4	81.5	
	11-20	1.25	1.06	-0.76	72.7	71.4	- 1.6	83.2	
	21-31	0.19	1.01	-0.19	75.6	71.4	+ 5.5	84.1	
Total or av.		1.83	3.51	-1.70	74.7	70.9	+ 1.1	83.0	76.7
August	1-10	2.56	1.04	-0.76	73.2	70.4	- 0.4	79.6	
	11-20	1.71	0.93	-0.26	76.4	69.0	- 1.6	77.3	
	21-31	0.36	1.04	-0.53	64.5	66.9	- 7.0	68.7	
Total or av.		4.63	3.01	-1.55	71.1	68.7	- 3.1	77.1	73.9
September	1-30	4.56	2.20	+0.69	58.2	59.0	0	63.0	61.5
October	1-31	0.46	1.74	-1.32	41.6	47.2	- 5.5	46.9	47.8
November	1-30	1.07	0.97	-0.15	27.7	29.7	+ 5.3	33.3	33.6
December	1-31	0.45	0.68	-0.01	16.3	15.2	+ 5.7	23.8	23.4
April-Aug. Growing Season		9.23	15.71	-7.26	65.6	61.0	+ 2.6	68.4	63.8
January-December Annual		23.78	23.78	-8.01	43.1	42.0	+ 4.2	47.7	46.7

CONTINUOUS CORN SILAGE
MORRIS, 1988[1]

S. D. Evans[2]

ABSTRACT: This long-term study addresses the effects of removal of continuous corn silage and corn grain on soil properties and yield. Results after 23 years show no yield differences due to the removal of silage versus grain. A significant difference in yields exists between high and low fertilizer levels.

OBJECTIVES

This is the 23rd year of a continuing study initiated in 1965 on a McIntosh silt loam soil. This study was initiated to determine the effects of removal of continuous corn silage and fertilizer rate on soil properties and yields. Silage and shelled corn yield samples were collected. Half of the plots received a fertilizer rate of 74+48+48 ($N+P_2O_5+K_2O$) in lbs./acre) and the other half a rate of 148+96+96.

MATERIALS AND METHODS

The experiment is set up as a latin square with 4 treatments: (1) silage, low fertility, (2) silage, high fertility, (3) grain, low fertility, and (4) grain, high fertility. The experimental area has been moldboard plowed each fall and tilled with a field cultivator prior to planting. In 1988 Dekalb 461 was seeded at 26,200 seeds/acre on April 25. Furadan 15G was applied in the row at planting at 10 lbs./acre (1.5 lbs./acre a.i.). The fertilizer was all applied the previous fall prior to plowing.

Lasso @ 3 lbs./acre a.i. + Bladex @ 2.2 lbs./acre a.i. were applied broadcast on April 27. Silage yields were taken on August 20 and grain yields on September 21. Yields were also taken as in past years on an adjacent unfertilized area where only the grain is removed. These check yields are an average from two measured areas.

RESULTS AND DISCUSSION

Grain and Silage Yields: Silage yields are given in Table 1. There was no significant difference in silage yields in 1988. Dry conditions reduced yields to about half of normal. The 23-year average shows no effect of silage versus grain but does show increased yields of high fertility over low fertility. Grain yields and an average of the two unfertilized checks adjacent to the experimental area are given in Table 2.

[1] Funding provided by the West Cent. Expt. Sta. Univ. of Minnesota
[2] Professor, West Cent. Expt. Sta., Univ. of Minnesota.

Table 1. Effect of removal of continous silage or grain on silage yields.

Treatment	1988 Yield	1966-88 Yield
	- - - dry matter, tons/acre - - -	
Silage, Low fertility	4.09	5.42
Silage, High fertility	4.16	5.93
Grain, Low fertility	3.39	5.45
Grain, High fertility	3.39	5.80
Signif. levels (%):		
Treatment	72	>99
Year	--	>99
Treatment x Year	--	99
LSD, treatment (.05)	NS	0.16

Table 2. Effect of fertilizer level on grain and silage yields.

Treatment	1988 Yield	1966-88 Yield
	- - - - bu./acre @ 15.5% M. - - - -	
Grain, Low fertility	52.2	87.0
Grain, High fertility	39.8	91.8
Grain, Check	48.0	46.7
	- - - - dry matter, ton/acre - - -	
Silage, check	3.45	3.52

MANURE RATE STUDY
Morris, 1988[1]

S. D. Evans, P. R. Goodrich, G. L. Malzer and R. C. Munter[2]

ABSTRACT: This is the 16th year of a study initiated in 1972 to investigate the effect of application of three rates of solid and and three rates of liquid beef manure on corn growth and soil properties. Seven fall applications of manure were made from 1972 thru 1978 (application omitted in 1977). Residual effects of the seven applications has been measured from 1979-1988. Higher rates of manure did not result in higher yields during the application years, but the highest manure rate did indicate a measurable response to residual fertility in the post-application years. NO_3-N movement below the root zone of corn is much higher with the higher rates of manure.

Objectives

This study was initiated in 1972 to investigate the effect of application of three rates of solid and three rates of liquid beef manure on corn growth and soil properties. The manure treatments were compared to commercial fertilizer and check treatments. Seven fall applications of manure were made from 1972 thru 1978 (omitted in 1978). Fertilizer was applied to the commercial fertilizer treatment each year at the same rate. The treatments and abbreviations are as follows:

CHECK- CK - No fertilizer or manure
FERTILIZED - FE - 120 + 50 + 50 ($N + P_2O_5 + K_2O$) lbs/acre/year
SOLID BEEF MANURE, RATE 1 - SB1 - 33 tons/acre annually (wet weight), total application of 233 tons/acre
SOLID BEEF MANURE, RATE 2 - SB2 - 67 tons/acre annually (wet weight), total application of 467 tons/acre
SOLID BEEF MANURE, RATE 3 - SB3 - 100 tons/acre annually (wet weight), total application of 700 tons/acre
LIQUID BEEF MANURE, RATE 1 - LB1 - 4530 gallons/acre annually, total application of 31700 gallons/acre
LIQUID BEEF MANURE, RATE 2 - LB2 - 9060 gallons/acre annually, total application of 63400 gallons/acre
LIQUID BEEF MANURE, RATE 3 - LB3 - 13580 gallons/acre annually, total application of 95100 gallons/acre

Materials and Methods

Plots were fall plowed in 1987 and field cultivated on April 25 and then planted to Pioneer 3906 corn at 26,200 seeds/acre. Furadan 15G was applied at 10 lbs/acre (1.5 lbs/acre a.i.) in the row to the entire area at planting. Lasso @ 3 lbs/acre (a.i.) + Bladex @ 2.2 lbs/acre (a.i.) were broadcast on April 27. The fertilized plots had received an application of 120 + 50 + 50 the previous fall. On June 2 plant heights were recorded and 10 plants were harvested for dry weight determination. Plots were cultivated on June 3. Silage yields were calculated from two 10-foot rows hand harvested on August 31. Two 40-foot rows were harvested with a plot combine on September 21. Following harvest the plots were sampled to a depth of 4 feet in 1-foot increments. Two cores were combined for each plot and divided into two parts; one for N analysis and the other for moisture determination. The cores for N analysis were dried at 95°F.

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1 Funding provided by the West Cent. Expt. Sta. Soil analysis provided by the Center for the Impacts of Agricultural Practices on Water Quality.

2 Professor, West Cent. Expt. Sta. Assoc. Prof., Dept. of Soil Science, and Asst. Prof., Dept. of Soil Science, respectively, Univ. of Minnesota.

Results and Discussion

Plant and Yield Measurements: Early plant height, early dry weight, silage yields and grain yields are given in Table 1. Early plant height and dry weight were significantly taller and heavier for the solid beef manure treatments than for the liquid manure and fertilizer treatments. Even though the SB treatments early plant growth was greater, there was no difference in grain and silage yields. Extremely dry conditions reduced yields to about half of normal and probably overcame any early plant growth advantages.

Fall 1988 Soil Samples: The results of the NO_3-N analyses are given in Table 2. Levels in the manure treatments increased with rate. The CK, SB1, and LB1 had significantly lower NO3-N levels than the other treatments. All other manure treatments except SB3 are not different from the fertilizer treatment. Nitrates accumulated in the 2-, 3-, and 4-foot depths and were significantly higher than in the top foot.

Table 1. Summary of plant measurements - 1988.

			Grain		Silage		
Treatment	Early plant height	Early plant (10) dry wt.	Moisture at harvest	Yield at 15.5% moisture	Dry matter at harvest	Silage yield (D.M.)	Ear Wt. as a % of silage
	-in.-	grams	-%-	bu/acre	-%-	lbs/acre	-%-
CK	11.0	15.1	25.6	49.1	45.2	7265	51.2
FE	11.5	16.0	26.1	48.2	42.0	8173	48.5
SB1	14.5	27.4	24.3	52.7	44.3	9303	47.7
SB2	14.5	28.7	25.8	45.3	39.4	6468	41.5
SB3	16.2	34.5	27.4	43.6	41.8	6530	40.3
LB1	11.5	17.4	25.2	56.5	46.8	7024	49.8
LB2	12.5	21.1	25.2	49.7	47.4	9003	52.1
LB3	12.8	20.7	24.1	54.4	44.1	8331	50.9
Signif. Level(%)	>99	>99	59	8	>99	93	96
BLSD (.05)	1.3	5.9	NS	NS	3.3	NS	9.0
CV (%)	5.9	15.6	6.7	26.1	4.2	15.5	9.4

Table 2. Effect of two types of cattle manure and commercial fertilizer on the nitrate - nitrogen level of a Tara Soil profile - Fall 1988

Depth Increment	CK	FE	SB1	SB2	SB3	LB1	LB2	LB3	MEAN
- ft -	ppm NO_3 - N								
0-1	5.1	15.0	6.9	12.1	24.7	5.0	6.3	12.1	10.9
1-2	.9	49.6	13.0	16.2	77.5	2.7	20.7	43.8	28.0
2-3	.9	25.1	20.9	30.1	82.6	3.3	21.4	34.0	27.3
3-4	2.7	18.9	14.5	37.5	62.4	10.3	17.7	17.1	22.6
MEAN	2.4	27.2	13.8	24.0	61.8	5.3	16.5	26.7	

Signif. Levels (%)

Replication	95		
Treatment	95	BLSD (.05)	11.7
Depth	>99	BLSD (.05)	8.9
Trt x depth	89		

RESIDUAL EFFECT OF HEAVY APPLICATIONS OF ANIMAL MANURES ON CORN GROWTH, YIELD, AND ON SOIL PROPERTIES[1]
Morris, 1988

S. D. Evans, P. R. Goodrich, G. L. Malzer, and R. C. Munter[2]

ABSTRACT: This study is continuing and 1988 was the 18th year. Nitrate movement and yield responses from two initial annual large applications of manure have been measured. Results over the 18 years show 1986 as the first year the fertilized check yielded significantly better than the manure treatments. Soil samples were taken to a depth of 18 feet in the fall of 1987. The fertilizer treatment had the most NO_3-N in the root zone. Below the root zone (4 feet) NO_3-N levels in the manure treatments exceeded the fertilizer treatment. Most of this manure fertilizer is 6 feet or deeper, therefore, below the root zone of corn and not available to the crop and susceptible to deeper movement to the groundwater.

This is the 18th year of a continuing study initiated to measure the residual effects of 1970 and 1971 applications of two types of manure on corn yields and soil nitrogen levels. The total manure applications were as follows: Solid Beef Manure-200 tons/acre (wet weight), Liquid Beef Manure- 36,000 gallons/acre, and Liquid Hog Manure-136,000 gallons/acre. The fertilized plots received the same amount of fertilizer annually (120 + 50 + 50 of N + P_2O_5 + K_2O in lbs/acre, respectively).

Planting and Harvesting Information

The study was seeded to Pioneer 3906 corn on April 25 at 26,200 seeds/acre. Furadan 15G was applied @ 10 lbs/acre (1.5 lbs/acre a.i.) in the row at seeding. The fertilized plots received 120 + 50 + 50 (N + P_2O_5 + K_2O) lbs/acre on October 26, 1987. The plots were moldboard plowed following fertilizer application. A Lasso and Bladex tank mix applied at 3.0 and 2.2 lbs/acre a.i. respectively was applied broadcast preemergence on April 27. Plots were cultivated on June 3. Silage yields were calculated from two 10-foot rows hand harvested on August 31. Grain yields were calculated from two 110-foot rows harvested with a plot combine on September 21.

Soil Sampling and Analysis

Two soil cores were taken from each plot in the fall of 1988 to a depth of 4 feet in one-foot increments. The two cores were combined and divided into two parts; one for N analysis and the other for moisture determination. The cores for N analysis were dried at 95°F. There was a significant difference between the fertilized check and all other treatments in NO_3-N levels (Table 1). The fertilized check has far more nitrates in the upper 4-foot profile than the other treatments. However, the manure treatments (Table 2) have far more nitrates deeper in the soil profile out of the rooting zone for corn, therefore, susceptible to deeper movement into the soil. NO_3-N levels (Table 1) increased with depth while NH_4-N levels decreased with depth.

Plant and Yield Measurements

Early plant height, early plant weight, silage yields, and grain yields are given in Table 3. Early plant height and early plant weight were significantly higher and heavier for the manure treatments over the fertilizer treatment. There were no differences between manure and fertilizer treatment yields. Due to extreme dry conditions yields were about half of normal.

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[1] Funding provided by the West Cent. Expt. Sta. Soil analysis provided by the Center for the Impacts of Agricultural Practices on Water Quality.

[2] Professor, West Cent. Expt. Sta., Assoc. Prof., Dept. of Agr. Eng., Assoc. Prof., Dept. of Soil Science, and Asst. Prof., Dept. of Soil Science, respectively, Univ. of Minnesota.

Table 1. Nitrate and ammonium nitrogen levels of Tara Soil 18 years (Fall 1988) after application of high rates of manure.

Depth Increment	Check	Fertilized	Solid Beef Manure	Liquid Beef Manure	Liquid Hog Manure	Mean	Check	Fertilized	Solid Beef Manure	Liquid Beef Manure	Liquid Hog Manure	Mean
	Treatment (ppm NO_3-N)						Treatment (ppm NH_4-N)					
0-1	3.0	7.3	4.2	5.4	2.6	4.5	4.6	4.9	2.2	5.0	5.8	4.5
1-2	1.5	24.3	2.7	3.9	1.7	6.8	2.7	3.0	2.3	3.4	2.7	2.8
2-3	.7	19.4	2.3	5.1	2.4	6.0	2.2	2.3	2.2	2.0	2.2	2.2
3-4	1.2	9.5	6.4	14.6	4.9	7.3	2.5	2.7	2.5	2.3	2.3	2.5
Mean	1.6	15.1	3.9	7.2	2.9		3.0	3.2	2.3	3.2	3.2	

Signif. Level (%)

Nitrate			Ammonium		
Replication	- NS		Replication	- NS	
Treatment	- 99	BLSD (.05) 7.1	Treatment	- NS	
Depth	- NS		Depth	- >99	BLSD (.05) .4
Trt x Depth	- >99		Trt x Depth	- >99	

Table 2. Calculated nitrate - nitrogen contents of various profile increments of a Tara soil in the fall of 1987.

Depth Increment	Check	Fertilized	Solid Beef Manure	Liquid Beef Manure	Liquid Hog Manure
	Treatments				
- ft. -	-NO_3-N, lbs/acre-				
0-6	96	268	80	152	120
6-18	232	396	700	832	584
Total	328	664	780	984	704

Table 3. Summary of plant measurements - 1988.

Treatment	Early plant height	Early plant(10) dry wt.	Grain: Moisture at harvest	Grain: Yield at 15.5% moisture	Silage: Dry matter at harvest	Silage: Silage yield (D.M.)	Silage: Ear Wt. as a % of Silage
	- in. -	grams	-%-	bu/acre	-%-	lbs/acre	-%-
Check	9.7	13.0	24.9	45.1	43.6	6110	49.8
Fertilized	10.8	13.1	24.7	58.4	42.8	8581	52.2
Solid Beef Manure	13.8	22.6	24.5	48.6	41.1	6715	44.7
Liquid Beef Manure	13.5	25.1	24.6	50.5	45.9	7875	48.6
Liquid Hog Manure	12.5	19.0	25.4	52.8	47.7	7352	55.1
Signif. Level (%)	>99	>99	17	55	>99	85	88
BLSD (.05)	1.6	2.9	NS	NS	2.8	NS	NS
CV (%)	7.3	8.8	4.2	16.6	3.3	15.2	8.3

FOLIAR UAN CONCENTRATIONS ON HARD RED SPRING WHEAT[1]
Morris, 1988

S. D. Evans and G. A. Nelson[2]

ABSTRACT: Foliar application of 28% UAN to hard red spring wheat has the potential to burn leaf tissue and possibly adversely affect yield. This study addresses the use of four concentration rates of UAN and their effects on leaf burn and yield. Results of this one-year study indicate increasing rates of leaf burn occurred with increasing concentrations of 28% UAN. Yield was about 1/3 of normal due to extremely dry conditions.

There has been concern over leaf burn caused from 28% UAN on hard red spring wheat and its effects on yield. This study was set up to study the effects of leaf burn as related to N concentration in the spray and how much burn is permissible before yield decreases occur.

Experimental Procedure

The experiment was established on a Hamerly clay loam (Aeric Calciaquoll). A randomized complete block design with four replications was used. The entire plot area received 40 lbs N/acre as urea on April 11. In the fall of 1987 2-foot NO_3-N samples were taken and measured 80 lbs/acre/2 ft. Plot size was 8 ft x 45 ft. The 28% UAN treatments included: (1) 100% UAN, 0% water, (2) 50% UAN, 50% water, (3) 33% UAN, 67% water, and (4) 25% UAN, 75% water. The foliar N treatments were applied at 13.3-, 26.7-, 40.0-, and 53.3-gal/acre and 30 psi pressure for treatments 1, 2, 3, and 4, respectively. The treatments were applied at the 4-5 leaf stage (tiller) of the wheat to provide 40 lbs N/acre. Marshall wheat was seeded at 100 lbs/acre on April 12. Bronate (.25 lb/acre a.i.) and Hoelon (.25 lb/acre a.i.) were broadcast for weed control on May 24 and 26, respectively. Tilt was applied @ 4 oz/acre for disease control on June 2. The 28% UAN was applied on May 24 and leaf damage was recorded on May 27. Plant heights were taken on July 20 and plots were harvested with a plot combine on July 21. Samples of grain were taken for test weight and moisture.

Results and Discussion

Leaf damage on the 100% UAN and 50% UAN treatments was significantly greater than on the 33% UAN and 25% UAN treatments. Grain yield, test weight, grain moisture and plant height were not significantly (P=.05) affected by UAN concentration. The year 1988 was extremely dry and hot with wheat yields 1/3 or less than normal. This study will be repeated in 1989.

[1] Funding provided by the West Cent. Expt. Sta., Univ. of Minnesota.
[2] Professor and Junior Scientist, West Cent. Expt. Sta.,, Univ. of Minnesota

Table 1. The effect of concentration rate of 28% UAN to provide 40 lbs N/acre on spring wheat applied at tillering.

Trt No.	Concentration	Leaf[1] Damage	Plant Height	Grain Moisture at Harvest	Test Weight	Grain Yield at 13% Moisture
			inches	- % -	lbs/bu	Bu/acre
1	100% UAN	3.75	16.8	15.4	53.7	17.5
2	50% UAN 50% H_2O	3.50	16.3	15.6	55.8	17.8
3	33% UAN 67% H_2O	2.50	16.0	15.6	55.3	16.7
4	25% UAN 75% H_2O	2.00	16.0	15.4	56.1	16.8
Signif. Level (%)		>99	31	59	90	43
BLSD (.05)		0.8	NS	NS	2.3	NS
CV (%)		16.3	6.2	1.1	2.3	7.6

[1] Leaf Damage 3 days after application: 1=0%, 2=1-25%, 3=26-50%, 4=51-75%, 5=76-100%, expressed as estimation of percentage of the top leaf tissue burned by fertilizer.

SOIL AND FOLIAR APPLIED NITROGEN FOR HARD RED SPRING WHEAT[1]
Morris, 1988

S. D. Evans and G. A. Nelson[2]

ABSTRACT: Recommendations for increasing protein content and yields for hard red spring wheat with foliar N applications in combination with various soil N applications have yet to be developed. This study addresses soil and foliar nitrogen combinations used to increase protein content and yield of spring wheat. Leaf tissue damage was significantly affected by rate of foliar N applied but damaged a significant portion of the leaves only at the 40 lbs N/acre rate. Yield results of this one-year study were inconclusive due to extreme drought. Average yields were under 8 bu/acre. This study will be repeated in 1989.

In the past few years there has been an increased interest in spring wheat protein levels. This study was initiated to look at 4 foliar nitrogen rates, applied at the 4-5 leaf stage of wheat, on 4 rates of nitrogen, for a total of 16 treatments.

Experimental Procedures

The experiment was established on a Hamerly clay loam (Aeric Calciaquoll). Plot size was 8 feet x 45 feet. NO_3-N soil tests taken the fall of 1987 indicated 80 lbs NO_3-N/acre was available for plant growth in the top 2 feet of soil. Nitrogen (urea) was applied to appropriate plots to equal 80, 120, 160 and 200 lbs N/acre on April 11. The plot area was then worked with a field cultivator to incorporate the urea and prepare a seedbed. The plots were seeded to Marshall wheat at 100 lbs/acre on April 12. The foliar N treatments were applied with a sprayer delivering a volume of 50 gal/acre at 30 psi pressure. The foliar fertilizer, 28% UAN, was applied at 4-5 leaf stage on May 23. Rates applied were 0, 10, 20, and 40 lbs N/acre across the 80, 120, 160, and 200 lbs N/acre soil nitrogen plots. Bromate @ .25 lbs/acre a.i. and Hoelon @ .25 lbs/acre a.i. were broadcast on May 24 and 26, respectively. Tilt was applied @ 4 oz/acre for disease control on June 2. Foliar leaf damage was recorded on May 26, three days after foliar N application. Plant heights were taken on July 20 and the plots were harvested with a plot combine on July 21. Samples of grain were taken for yield, moisture, and test weight determination.

Results and Discussion

There was no significant effect of the soil or foliar fertilizer treatments on plant height, bushel weight, moisture, or grain yield. Leaf damage was affected significantly by the foliar N application. As N rate increased, so did leaf damage, but there was no effect on yield. Leaf damage was significant on the 40 lbs N/acre foliar treatment. Severe drought conditions existed in 1988 with wheat averaging 7 1/2 bu/acre. Because of extremely poor yields and plot variability, protein analysis was not run. This study will be repeated in 1989.

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[1] Funding provided by the West Cent. Expt., Univ of. Minnesota.

[2] Professor and Junior Scientist, West Cent. Expt. Sta., Univ. of Minnesota.

Table 1. Effect of Soil and Foliar Nitrogen Rates on Spring Wheat.

Soil Applied Fertilizer	LFD[1] (0-5)	Ht.	Bu. Wt.	Moist.	Yield @ 13% Moist.	Foliar Fertilizer	LFD[1] (0-5)	Ht.	Bu.Wt.	Moist.	Yield @ 13% Moist.
lbs N/acre		-in-	lbs/bu	%	bu/acre	lbs N/acre		-in-	lbs/bu	%	bu/acre
80	1.6	10.2	58.2	12.1	7.4	0	1.0	10.1	58.2	12.1	7.8
120	1.6	9.8	58.1	11.9	6.5	10	1.0	10.1	58.2	12.1	7.9
160	1.5	10.4	58.3	12.2	9.1	20	1.4	10.1	58.3	12.1	7.7
200	1.4	9.7	58.5	12.0	7.2	40	2.7	9.9	58.4	12.1	6.8
Significance											
Level (%)	51	59	47	77	68		>99	3	15	22	15
BLSD	NS	NS	NS	NS	NS		0.2	NS	NS	NS	NS
CV (%)	22.7	13.7	1.1	2.0	42.3		22.7	13.7	1.1	2.0	42.3

[1] Leaf Damage 3 days after application 1 = 0%, 2 = 1-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-100%, expressed as estimation of percentage of the top leaf tissue burned by fertilizer.

USING SPLIT APPLICATIONS AND A NITRIFICATION INHIBITOR FOR CORN PRODUCTION ON AN IRRIGATED SANDY SOIL

Kendall Langseth, Denzil Cooper, and George Rehm[1]

ABSTRACT: Past research in Minnesota has shown that split applications and nitrification inhibitors are effective management tools for improving the yield of irrigated corn grown on sandy soils. This study was designed to determine if the use of these two practices would reduce the rate of fertilizer N needed for most profitable yield. In 1988, at the Irrigation Center at Staples, N rate (160 or 200 lb./acre), the use of a nitrification inhibitor (DCD) and split applications had no effect on grain yield of corn. The NO_3-N in the root zone at the end of the growing season was significantly affected by N rate, but not by nitrification inhibitor use or split applications.

Efficient use of nitrogen fertilizers is essential for profitable corn production on irrigated sandy soils. Split applications and the use of nitrification inhibitors are two management tools that can be easily used to provide for the efficient use of fertilizer N. The importance of these two management tools has been documented in past research. There was, however, a need to determine if the use of these management options would allow for the use of lower rates of fertilizer N without any reduction in yield. Therefore, this trial was conducted to determine the impact of split rates of fertilizer N and a nitrification inhibitor on the yield of corn when 2 rates of N (160, 200 lb./acre) were used.

EXPERIMENTAL PROCEDURES:

This study was conducted at the Irrigation Center at Staples. The soil was a Sverdrup sandy loam. Soil samples were collected prior to corn planting and the results are summarized in Table 1.

Three variables were incorporated into a complete factorial design with 4 replications. These variables were: 1) N rate (160, 200 lb./acre), 2) application frequency (single, split), and 3) use of an inhibitor (DCD). The variety, Agripro 270 (90 day relative maturity) was planted on May 5 at a population of 32,000 plants per acre. All treatments received a starter fertilizer to supply 40 lb. N, 13 lb. P_2O_5, 26 lb. K_2O and 13 lb. S per acre. The Dual/Bladex herbicide combination was applied preemergence at rates of 1.5 pint and 1.3 qt per acre respectively.

For single applications, the N was applied at the 5-6 leaf stage of development. For split applications, one half of the fertilizer N was applied at this stage with the remainder applied approximately 2 weeks prior to silking. Urea (46-0-0) was used to supply the N for all treatments.

Grain yields were harvested in mid-October and corrected to the 15.5% moisture level. Soil samples from 0-12, 12-24, and 24-36 inches were also collected at this time. These samples were dried and analyzed for nitrate-nitrogen (NO_3-N).

RESULTS AND DISCUSSION:

The influence of N rate, split application and use of a nitrification inhibitor on grain yield is summarized in Table 2. None of the variables used in the study had a significant effect on yield. The yield goal established for this study was 170 bu./acre. The lowest N rate used was adequate to meet this goal. Because of the weather, there was a very low potential for leaching of NO_3-N through the root zone. Therefore, a response to the use of either split applications or nitrification inhibitors would not be anticipated.

The yield of approximately 185 bu./acre was certainly higher than expected for the 1988 growing season. These high yields are a reflection of the good management practices used throughout the growing season.

1/ County Extension Agent, Wadena County; County Extension Agent, East Ottertail County; and Extension Specialist, respectively.

Table 1. Relevant soil test values for the experimental site.

pH	6.7
P (lb./acre)	75
K (lb./acre)	374
O.M. (%)	2.0
NO_3-N (lb./acre to 24 inches)	38

Table 2. Influence of N rate, frequency of N application, and use of a nitrification inhibitor on the yield of irrigated corn.

N Rate	Inhibitor used	Application Frequency single	split
lb./acre		- - bu./acre - -	
160	No	185	188
	Yes	175	191
200	No	187	185
	Yes	179	184

Results of the analysis of soil samples collected in mid-October at harvest are summarized in Tables 3, 4, 5, and 6. The amount of NO_3-N present in the 12-24 inch depth was not significantly affected by any of the variables used (Table 3). Concentrations of NO_3-N were relatively low and quite uniform at this depth.

The variables used also had no significant on the amount of NO_3-N found at the 12-24 and 24-36 depths (Tables 4 and 5). Amounts of NO_3-N found at these depths were low and quite variable. Except for the situation where 200 lb. N was applied with a split application and the inhibitor was used, total amounts of NO_3-N to a depth of 3 feet were relatively uniform (Table 6).

In general, the amount of NO_3-N measured to the 3 ft. depth in the fall was less than the amount found to the 2 ft. depth in early spring. This would indicate very efficient use of the applied N during the 1988 growing season.

Table 3. The influence of N rate, frequency of N application, and use of a nitrification inhibitor on the amount of NO_3-N at the depth of 0-12 inches.

N Rate	Inhibitor Used	Application Frequency single	split
lb./acre		- - bu. NO_3-N/acre - -	
160	No	16	14
	Yes	14	14
200	No	14	15
	Yes	14	15

Table 4. The influence of N rate, frequency of N application, and use of a nitrification inhibitor on the amount of NO_3-N at the depth of 12-24 inches.

N Rate	Inhibitor Used	Application Frequency single	split
lb./acre		- - lb.NO_3-N/acre - -	
160	No	7	7
	Yes	6	7
200	No	7	22
	Yes	14	8

Table 5. The influence of N rate, frequency of N application, and use of a nitrification inhibitor on the amount of NO_3-N at the depth of 24-36 inches.

N Rate	Inhibitor Used	Application Frequency single	split
lb./acre		- - - lb./acre - - -	
160	No	5	5
	Yes	4	6
200	No	6	13
	Yes	8	6

Table 6. The influence of N rate, frequency of N application, and use of a nitrification inhibitor on the amount of NO_3-N in the 0-36 inch root zone.

N Rate	Inhibitor Used	Application Frequency single	split
lb./acre		- - - lb./acre - - -	
160	No	28	27
	Yes	24	28
200	No	27	50
	Yes	37	30

INFLUENCE OF POTASSIUM AND SULFUR ON THE YIELD OF RED CLOVER

Greg Cremers, Andy Scobbie, and George Rehm[1/]

ABSTRACT: Red clover may substitute for alfalfa in many farming enterprises where high costs of some inputs may discourage alfalfa production. Relatively little is known about the fertilizer requirements of red clover. In this study, neither K nor S increased the yield of red clover seeded in August of 1987. An erratic stand may have contributed substantially to variable yields which, in turn, masked treatment effects.

Red clover has the ability to tolerate soils with a relatively low pH. Therefore, lower rates of lime may be needed for profitable production. This reduced requirement for lime makes red clover an attractive legume for many farm enterprises that use legumes in their crop rotations.

The fertilizer requirements for the most profitable production of red clover are not well established. Red clover can easily substitute for alfalfa in rotations where soils are sandy with medium to low soil test values for potassium. Therefore, this study was conducted to measure the effect of potassium and sulfur on the yield of red clover.

EXPERIMENTAL PROCEDURE:

This study was conducted at the Irrigation Center at Staples. The soil is classified as a Sverdrup sandy loam. Results of the soil test showed a pH of 6.2, a P level of 34 lb./acre and a K level of 109 lb./acre. The organic matter content was 2.4%.

Lime at a rate of 2 ton/acre was broadcast and incorporated in mid-summer of 1987. The red clover was seeded with a Brillion seeder in early August of 1987. A seeding rate of 10 lb./acre was used. The Arlington variety was used.

Six rates of K (0, 20, 40, 80, 160, 320) were combined with 3 rates of S (0, 25, 50) in a complete factorial. The treatments were incorporated into a randomized complete block design with 4 replications. The K was supplied as 0-0-60 and granular gypsum was used to supply the S. Treatments were topdressed to the established stand in mid-April.

First cutting yields were measured on June 17 and 2nd cutting yields were harvested on July 26. The harvest area was approximately 3 ft. x 18 ft.

RESULTS AND DISCUSSION:

In 1988, neither K nor S had a significant effect on the yield of red clover (Table 1). Therefore, only total yields are shown.

Because of the relatively low soil test for K (109 lb./acre) and the sandy soil a response to both K and S was anticipated. There was, however, a substantial amount of variability in yields (C.V. of approximately 15%). This variability may have masked any response to K and S. Treatments will be repeated and this study will be continued in 1989.

Table 1. Effect of rate of K and S on total yield of red clover during the 1988 growing season.

S	K Rate (lb./acre)					
Rate	0	20	40	80	160	320
lb./acre	- - - - - - - -		ton D.M./acre		- - - - - - - - -	
0	3.01	3.21	3.22	2.97	2.76	3.19
25	3.07	2.89	3.16	3.48	3.38	3.23
50	2.95	2.70	3.10	3.68	3.66	2.91

1/ Assistant Scientist, Junior Scientist and Extension Specialist, respectively.

CORN-SOYBEAN ROTATION

H. Meredith, Mel Wiens, Greg Cremers, and Andy Scobbie[1]

ABSTRACT: This study was initiated in 1981 following widespread complaints by farmers that they were unable to maintain consistently high corn yields under a regime of continuous corn. The study contains two relative maturity hybrids and one soybean variety. Continuous corn and corn following first-year and second-year soybeans are evaluated. Corn yields have not increased following soybeans compared to a continuous corn regime.

The 1988 growing season was likely the best year in the history of irrigated corn in Minnesota. Early season temperatures permitted the crop to develop rapidly to capitalize on the long day length. Adequate moisture was provided through sprinkler irrigation to mitigate the intense heat experienced during the summer.

Table 1. Corn Yield @ 15.5% Moisture, Bu/A, Staples 1988.

No.	Treatment	1981	1982	1983	1984	1985	1986	1987	1988	Ave.
1	Cont. corn[1]	151	168	135	130	125	149	170	182	151
2	Cont. corn[2]	151	166	150	128	124	180	181	180	158
3	SB_1, SB_2, corn		168		137		142			149
4	Corn, SB	151		148		123		155	178	151
5	Corn, SB		170		140		144			151
6	SB_1, SB_2, corn			147				173		157
7	SB_1, SB_2, corn			155	132	115[3]			190	148

1/ Pioneer 3902, 90-day R.M. on all treatments except No. 2
2/ Pioneer 3790, 95-day R.M.
3/ Pioneer 3953, 80 day R.M.

Table 2. Soybean Yields, Bu/A, Staples 1988.

No.	1981	1982	1983	1984	1985[1]	1986	1987	1988
3	39	47	47	38	36		54	43
4						49		
5							52	47
6						53		44
7							53	

1/ Soybean yields averaged through 1985

Table 3. Supportive Information Pertaining to Corn Yields, Staples 1988

No.	Treatment	Harvest Population (X 1000)	Kernel Moisture (%H_2O)	Grain Yield T/A DM	Silage Yield T/A DM	Stover Yield T/A DM	Grain/ Stover Ratio
1	Cont. corn	29.5	17.0	4.31	7.92	3.61	.544
2	Cont. corn	29.2	19.5	4.27	8.36	4.09	.510
4	2nd year corn	28.8	17.4	4.22	8.07	3.85	.523
7	SB_1-SB_2-corn	31.4	17.7	4.48	8.17	3.69	.548

1/ Regional Director, Tennessee Valley Authority, Research Plot Coordinator, Staples Irrigation Center, Asst. Scientist, Jr. Scientist, University of Minnesota, respectively.

Table 4. Nutrient Removal in Corn Grain, Staples 1988

No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lbs/A										
1	144	9.8	27	34	.28	11.3	.26	.048	.29	.013	.032
2	137	9.8	26	30	.26	10.0	.19	.047	.24	.007	.027
4	142	9.5	26	34	.26	11.0	.25	.045	.27	.010	.031
7	148	10.5	26	35	.28	11.3	.31	.044	.33	.014	.032

Table 5. Nutrient Removal in Corn Silage (Grain & Stover), Staples 1988

No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lbs/A										
1	194	17	31	212	49	27	7.0	.64	.56	.034	.117
2	209	18	36	243	54	30	7.7	.79	.67	.037	.126
4	190	16	30	234	50	27	6.8	.67	.66	.029	.113
7	196	17	31	243	61	29	9.3	.88	.99	.035	.116

Table 6. Whole Corn Plant Nutrient Concentration at Silage Harvest, Staples 1988

No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%							ppm			
1	1.23	.10	.20	1.3	.31	.17	.045	40	36	2.1	7.4
2	1.25	.11	.21	1.4	.32	.18	.046	48	40	2.2	7.6
4	1.18	.10	.19	1.4	.31	.17	.042	42	41	1.8	7.0
7	1.20	.10	.19	1.5	.37	.18	.057	53	60	2.1	7.1

Table 7. Corn Leaf Tissue Concentration at Silking, Staples 1988

No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%							ppm			
1	2.8	.23	.25	2.6	.66	.20	.10	89	71	4.7	6.5
2	2.8	.24	.27	2.6	.65	.22	.09	82	61	4.8	7.2
4	2.9	.24	.26	2.5	.67	.22	.10	84	59	4.6	6.0
7	2.9	.23	.25	2.6	.68	.22	.11	101	99	4.3	4.9

Table 8. Chemical Analysis of Corn Grain, Staples 1988

No.	N	S	P	K	Mg	Fe	Mn	Zn	Cu	B	Ca
	%					ppm					
1	1.68	.11	.31	.40	.13	30	5.6	33	1.5	3.8	32
2	1.62	.12	.30	.26	.12	23	5.6	28	1.5	3.2	30
4	1.67	.11	.30	.40	.13	29	5.3	32	1.5	3.6	31
7	1.65	.12	.30	.39	.13	35	4.9	37	1.6	3.5	31

Table 9. Soybean Whole Plant Concentration, Staples 1988

No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%						ppm				
3	3.2	.22	.39	2.7	1.0	.38	.057	82	32	3.0	33
5	3.2	.22	.39	2.7	1.0	.39	.055	90	31	3.2	35
6	3.3	.22	.39	2.6	1.1	.37	.065	83	40	3.0	34

Table 10. Soybean Whole Plant Uptake, Staples 1988

No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	Lbs/A										
3	176	12	22	149	56	21	3.1	.46	.18	.017	.18
5	168	12	20	142	52	21	3.0	.48	.16	.017	.18
7	196	13	23	153	67	22	3.9	.50	.24	.018	.20

Table 11. Concentration of Nutrients in Soybean Grain, Staples 1988

No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%						ppm				
3	6.6	.37	.74	2.3	.18	.27	99	33	62	5.8	3.4
5	6.7	.37	.72	2.2	.17	.27	116	34	58	7.0	3.7
7	6.7	.38	.74	2.3	.17	.27	109	33	64	6.3	3.6

Table 12. Soybean Grain Nutrient Uptake, Staples 1988

No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	Lbs/A										
3	147	8.3	16	51	3.9	6.0	.22	.07	.14	.013	.077
5	164	9.2	18	55	4.3	6.5	.28	.08	.14	.017	.090
7	152	8.5	17	51	3.8	6.1	.25	.07	.14	.014	.083

Table 13. Soybean Trifoliate Leaf Analysis (early pod set), Staples 1988

No.	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%							ppm			
3	4.8	.36	.53	2.7	.92	.44	.034	110	59	3.5	41
5	4.8	.36	.53	2.7	.94	.44	.034	127	56	3.1	43
6	5.0	.36	.55	2.6	.89	.43	.031	110	53	3.5	41

LUPIN BEAN FERTILITY STUDY

H. Meredith, Mel Wiens, Greg Cremers, and Andy Scobbie[1]

ABSTRACT: The revival of an old legume specie (Lupinis albus) dating to biblical times kindled a need for an understanding of the nutritional requirements of this plant. This plant has a built-in "survival" system, which enables it to alter the rhizosphere and solubilize needed nutrients. A study was undertaken to determine if the lupin plant would respond to nutrient addition when managed for high yield levels. A study was initiated in 1984 which included five elements most limiting for production of agricultural legumes on the irrigated sands in central Minnesota.

In 1988, two sites were planted to lupins (Lupinus albus) and fertilized with sulfur (100 lbs. S/A) phosphorus (60 lbs. P_2O_5/A), potassium (300 lbs K_2O/A), zinc (10 lbs Zn/A) and boron (2 lbs B/A). One site is a continuous fertilized site since initiation of the studies in 1984. The second site had not been seeded to lupins previously.

Table 1. Summary of Lupin Yields 1984 to date. Staples Station, Staples, MN. Yields are based on 13.5 percent moisture and 60 pound bushel weight.

		Yield bu/A							
No.	Treatment	1984	1985	1986		1987		1988	
1	No fertilizer	39.1	71.4	40.6[1]	32.0[2]	57.2[1]	61.8[2]	47.6[1]	61.9
2	Sulfur	43.2	71.2	44.0	31.7	54.2	62.8	58.7	67.2
3	Potassium + S	40.5	63.8	40.6	43.3	49.9	61.9	50.9	61.1
4	Phosphorus + S+K	39.4	68.8	39.2	40.2	56.6	61.8	42.3	57.2
5	Zinc + S+K+P	39.4	64.1	41.8	37.4	47.2	56.3	42.8	58.0
6	Boron + Zn+S+K+P	41.5	64.9	33.8	32.8	54.8	60.8	52.0	52.3

1/ Old Fertility Site
2/ New Fertility Site

Because of the variability of yield within treatments, no significant differences in yield due to fertility treatments exist. The yield from the sulfur amended plots was highest in 1988 but upon application of statistical analysis, no significant differences were noted. the population was variable and weeds were a compounding factor.

Table 2. Nutrient Content of Lupin Beans, Staples 1988, Continuous Lupins

Treatment	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B	Fe
No.	%							ppm			
1	6.2	.27	.43	1.1	.26	.20	.069	45	3.5	14	28
2	6.4	.29	.42	1.2	.26	.20	.067	45	3.5	15	28
3	6.3	.28	.43	1.2	.26	.20	.067	46	3.6	13	27
4	6.0	.28	.42	1.2	.27	.20	.061	41	2.7	13	26
5	6.1	.28	.48	1.4	.26	.22	.060	52	2.6	12	28
6	6.0	.29	.44	1.3	.26	.21	.062	53	2.9	26	27

1/ Regional Director, Tennessee Valley Authority, Research Plot Coordinator, Staples Irrigation Center, Asst. Scientist, Jr. Scientist, University of Minnesota, respectively.

Table 3. Nutrient Content of Lupin Beans, Staples 1988, first year lupin fertility

	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B	Fe
No.	%							ppm			
1	5.6	.28	.49	1.2	.25	.20	.097	57	4.2	19	38
2	5.6	.28	.53	1.3	.26	.20	.094	60	4.1	19	34
3	5.4	.29	.56	1.4	.26	.20	.118	62	4.1	18	40
4	5.5	.28	.58	1.4	.27	.20	.105	59	4.1	18	36
5	5.5	.28	.58	1.4	.26	.20	.099	62	3.8	18	34
6	5.4	.30	.58	1.4	.27	.20	.102	60	3.4	26	35

LUPIN LIME, GYPSUM, AND SULFUR AMENDED STUDIES

H. Meredith, Mel Wiens Greg Cremers, and Andy Scobbie[1/]

ABSTRACT: Ground agricultural limestone, gypsum, and elemental sulfur were applied at various rates to determine if a change in soil pH would effect performance and uptake of nutrients for lupins.

Elemental sulfur, ground limestone, and gypsum were applied at various rates prior to planting of lupins to evaluate effect of soluble salts and soil pH on growth and uptake of selected nutrients.

Table 1. Nutrient Concentration of Lupin Beans Grown in Lime Amended Soils, Staples 1988.

Lime Lbs/A	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
0	6.2	.26	.42	1.2	.26	.21	26	1/	44	6.9	17
500	6.2	.26	.43	1.2	.26	.22	26	1/	43	1/	17
1000	6.0	.26	.42	1.2	.27	.21	26	1/	44	5.6	18
2000	6.2	.27	.42	1.2	.27	.21	28	1/	44	7.7	17

1/ Data unreliable

Table 2. Nutrient Concentration of Lupin Beans Grown on Gypsum Amended Soils, Staples 1988.

Gypsum	N	S	P	K	Ca	Mg	Mn	Fe	Zn	Cu	B
Lbs/A	- - -	- - -	- - -	%	- - -	- - -	- - -	- - -	- - -	ppm	- - -
0	6.0	.31	.41	1.1	.25	.20	.09	29	50	3.7	18
500	6.1	.34	.40	1.2	.27	.19	.10	29	50	3.8	18
1000	6.1	.36	.38	1.1	.27	.19	.10	29	50	3.8	17
2000	6.1	.26	.38	1.2	.27	.18	.10	28	51	3.6	18

Table 3. Nutrient Concentration of Lupin Beans Grown on Elemental Sulfur Amended Soil, Staples 1988.

Sulfur	N	S	P	K	Ca	Mg	Mn	Fe	Zn	Cu	B
Lbs/A	- - -	- - -	- - -	%	- - -	- - -	- - -	- - -	- - -	ppm	- - -
0	6.0	.30	.44	1.2	.26	.20	.11	31	52	6.8	19
500	6.2	.31	.43	1.2	.26	.20	.11	28	52	4.4	20
1000	6.1	.33	.43	1.2	.27	.20	.12	29	53	7.8	19
2000	6.0	.32	.42	1.2	.27	.20	.11	29	54	4.7	20

1/ Regional Director, Tennessee Valley Authority, Research Plot Coordinator, Staples Irrigation Center, Assist. Scientist, Jr. Scientist, University of Minnesota, respectively.

Table 4. Yield and Test Weight of Lupins Grown on Lime, Gypsum and Sulfur Amended Soils, Staples 1988.

	Lime Amended		Gypsum Amended		Sulfur Amended	
Treatment	Yield Bu/A	Test wt lbs/bu	Yield Bu/A	Test wt lbs/bu	Yield Bu/A	Test wt lbs/bu
0	47.3	64.9	45.0	64.5	56.1	65.0
500	52.6	64.6	44.3	63.9	56.9	65.0
1000	57.3	64.7	38.9	64.2	52.5	64.7
2000	50.6	64.8	40.4	63.9	58.3	64.8

There were no significant differences in concentration of nutrients in the beans or in yield due to any of the amendments. There appeared to be an increase in sulfur in the beans with the gypsum and sulfur treatments.

ANALYSES OF LUPIN HULLS, DEHULLED, AND WHOLE LUPINS

H. L. Meredith[1/]

ABSTRACT: Lupins are a high protein supplement used in ruminant, swine, poultry, and human diets. The high fiber containing hull of the lupin finds use in baking flour. The dehulled lupin is higher in protein and lower in fiber than the whole lupin.

Three lupin samples - whole lupins, the hulls of lupins, and the dehulled lupins were analyzed for chemical constituents to better understand the chemical nature and the nutrient value of the hull vs. the dehulled cotyledon portion of the seed.

Table 1. Analyses of Whole Lupins, Lupin Hulls, and Dehulled Lupin Cotyledon.

Seed Part	N	S	P	K	Ca	Mg	Mn	Fe	Zn	Cu	B	Al	Na
	%							ppm					
Hulls	0.75	.038	.04	.52	.79	.07	.026	26	7.2	3.3	14	5.6	50
Dehulled	6.14	.333	.55	.14	.16	.20	.254	31	60	7.9	23	1.6	79
Whole seed	5.68	.315	.55	.14	.22	.19	.186	39	72	8.2	22	2.0	71

The hull is low in protein (less than 5%), lower in sulfur, phosphorus, magnesium, manganese, iron, zinc, copper, boron, and sodium. The hulls are higher in potassium, calcium, and aluminum.

1/ Regional Director, Tennessee Valley Authority

TRITICALE - RYE STUDIES

H. Meredith and Mel Wiens[1/]

ABSTRACT: When the Latin terms for wheat and rye - Triticum and Secale-are combined, the term Triticale results. Triticale is a product of the selection of the desirable characteristics of wheat and rye into one species. Triticales are largely self fertilized and breed true from one generation to the next. As new triticale varieties are being developed, the yield potential under irrigation was evaluated.

Winter triticale and rye plots were fertilized to attain high yields under irrigation. High temperatures took their toll on the crop and yields were lowered.

Table 1. Yield of Rye and Triticale, Staples 1988

No.	Variety	Crop	Yield	Test Wt.	Straw Yield
			bu/A	lbs/bu	tons/A
1	Ind 6-6-2	Triticale	34.9	51.9	1.79
2	Ind 5-3-3	"	31.6	50.2	2.00
3	Mitzi Rye	Rye	55.3	60.2	2.04
4	Iowa 2-19-4	Triticale	35.9	56.1	1.68
6	Rymin	Rye	61.1	61.0	2.09
7	Ind 3-2-2	Triticale	40.1	54.7	2.06
8	Ind 2-2-4	"	45.9	55.0	2.00

1/ Regional Director, Tennessee Valley Authority, Research Plot Coordinator, Staples Irrigation Center, University of Minnesota, respectively.

WATER QUALITY STUDIES

H. Meredith and Mel Wiens[1/]

ABSTRACT: The Staples Station irrigation pumps lift water from an aquifer about 15 feet below the surface. The sand plain composed of coarse materials permits excessive internal drainage of the soil profile. Leaching of soluble nutrients occurs in the presence of excessive water. Water samples from pumping wells lends a tool to monitor the nutrient status of these wells.

Table 1. Nutrients in Irrigation Water, Staples 1988

Date	Location	NO^{3}	SO^{4}	P	K	Ca	Mg	Na	Zn	Cu	B	Mn
		ppm										
7/21	Well Farm Shop	0.43	33.5	T	.9	81	24	3.3	.03	T	T	T
7/21	2 Tower	9.5	27.0	T	2.1	85	26	3.4	T	T	T	T
7/21	Well B	5.1	6.0	T	1.0	95	25	2.1	T	T	T	.5
7/9	SW Lagoon	1.4	8.7	T	2.5	54	15	1.9	T	T	T	T
7/21	2 Tower	8.1	34.4	T	T	94	25	2.6	T	T	T	T
7/21	Single Tower	7.3	32.1	T	13.1	83	25	3.4	T	T	.02	.7
7/1	Well B	6.1	5.7	T	1.0	93	25	2.1	T	T	T	.02
7/7	SW Pit	1.5	5.6	T	1.8	53	15	1.9	T	T	T	T
6/24	2 Tower	9.8	33.3	T	2.3	89	24	2.6	T	T	T	.4
7/21	Well C	4.1	5.2	T	T	86	24	2.0	T	T	T	.5
7/21	Well D	3.4	6.7	T	.9	78	21	2.0	T	T	T	.3
7/21	Well A	11.0	12.4	T	1.1	92	25	2.6	T	T	T	T
6/24	Well D	3.7	7.1	T	1.3	79	22	1.8	.17	.31	T	.4

Table 2. Nutrients in irrigation water expressed in pounds per acre and on 12 inches of irrigation water, Staples 1988.

Location	NO_3-N	SO_4-S	$CaCO_3$ Equivalent
	Pounds/A		
Well Farm Shop	.2	30	593
2 Tower	5.6	24	582
Well B	3.2	5.4	667
SW Lagoon	.8	7.9	504
2 Tower	4.9	31.2	646
Single Tower	4.3	28.8	672
Well B	3.8	5.2	770
SW Pit	.8	5.2	478
2 Tower	26.4	30	616
Well C	11.0	4.6	743
Well D	9.2	6.0	667
Well A	30	11.2	672
Well D	10.0	6.5	689

1/ Regional Director, Tennessee Valley Authority, Research Plot Coordinator, Staples Irrigation Center, University of Minnesota, respectively.

SOUTHERN EXPERIMENT STATION
WASECA, MINNESOTA

WEATHER DATA - 1988

Month	Period	Precipitation 1988	Precipitation Normal 1/	Avg. Air Temp. 1988	Avg. Air Temp. Normal 1/	Growing Degree Days 1988	Growing Degree Days Normal 1/
		---- inches ----		------ °F -----			
January	1-31	2.44	0.84	7.0	10.0		
February	1-29	0.36	0.99	10.9	16.4		
March	1-31	1.34	1.99	33.0	27.6		
April	1-30	2.43	2.64	44.6	44.7		
May	1-10	1.62		62.6		138.0	
	11-20	.10		61.1		130.5	
	21-31	.27		70.9		211.5	
	Total	1.99	3.76	64.8	57.7	480.0	334
June	1-10	0.00		72.2		220.0	
	11-20	0.63		74.3		224.5	
	20-30	0.70		75.1		223.5	
	Total	1.35	4.48	73.9	67.1	668.0	518
July	1-10	0.23		74.8		230.0	
	11-20	0.19		74.3		225.5	
	21-31	0.19		74.5		261.5	
	Total	0.61	4.02	74.5	71.2	717.0	641
August	1-10	3.44		77.2		243.5	
	11-20	0.27		78.2		259.0	
	21-31	0.61		64.0		168.5	
	Total	4.32	3.99	73.1	68.8	671.0	579
September	1-30	5.34	3.36	62.1	59.8	412.5	311
October	1-31	0.32	2.08	43.0	48.9	18.5	38
November	1-30	3.98	1.43	32.4	32.5		
December	1-31	0.74	1.02	18.9	18.0		
Year	Jan-Dec	25.22	30.60	45.0	43.6	2970.0 2/	2421
Growing Season	May-Sep	13.61	19.61	69.7	64.9	2948.5	2383

1/ 30-year normal from 1951 - 1980.
2/ 50 to 86°F base, May 1 until first fall frost.

Notes:
1) Highest temperature on August 1 -- 103°.
2) Highest 24-hour precipitation on August 3 -- 1.81".
3) Last spring frost -- April 28.
4) First fall frost -- October 3.
5) Warmest growing season in 74 years of records.
6) Driest year since 1976.
7) Driest May-July period in 74 years of records.

NITRATE LOSSES TO TILE DRAINAGE AS AFFECTED BY NITROGEN FERTILIZATION OF CORN IN A CORN-SOYBEAN ROTATION[1/]

Waseca, 1988

Gyles W. Randall, Gary L. Malzer and Brian W. Anderson[2/]

ABSTRACT: A study to determine the influence of time of N application and N-Serve on the uptake of N by corn and the loss of NO_3 to tile drainage was continued in 1988. Results from this second year were greatly affected by the hot and dry stress conditions. Yields were not consistently affected by N nor its time of application. Nitrogen efficiency was extremely poor. The majority of N uptake occurred prior to silking for all treatments. Tile lines flowed sporadically in late April and early May and averaged less than 1 acre-inch discharge. Even though NO_3-N concentrations averaged about 18 mg/L, NO_3-N losses were very low. Apparently soil mineralization was abundant because residual NO_3 remaining in the soil profile at the end of the season was quite high even when no N had been applied to corn. Accumulation of NO_3 in the top 2' was substantial (200 to 230 lb/A) where N had been applied as a split application.

Nitrogen (N) losses to tile drainage water have been directly linked to N additions, crop grown, and soil organic matter level. Research has been conducted on NO_3 losses to tile water in Minnesota since 1972. This research has focused primarily on the effects of rates and timing of fertilizer N application and tillage in a continuous corn system. The purpose of this study is to determine the influence of time of N application and the use of a nitrification inhibitor on NO_3 movement and accumulation in the soil, NO_3 losses via tile drainage, and yield and N uptake by corn grown in a rotation with soybeans.

EXPERIMENTAL PROCEDURES

Thirty-six individual tile line plots were installed on a poorly drained Webster clay loam at the Southern Experiment Station in 1976. Each 20 x 30' plot is completely surrounded by plastic sheeting to a depth of 6' to prevent lateral flow and contains a tile line (4' deep) 5 feet from one end. All tiles drain to collection pits where flow rates can be measured and water samples collected for analyses. After completing a research project in 1983 using this tile facility, the plots were cropped to corn with a blanket N rate in 1984 and 1985 to establish uniformity.

Beginning in 1986 corn was planted on one-half of the experimental site while soybeans were planted on the other half. Thirty two plots (16 with corn and 16 with soybeans) with the most uniform drainage were selected from the 36 for the primary study. The experimental design consists of a 4 x 4 Latin square where the rows and columns were based on the previous (1977-83) tile flow rates from each plot. The four basic N treatments (see Table 1) are applied to the corn phase each year with the residual effects measured in the soybean phase. Three additional N treatments were replicated four times around the edge of the core 16-tile-plot area and were planted to corn. These three treatments were analyzed along with the other four as a completely randomized design.

Anhydrous ammonia was applied at a rate of 135 lb/A for all N treatments while N-Serve was applied at 0.5 lb/A. Fall treatments were applied on October 21. Average soil temperature at the 4" depth on that date was 43°F with an average of 43°F over the following 10-day period. Spring preplant treatments were applied on April 18. The sidedress portion (60%) of the split treatments was applied at the V-7 stage on June 15.

No primary or secondary tillage was done on the soybean area that was planted to corn in 1988. The corn area, however, was fall chiseled and spring disked once prior to planting soybeans. Surface residue accumulation estimated by the line-transect method on June 2 showed an average of 18 and 30% for the areas that were planted to corn and soybeans, respectively, in 1987. Because of high soil P and K tests, no broadcast nor starter fertilizer was used.

1/ Partial funding provided by Dow Chemical U.S.A., Center for Agricultural Impacts on Water Quality, and Minnesota Agric. Exp. Stn.

2/ Professor, So. Exp. Stn.; Assoc. Prof. Dept. of Soil Science; Assistant Scientist, So. Exp. Stn., Waseca.

Corn (Pioneer 3737) was planted at 30,800 plants/acre on May 6 with a JD Max-Emerge planter equipped with waffle coulters. A corn rootworm insecticide was not used. Weeds were chemically controlled with a preemergence application of Lasso (3.5 lb/A) plus Bladex (3 lb/A).

Soybeans (Hardin) were planted in 13" rows at 3-4 beans per foot of row on May 19. Weeds were chemically controlled with a preemergence application of Lasso (3½ lb/A) plus Amiben (3 lb/A). Pursuit (imazethapyr) was applied on June 7 at 0.06 lb/A plus 0.25% v/v X-77 to plots 1, 5, 6, 11, 12, 13, 15 & 16 to determine if it could be found in tile drainage water.

Two plots within each of the corn and soybean areas were not planted and were fallowed all summer. These four fallow plot areas were located on those tile plots that showed greatest water flow variability (1977-83). The purposes of these plots were to simply check the NO_3-N concentrations in the tile water in a fallow system and to utilize all 36 of the tiled plots, even though these four historically showed the highest flow variability.

Stand counts were taken at the V-7 stage and plots were thinned to a uniform population. Eight randomly selected plants were removed from the center rows at silk initiation (July 19) and were chopped, dried, weighed and ground for total dry matter accumulation and analyzed for total N concentration. Stover and grain samples were taken at physiological maturity by hand harvesting 30' of row for stover yields and 60' of row for grain yields and moisture. Chemical analyses of whole plant, stover and grain samples were performed by the Research Analytical Laboratory, University of Minnesota.

Tile line flow rates were determined daily and were recorded when flow exceeded 10 ml/minute (0.01"/day). Samples were collected for NO_3-N analysis on an every-other-day basis. Periodic samples were collected for alachlor (Lasso) and cyanazine (Bladex) analyses.

Soil samples for NO_3-N analysis were taken in 1-foot increments to a depth of 8 feet from the fallow plots and selected corn and soybean plots on April 19. The same technique was used to sample all fallow and corn plots and selected soybean plots after harvest on October 14.

RESULTS AND DISCUSSION

Plant

Whole plant N concentration at the silking stage was greatly increased over the check by all of the N treatments with little difference among the six N treatments (Table 1). Dry matter accumulation at this stage was unaffected by N treatment. Stover N concentration at physiological maturity (PM) was increased consistently over the check by all N treatments. Stover yield at PM was higher for the three additional N treatments (even the control) than for the four primary N treatments. This unexpected result was noticed for all yield parameters at PM. It was probably due to "over" drainage in the small plots with the 25' tile spacing compared to the border plots without the close spacing in this very dry year. This phenomenon had never been encountered in 11 previous years of experiments at this tile drainage site. Final population was not significantly different among the N treatments.

Table 1. Influence of time of N application and N-Serve on whole plant N, stover yield, and final population of corn following soybeans.

N application		Whole Plant Silk Stage		Stover		
Time	N-Serve	N	DM	N	Yield	Final Population
		%	g/plt	%	TDM/A	ppA x 10[3]
Primary trts						
Fall (Oct.)	No	1.44	102	.69	1.74	29.1
Fall (Oct.)	Yes	1.48	102	.67	1.65	29.2
Spr. (April)	No	1.47	96	.72	1.63	29.7
Split[1/]	No	1.41	96	.67	1.52	28.8
Additional trts						
Check	-	1.20	92	.53	1.74	29.2
Spr. (April)	Yes	1.54	103	.71	2.07	29.7
Split[1/]	Yes	1.43	97	.68	1.93	30.0
Statistical Analysis						
Latin square (Primary Trts)						
Signif. Level (%):		50	58	18	58	23
CV (%) :		4.8	7.6	11.	10.	4.1
Completely randomized (7 trts)						
Signif. Level (%):		99	83	94	99	31
BLSD (.05) :		.07	-	-	.30	-
CV (%) :		3.8	6.7	12.	11.	3.5

1/ 40% preplant + 60% sidedress.

Grain yields in general were low but were also lower for all primary N treatments located in the Latin square design compared to the additional N treatments along the border (Table 2). Significant differences in yield were not found among the four primary N treatments due to the high CV (15%). Although grain moisture tended to be higher in the additional N treatments, differences were not significant due to the high variability. Grain N concentration was improved significantly over the 0-lb N control by all N treatments. In the primary study, grain N was significantly higher for the fall treatment without N-Serve than the split treatment. Grain N removal (product of grain yield times N concentration), silage DM yield, and total N uptake in the silage were not different among the four primary N treatments but were lower for these four treatments than for the border plots when N was applied.

Total N removal in the grain ranged from 66.9 to 92.6 lb/A for the six N treatments (Table 2). Based on these removal amounts, N efficiency (N removed by a treatment - N removed in the check ÷ 135 lb N/A) ranged from 1 to 16% for the four primary treatments up to a maximum of 39% with the spring preplant application with N-Serve. Nitrogen efficiency based on the total plant uptake ranged from 6 to 16% for the four primary treatments up to a high of 43% with the spring preplant application with N-Serve. These efficiency values are very low and reflect the stress conditions during the 1988 growing season.

Total N uptake by the plants prior to silking (Fodder N yield at silking) divided by total N uptake at PM shows that from 79 to 102% of the N was accumulated by the plants prior to silking (Table 3). The lowest amounts of pre-silk N accumulation were found on the additional border plots. In general, split application of N reduced pre-silk N uptake slightly. NEW N in the grain (assumed to be taken up by the plant after silking and translocated to the grain) ranged from -3 to 23%. Under these conditions fall applications of N with or without N-Serve and spring application without N-Serve resulted in almost no post-silk N uptake into the grain. However, post silk N uptake into the grain ranged from 11 to 23% with the split applications.

Table 2. Corn grain and silage production as influenced by time of N application and N-Serve.

N application		Grain					Total N
Time	N-Serve	Yield	H_2O	N	N removal	Silage	uptake
		bu/A	%	%	lb/A	TDM/A	lb/A
Primary trts							
Fall (Oct.)	No	90.9	15.4	1.66	71.4	4.42	95.4
Fall (Oct.)	Yes	101.4	15.8	1.60	76.8	4.65	98.8
Spr. (April)	No	87.6	15.6	1.62	66.9	4.26	90.2
Split[1/]	No	99.6	15.7	1.55	73.2	4.53	93.8
Additional trts							
Check	-	102.4	17.7	1.37	66.4	4.76	85.2
Spr. (April)	Yes	121.4	17.2	1.62	92.6	5.74	122.1
Split[1/]	Yes	123.4	18.5	1.52	89.0	5.57	115.5
		Statistical Analysis					
Latin square (Primary trts)							
Signif. Level (%):		84	1	99	59	72	23
BLSD (.05) :		-	-	0.03	-	-	-
CV (%) :		8.9	12.	1.2	11.	5.8	12.
Completely randomized (7 trts)							
Signif. Level (%):		97	66	99	97	99	98
BLSD (.05) :		26.2	-	0.07	20.0	0.63	24.7
CV (%) :		15.	13.	3.2	16.	8.8	15.

1/ 40% preplant + 60% sidedress.

Table 3. Influence of time of N application and N-Serve on time of N uptake.

N application		Fodder N Yield at[1/]		Grain N Yield at PM			
Time	N-Serve	Silk	PM	Total	OLD[2/]	NEW[3/]	NEW[3/]
		lb N/A					%
Primary trts							
Fall (Oct)	No	94.8	24.1	71.3	70.7	.6	1
Fall (Oct)	Yes	97.9	21.9	76.8	76.0	.8	1
Spr (April)	No	92.3	23.3	67.0	69.0	-2.0	-3
Split[4/]	No	85.6	20.6	73.2	65.0	8.2	11
Additional trts							
Check	-	71.3	18.7	66.5	52.6	13.9	19
Spr (April)	Yes	103.5	29.4	92.6	74.0	18.6	17
Split[4/]	Yes	91.7	26.4	89.0	65.3	23.7	23
		Statistical Analysis					
Latin square (Primary trts)							
Signif. Level (%):		46	36	59	56	76	77
CV (%) :		13.	18.	11.	13.	318.	332.
Completely randomized (7 trts)							
Signif. Level (%):		99	98	97	99	94	93
BLSD (.05) :		11.8	6.3	20.0	10.2	-	-
CV (%) :		8.9	16.	16.	10.	137.	135.

1/ Silk = silk stage, PM = physiological maturity.
2/ OLD N = N in stover at silk - N in stover at PM; the difference is assumed to be translocated to the grain.
3/ NEW N = Total N in grain - Old N; the difference is assumed to be absorbed from the soil and/or translocated from the roots after silking.
4/ 40% preplant + 60% sidedress.

Water

April through July conditions were extremely hot and dry and resulted in rapid early season growth with subsequent stunting due to low soil water levels. Because precipitation for April through May totaled only 4.42" (69% of the normal 6.40"), tile lines flowed only sporadically from April 28 thru May 20. Drainage ranged from 0.38 to 1.10 acre inches in the plots planted to corn (Table 4).

Table 4. Influence of N application time and N-Serve on NO_3-N concentration and N loss to tile lines in 1988.

N Application		Tile Flow 1/	NO_3-N	
Time	N-Serve		Concentration	Loss
		acre-inches	mg/L	lb N/A
Fall	No	0.62	18.0	2.54
Fall	Yes	1.10	16.1	4.01
Preplant	No	0.87	22.3	4.40
Split	No	0.38	15.5	1.33
None (Fallow) 2/	-	0.62	19.4	2.71

1/ Tile flow occurred August 28 to May 20.
2/ Average of 4 replications.

Flow-weighted NO_3-N concentrations averaged from 15.5 to 22.3 mg/L. Perhaps these high values were partially due to the soybeans in 1987 and the high rate of N (260 lb N/A) applied for the 1986 corn crop. Nitrate-N losses via the drainage water ranged from 1.3 to 4.4 lb/A in 1988 and were highly dependent on volume of drainage water.

Soil

Nitrate-N remaining in the 0-8' soil profile in mid-April was very high in the fallow plots (207 lb/A) compared to those where either soybeans or corn were grown in 1987 (Table 5). Soybeans that had not received fall-applied N averaged 109 lb/A with 76 lb/A remaining in the top 5'. Little residual NO_3-N remained in the 0-8' profile when corn was the previous crop, especially when no N was applied (49 lb/A). Differences among the fall, preplant and split applications were small. Distribution of NO_3 within the profile was consistently high to 6' with the fallow system, high in the surface 1-foot and uniformly medium to high to 7' with soybeans, and generally high in the surface 1-foot, medium to high in the 1 to 2' zone, and low below 2' for corn.

Table 5. Nitrate-N in the soil profile in April, 1988 as influenced by previous crop and N treatment for corn in 1987.

Profile depth	1987 Crop					
			Corn			
	Fallow	Soybean	0 lb N	Fall	Preplant	Split
feet	lb/A 1/					
0-1	36.4	23.0	20.4	22.0	27.8	23.8
1-2	34.2	13.4	4.8	13.0	16.3	12.2
2-3	35.6	10.5	1.4	5.6	13.4	7.0
3-4	34.3	10.7	1.8	4.7	7.1	6.0
4-5	23.4	18.1	3.6	4.4	5.6	5.1
5-6	19.3	14.7	5.0	4.8	5.0	5.1
6-7	12.0	10.0	6.1	4.9	4.8	5.1
7-8	11.7	8.4	5.6	5.4	4.6	5.1
Total in						
0-5' profile	163.9	75.7	32.0	49.7	70.2	54.1
0-8' profile	206.9	108.8	48.7	64.8	84.6	69.4

1/ Average of 4 replications

Residual NO_3-N remaining in the 0-8' profile after the 1988 crop was considerably higher in the fallow plots (447 lb/A) and the soybean area planted to corn without N (224 lb N/A) than in April (Table 6). This was due to high mineralization activity during the 1988 growing season. Residual NO_3 remaining in the fertilized corn plots was also quite high and reflects the low crop demand. Differences among the N treatments were not substantial; however, consistently higher levels were found with the N-Serve treatments.

Table 6. Residual NO_3-N remaining in the 0-8' soil profile after harvest as influenced by time of N application and N-Serve.

Profile			Application Time					
			N-Serve			No N-Serve		
depth	Fallow	Check	Fall	Preplant	Split	Fall	Preplant	Split
ft.	lbs NO_3-N/A[1/]							
0-1	85.3	45.1	75.8	67.9	138.7	56.9	69.4	93.9
1-2	84.7	26.0	59.1	60.7	95.0	57.1	93.3	108.9
2-3	63.9	20.0	40.9	34.5	29.3	42.7	37.9	40.9
3-4	57.9	24.0	28.1	24.6	23.1	36.4	31.7	29.2
4-5	56.4	24.3	37.7	25.6	27.4	38.1	33.4	28.4
5-6	43.0	29.4	33.9	25.7	25.2	30.9	30.0	30.3
6-7	29.5	28.7	26.5	23.0	25.6	33.9	27.4	26.7
7-8	26.6	26.7	24.2	19.7	20.6	32.6	28.4	24.9
Total in								
0-5' profile	348	139	242	301	314	231	266	213
0-8' profile	447	224	326	282	385	329	352	383

1/ Avg. of 4 replications

CONCLUSIONS

The hot and dry conditions resulted in low and highly variable corn yields, poor N efficiency, and low drainage volume and accompanying NO_3-N losses. Nitrate N concentrations in the tile water averaged about 18 mg/L. Mineralization of soil organic matter is thought to have caused substantial increases in soil NO_3-N in the 0-8' profile between April and October even when corn received no N fertilizer. As of mid-October high levels of residual NO_3 remained in the upper two feet of the profile in all corn plots except the 0-lb N rate.

NITROGEN LOSS TO TILE LINES AS AFFECTED BY TILLAGE[1/]

Waseca, 1988

G. W. Randall and B. W. Anderson[2/]

ABSTRACT: No tillage (NT) is thought to increase infiltration and, therefore, should increase the amount of water percolating through the soil compared to conventional tillage. This long-term study is being conducted to determine if greater amounts of NO_3-N and pesticides are being lost to tile drainage water with NT compared to moldboard plow (MP) tillage. Rainfall during 1988 was 5.4" below normal and tile flow was limited. Although NO_3-N losses were similar for the two tillage systems, NO_3-N concentrations were markedly higher with MP tillage -- the first time in seven years. Corn yields and N uptake were consistently higher with MP but due to high variability these differences were often not significant at the P = 90% level. Substantially higher amounts of NO_3 remained in the 8-foot soil profile in October with the MP system compared to NT.

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

EXPERIMENTAL PROCEDURES

A study was initiated in 1975 on a Webster clay loam at Waseca to monitor the movement of N into a tile line installed in each of 12 plots measuring 45' by 50'. Each plot is enclosed with plastic sheeting to a 6' depth. Annual N rates of 0, 100, 200, and 300 lb N/A were applied from 1975-1979. No N was applied for the 1980 and 1981 crops. Residual N from N applied over the 5-year period (75-79) was utilized by the 1980 and 1981 corn crops. Soil samples to 10' and tile water samples taken in late 1981 showed little remaining evidence of the previous treatments.

In the fall of 1981, eight plots with the most uniform tile flow rates over the 1975-81 period were selected. Two tillage treatments (fall moldboard plow and no tillage) were replicated four times and randomized over the previous plot histories. Corn was grown on these plots in 1982 through 1987. The stalks were chopped in October, 1987 and moldboard plots plowed.

On April 18, 180 lb N/A as ammonium nitrate was broadcast applied to the surface of all plots. The moldboard treatment was then field cultivated. Corn (Pioneer 3732) was planted on May 6 at a population of 27700 plants/A with a John Deere Max-Emerge planter equipped with ripple coulters. Starter fertilizer was not used because of the high soil tests. Counter was applied at 1 lb (ai)/A to control rootworms. Weeds were controlled with a preemergence application of Lasso (3½ lb/A) and atrazine (3 lb/A) applied May 13. Weed and insect control were excellent. Percent surface residue was measured on April 8 and averaged 6 and 97% for the MP and NT systems, respectively.

The leaf opposite and below the ear was taken from 10 randomly selected plants per plot at silking (MP = July 14 and NT = July 21) and was analyzed for N. Silage and grain yields were taken at physiological maturity by hand harvesting 40' and 80' of row, respectively, from each plot.

Tile lines flowed from only April 27 to May 26. When tile lines were flowing, flow rates were measured daily and samples taken on a daily basis for the first week and then on a M-W-F basis thereafter for NO_3 analysis. All analyses were done by the Research Analytical Lab.

Soil NO_3-N in the 0-8' profile was determined from two cores/plot taken in 1-foot increments on October 14, 1988.

1/ Funding provided by the North Central Regional Research Committee (NC-98) and the Southern Experiment Station.

2/ Professor and Asst. Scientist, Southern Experiment Station, Univ. of Minnesota.

RESULTS

Although yields and N removal tended to be consistently higher with the moldboard plow (MP) system compared to the no tillage (NT) system, differences between the two tillage systems were not significant at the P = 90% level (Table 1). Total N uptake in the silage was significantly increased 93% level) by the MP tillage system. This was due to the high variability caused by the moisture and heat stress conditions during June, July and early August. Leaf N was increased significantly by the MP tillage system, but grain N concentration was not affected by tillage.

Table 1. Influence of tillage system on corn production and N utilization at Waseca in 1988.

Tillage system	Final population	Leaf N	Silage Yield	Silage N uptake	Grain Yield	Grain N	Grain N removal
	x10^{3}	%	T DM/A	lb N/A	bu/A	%	lb N/A
Moldboard Plow	24.8	2.58	3.79	102.1	100.6	1.67	78.9
No Tillage	24.4	2.28	3.26	87.5	83.3	1.64	64.7
Signif. Level (%):1/	33	98	79	93	75	45	86
CV (%) :	5.8	4.3	13.	7.8	19.	4.2	14.

1/ Probability level of significance.

Precipitation during the growing season was 6.0" below normal. Thus, tile flow was confined from late-April into late-May. Tile flow was slightly higher for the NT system; however, NO_3-N concentrations were markedly higher with the MP system. Nitrate losses to the drainage water were similar for the two systems. Soil moisture samples taken July 21 showed 1.76 and 3.26" of available water in the 5-foot profile for the MP and NT systems, respectively. This is probably the reason corn fared better on the NT plots than on the MP plots in late July and August.

Table 2. Influence of tillage system on tile flow, NO_3-N concentration and NO_3-N loss in 1988.

Tillage system	Tile flow	Nitrate-N Concentration1/	Nitrate-N Loss
	acre inches	mg/L	lb N/A
Moldboard Plow	1.80	14.8	5.68
No Tillage	2.52	9.4	5.27

1/ Flow-weighted

Residual NO_3-N in the soil profile at the end of the 1988 growing season showed about 112 lb/A more N remaining with the MP system (Table 3). The largest differences between the two tillage systems occurred in the top 2' where substantially more NO_3 accumulated with MP. These results are similar to 1987.

Table 3. Influence of tillage systems on residual NO_3-N in the soil profile in Oct., 1988.

Profile depth	Tillage System: Mb. Plow	Tillage System: No Tillage
feet	NO_3-N (lb/A)	
0-1	97.2	54.0
1-2	64.1	24.2
2-3	30.6	27.6
3-4	31.1	22.5
4-5	31.6	24.4
5-6	32.8	28.9
6-7	32.5	28.9
7-8	28.7	26.3
Total (lb NO_3-N/A 0-8')	348.6	236.8

SEVEN-YEAR SUMMARY

The cumulative totals for the 7-year period (1982-1988) are shown in Table 4. Corn yields over this period have averaged 9 bu/A better with moldboard plow tillage. Approximately 11% more N has been removed in the grain with moldboard plow tillage. This has been due to both higher yields and slightly higher grain N concentrations with the moldboard tillage system some years. Even so, very little difference in applied N removed in the grain exists between the two treatments (49% vs 44% for MP vs NT, respectively). Even though total water flow and NO_3-N lost through the tile lines was about 8% higher with no tillage, this small difference is considered to be insignificant when considering tile flow variability among the eight plots over this 7-year period.

Table 4. Cumulative effects of the two tillage systems over the 7-year period.

Parameter	Tillage System: Mb. plow	Tillage System: No tillage
Fert. N applied (lb/A)	1260	1260
Corn grain removed (bu/A)	932	869
N removed in grain (lb/A)	623	559
N removed in grain as a percent of applied N (%)	49	44
Tile flow (acre inches)	60.4	65.2
Nitrate-N lost in tile (lb/A)	146.4	157.8
N lost via tile lines as a percent of applied N (%)	12	13

RESIDUAL SOIL NITRATE FOLLOWING ALFALFA AS INFLUENCED BY TILLAGE AND CORN HYBRID[1/]

C. G. Zadak, G. W. Randall, and M. P. Russelle[2/]

ABSTRACT: Experiments were initiated at three locations in 1988 to determine the influence of tillage, N rate, and corn hybrid on the residual NO_3-N remaining after harvest in a first year corn after alfalfa cropping system. Soil NO_3 in the 0-5' profile was low prior to tillage and planting in the spring. Thirty to 50% of the profile NO_3 was found in the top foot. The applied N resulted in higher residual NO_3 in the fall at all three locations with the majority accumulated in the top foot. Corn hybrid affected residual NO_3 in one location while tillage significantly affected fall NO_3 levels at another location. Substantially more NO_3-N remained with moldboard plow tillage compared to no tillage especially when 62 lb N/A was applied. These data indicate that soil NO_3-N levels following alfalfa change dramatically between the spring and fall and that N rate, tillage and hybrid can affect NO_3 levels.

Recent evidence has shown that residual soil nitrate (NO_3) in the upper part of the root zone may be helpful in more accurately predicting fertilizer N needs of corn. The purpose of this study was to determine: (1) the amount of NO_3-N in the 0 to 5' profile in the spring following alfalfa, (2) the amount of residual NO_3-N remaining after 1st year corn following alfalfa was harvested, and (3) the effect of tillage, corn hybrid, and fertilizer N rate in this alfalfa-corn sequence on residual NO_3-N.

EXPERIMENTAL PROCEDURES

Studies were initiated into growing alfalfa stands at the Rosemount Agricultural Experiment Station, Southern Experiment Station at Waseca, and on the Gary Luehmann farm in Winona Co. in April, 1988. The primary soil type at each location was Port Byron sil, Nicollet cl, and Seaton sil, respectively. A randomized, complete-block experiment in a split-plot arrangement with four replications was used. Main plots consisted of two primary tillage variables (moldboard plow vs no tillage) while subplots consisted of six genetically dissimilar 105-day RM corn hybrids.

Random soil cores were taken in 1-foot increments to a depth of 7', 6' and 5' at the Rosemount, Winona, and Waseca locations in mid-April prior to spring tillage. Specific treatments were sampled in mid-October after corn harvest by taking two cores per plot and compositing the cores according to the depth increments. The soil was forced-air, oven-dried at 120°F, crushed to pass a 2 mm sieve, and analyzed for NO_3-N concentration.

RESULTS AND DISCUSSION

Spring sampling

Samples taken prior to tillage of the alfalfa showed low levels of NO_3-N in the 0-5' profile at each site (Table 1). Lowest values were obtained at Winona and Waseca. From 30 to 50% of the NO_3 in the 5-foot profile was found in the top foot.

Fall sampling

Rosemount

Fall soil NO_3-N data for Rosemount are given in Tables 2 and 4. In contrast to the spring data, this site showed the lowest amount of total NO_3-N in the profile of the three sites -- as much as 100-150 lbs N/A less. These differences might be due to differences in the 1987 alfalfa stand. There were no differences in total residual NO_3-N at Rosemount due to tillage when averaged over hybrid and N rate, but differences due to N rate and hybrid were present. The magnitude of the difference between the 0 and 62 lb N/A rates was nearly equal to the 62 lb N/A application. Most of this N remained in the top foot of soil, however. In fact, very little

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1/ Funding provided by the Minnesota Agric. Exp. Stn. and the So. Exp. Stn. at Waseca.
2/ Graduate research assistant, Dept. of Soil Science; Professor, So. Exp. Stn., Waseca; and Assoc. Professor, Dept. of Soil Science and USDA-ARS-USDFRC.

NO_3-N was detected below 2 feet. Approximately 20 lbs less N/A was present under P3569 than under P3732 (no difference in total N uptake between these hybrids was detected, however).

Winona Co.

Fall results for the Winona Co. site are given in Tables 3 and 4. Again, a significant increase in total profile NO_3-N occurred due to N application, with most of the NO_3-N concentrated in the top foot. There were 80 lbs N/A more in the profile under moldboard tillage than under no-tillage when averaged over N rates and hybrids. This is likely the result of greater mineralization of the alfalfa residues caused by the tillage. The presence of a significant tillage X N rate interaction is a bit puzzling. Perhaps this was due to greater uptake of the fertilizer N under no-tillage (a good response to fertilizer N addition was observed for no-tillage) or greater immobilization of the surface-applied N occurred under no-tillage. No differences in residual NO_3-N between the two hybrids (P3732 and DK547) were detected.

Waseca

Fall total profile NO_3-N values were similar to those at Winona Co. (Tables 5 and 6). Again, addition of N resulted in higher residual NO_3-N levels, with most of the NO_3-N in the top foot. Little to no differences in the residual NO_3-N are apparent under the 30, 62, and 90 lb N/A rates, however. No difference in residual N due to tillage is apparent. Clearly, the low yields that occurred at this site minimized the potential for differences in soil NO_3-N to show up.

Table 1. Soil nitrate-N following alfalfa in April, 1988.

Profile depth	Location: Rosemount	Winona Co.	Waseca
feet	------ lb NO_3-N/A ------		
0 - 1	32.4	13.2	16.0
1 - 2	13.6	7.1	9.7
2 - 3	6.7	4.3	6.6
3 - 4	4.2	2.9	3.1
4 - 5	2.2	2.0	3.5
Total in profile	59	30	39

Table 2. Residual soil nitrate-N after harvest in October, 1988 at Rosemount as influenced by tillage, hybrid, and N rate.

Profile		Moldboard				No-tillage			
		P3732		P3569		P3732		P3569	
depth	lb N/A:	0	62	0	62	0	62	0	62
feet		------ lb NO_3-N/A ------							
0 - 1		51.4	103.3	52.4	88.9	38.8	122.5	36.2	53.2
1 - 2		10.5	17.9	6.7	23.1	4.8	15.4	4.4	8.1
2 - 3		3.1	3.3	1.7	4.7	1.7	3.0	1.4	2.3
3 - 4		1.4	2.3	1.2	2.8	1.3	1.9	1.0	1.4
4 - 5		0.8	1.2	0.9	2.2	1.6	1.4	1.0	1.1
Total in 0-5' profile		67	128	63	122	48	144	44	66

Table 3. Residual soil nitrate-N after harvesting in October, 1988 at Winona Co. as influenced by tillage, hybrid, and N rate.

Profile depth		Moldboard				No-tillage			
		P3732		DK547		P3732		DK547	
	lb N/A:	0	62	0	62	0	62	0	62
feet		lb NO_3-N/A							
0 - 1		71.4	160.2	75.0	148.4	53.8	83.9	36.7	89.3
1 - 2		51.4	86.8	43.3	56.6	32.9	47.2	24.0	46.9
2 - 3		16.6	18.0	16.2	17.5	15.8	18.2	15.1	16.4
3 - 4		20.4	17.7	13.1	17.2	13.9	16.1	12.8	13.5
4 - 5		18.5	19.1	15.8	19.6	20.0	16.3	15.4	16.0
Total in 0-5' profile		178	302	163	259	136	182	104	182

Table 4. Means for main effects and interactions for total residual soil nitrate-N (0-5') after harvest at Rosemount and Winona Co. in October, 1988.

Treatment			Location	
			Rosemount	Winona Co.
			lb NO_3-N/A	
Tillage				
	Moldboard		95	231
	No-tillage		76	151
	P >F		0.44	0.05
N Rate (lb/A)				
	0		56	139
	62		115	231
	P >F		0.01	0.01
Hybrid				
	P3732		97	200
	P3569/DK547		74	177
	P >F		0.04	0.15
Tillage X N Rate Interaction				
	Moldboard	0	65	164
		62	125	281
	No-tillage	0	46	120
		62	105	182
	P >F		0.97	0.03
Tillage X Hybrid Interaction				
	Moldboard	P3732	98	247
		P3569/DK547	92	215
	No-tillage	P3732	96	159
		P3569/DK547	55	143
	P >F		0.10	0.65
N Rate X Hybrid Interaction				
	0	P3732	58	152
		P3569/DK547	53	126
	62	P3732	136	242
		P 3569/DK547	94	221
	P >F		0.08	0.90
Tillage X N Rate X Hybrid Interaction				
	P >F		0.10	0.34

Table 3. Residual soil nitrate-N after harvesting in October, 1988 at Winona Co. as influenced by tillage, hybrid, and N rate.

Profile depth		Moldboard				No-tillage			
		P3732		DK547		P3732		DK547	
	lb N/A:	0	62	0	62	0	62	0	62
feet		lb NO_3-N/A							
0 - 1		71.4	160.2	75.0	148.4	53.8	83.9	36.7	89.3
1 - 2		51.4	86.8	43.3	56.6	32.9	47.2	24.0	46.9
2 - 3		16.6	18.0	16.2	17.5	15.8	18.2	15.1	16.4
3 - 4		20.4	17.7	13.1	17.2	13.9	16.1	12.8	13.5
4 - 5		18.5	19.1	15.8	19.6	20.0	16.3	15.4	16.0
Total in 0-5' profile		178	302	163	259	136	182	104	182

Table 4. Means for main effects and interactions for total residual soil nitrate-N (0-5') after harvest at Rosemount and Winona Co. in October, 1988.

Treatment			Location	
			Rosemount	Winona Co.
			lb NO_3-N/A	
Tillage				
	Moldboard		95	231
	No-tillage		76	151
	P> F		0.44	0.05
N Rate (lb/A)				
	0		56	139
	62		115	231
	P> F		0.01	0.01
Hybrid				
	P3732		97	200
	P3569/DK547		74	177
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	P> F		0.10	0.65
N Rate X Hybrid Interaction				
	0	P3732	58	152
		P3569/DK547	53	126
	62	P3732	136	242
		P 3569/DK547	94	221
	P> F		0.08	0.90
Tillage X N Rate X Hybrid Interaction				
	P> F		0.10	0.34

Table 5. Residual soil nitrate-N after harvest in October, 1988 at Waseca for P3732 as influenced by tillage and N rate.

Profile		Moldboard				No-tillage			
depth	lb N/A:	0	30	60	90	0	30	60	90
feet		------	------	------	lb NO_3-N/A	------	------	------	------
0 - 1		64.5	90.0	103.2	112.1	66.4	96.4	105.0	116.6
1 - 2		38.1	56.4	57.5	57.4	44.5	51.5	42.6	45.0
2 - 3		20.1	17.5	24.1	20.7	27.1	26.8	23.2	23.7
3 - 4		24.0	21.2	22.4	21.2	22.7	21.6	27.8	24.5
4 - 5		23.5	24.7	24.8	23.2	23.3	26.0	24.2	25.6
Total in 0-5' profile		170	210	232	235	184	222	223	236

Table 6. Means for total residual soil nitrate-N after harvest for tillage and N rate at Waseca.

Treatment	Residual N
	lb NO_3-N/A
Tillage	
Moldboard	212
No-tillage	216
N Rate (lb/A)	
0	177
30	216
60	227
90	235

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IMPACT OF NITROGEN AND TILLAGE MANAGEMENT PRACTICES ON CORN YIELD AND POTENTIAL GROUNDWATER CONTAMINATION IN SOUTHEASTERN MINNESOTA[1/]

Center for Agricultural Impacts on Water Quality
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ABSTRACT: Studies are being conducted on the silt loam soils of southeastern Minnesota to evaluate specific N and tillage practices for their role in providing profitability (BENEFIT) while minimizing NO_3 occurrences in the water below the root zone (RISK). The dry conditions seriously impacted corn yields and NO_3 leaching at two of the three sites. In general, continuous corn yields were optimized at N rates from 100 to 150 lb N/A except when alfalfa and manure were in the system (1983-85). Corn yields were not improved with split or sidedress N applications. Tillage did not appear to effect either corn yield or NO_3-N concentrations in the soil water. Manure applications resulted in slightly higher yields but greatly increased NO_3-N concentrations in the water. When profitability was highest, NO_3-N concentrations at 5' ranged between 10 and 14 mg/L. Fall applications of N doubled the NO_3-N concentration in the soil water at 5'. In an effort to more clearly define BMP's for these soils, additional years will be needed to more closely ascertain benefit vs risk relationships of these various N and tillage practices.

Current agricultural production systems are being linked closely to the occurrence of agricultural chemicals in the groundwater. This concern is especially prevalent in southeastern Minnesota where agriculture is quite intensive and the soils are rather shallow over a fractured limestone and sandstone bedrock geology (karst). The purposes of these studies are to: (1) determine the cause and effect relationship of specific N and tillage management practices on corn production and NO_3 and pesticide accumulation/movement through the soil and (2) identify best management practices that minimize groundwater contamination while maintaining economic profitability.

EXPERIMENTAL PROCEDURES

Three sites were continued for the 1988 studies. The primary site with the most intensive investigation is being conducted in Olmsted Co. on the Lawler Farm. The other sites are in Goodhue Co. on the Foss Farm and in Winona Co. on the Kalmes Farm.

Olmsted County - Lawler Farm

In April of 1986 a 6½ acre site of Port Byron soil was identified on the Richard Lawler and Sons Farm approximately 6 miles east of Rochester. A very comprehensive field history for the last 7 years was provided. Corn was grown in 1986. No herbicides and no nitrogen (N) fertilizer were applied to the corn which was cultivated three times.

Nitrogen Study

A randomized, complete-block with 4 replications was established in the fall of 1986 and was continued in 1988. Ten N treatments including both anhydrous ammonia and manure were established for a total of 40 plots (Table 1). Each plot was 30' wide and 65' long. The fall N treatments were applied on October 30, 1987. Spring N fertilizer treatments were applied on April 21 and again on June 16, 1988. Liquid hog manure was obtained from a neighbor, James Stellplug, on April 15 and applied to the soil surface using his equipment. The manure was incorporated with a disk within 3 hours. The rates of application were 6600 and 9500 gal/A. Six manure samples were taken and sent to Minnesota Valley Testing for analyses. Nitrogen, P_2O_5 and K_2O concentrations averaged 40.3, 27.4 and 8.1 lb/1000 gallons, respectively. All plots except the no-till treatment were disked again on April 25.

Corn (Pioneer 3737) was planted on May 4 at 30,600 plants/A. Lasso (3 lb/A) and atrazine (2½ lb/A) were applied preemergence. Counter was applied in the furrow at a rate of 8 oz/1000' of row to control rootworms. Cultivation was not performed during the season.

1/ Funding provided by the Legislative Commission on Minnesota Resources, Center for Agricultural Impacts on Water Quality, and the Minnesota Agricultural Experiment Station.

Whole plants were harvested from selected rows at silking, were weighed, dried, ground and analyzed for total N to determine pre-silk N uptake. Stover and grain yields were taken from 20' and 80' of row, respectively, at physiological maturity (Sept. 24). All samples were weighed, dried, ground and analyzed for total N.

Soil samples were obtained from each plot on April 12 and Oct. 24 by taking two 2-inch cores in 1-foot increments to the bedrock and then compositing the cores from each increment. The samples were forced-air, oven-dried at 120°F, ground, and analyzed for inorganic N (NH_4-N and NO_3-N).

Suction lysimeters installed in 1987 at the 5 and 7.5-foot depths in each plot were used to extract soil water from these depths to measure NO_3 concentrations in the soil water. Samples were collected on April 18, May 13, Aug. 12, Oct. 5 and Nov. 14.

Pesticide Study

An area adjacent to the N study was established in the fall of 1986 to accommodate a study to evaluate the movement of Lasso, atrazine, Banvel and Counter through the soil profile as influenced by four tillage systems. The four tillage treatments (moldboard plow, chisel plow, ridge tillage, and no tillage) were initiated in November, 1986. Nitrogen was applied on April 21 at a rate of 180 lb N/A as anhydrous ammonia. All other planting operations were the same as in the N study. The herbicides were applied using specialized plot equipment. Potassium bromide was broadcast-applied to a 15-foot section of each plot. The Br serves as a tracer to which pesticide movement can be compared. The corn was cultivated two times. The ridge plots were ridged in mid-June.

Each plot was intensively soil sampled throughout the season to monitor herbicide movement. Stainless steel suction lysimeters installed at 5' and 7½' depths were used to extract soil water. Grain and stover yields were taken at physiological maturity (PM) from the non-Br treated areas.

Goodhue County - Foss Farm

In May of 1986 an area of 5.1 acres of Port Byron soil was identified on the Selmer Foss and Sons (James Foss) farm in Goodhue County. A good field history was provided for the past 6 years. Corn was grown in 1986 and received a minimal amount of N (75 lb N/A) because it was in continuous corn. Weeds were controlled with 4 lb atrazine/A. Due to wet conditions no primary tillage was performed in the fall of 1986.

A randomized, complete-block design with 4 replications was established at this site in April, 1987 and was continued in 1988. Sixteen N treatments all consisting of anhydrous ammonia applied to chiseled and no-till plots were established. Each of the 64 plots measures 30' wide and 65' long. Chisel plowing was done with a John Deere Mulch Tiller on November 4, 1987. Anhydrous ammonia was applied preplant on April 20. All chisel plots were disked on May 5.

Corn (Pioneer 3790) was planted at 30,200 plants/A on May 6. Lasso (3 lb/A) and Bladex (2½ lb/A) was applied preemergence. Counter was applied at 1 lb a.i./A to control corn rootworms. The chisel plowed plots were cultivated to remove weeds and volunteer corn. Sidedress applications of N as anhydrous ammonia were applied at the 6-leaf stage (June 6) and 8 to 9-leaf stage (June 16).

Plant sampling procedures at silking and at PM were essentially the same as at the Olmsted Co. site. Soil sampling to the 10-foot depth on April 15 and October 31 was accomplished using the same procedures as in Olmsted Co. Suction lysimeters installed in six treatments (24 plots) to a 5' depth in 1987 were sampled on Apr. 15, May 12, Sept. 30 and Nov. 17 to determine the NO_3 and pesticide concentrations in the extracted soil water.

Winona County - Kalmes Farm

A 3.0 acre contour strip of Seaton soil was identified in early April, 1987. This farm is owned by Eugene Kalmes and son, Robert Kalmes. A field history was provided for the last 4 years. Corn was grown in 1986 and received 70 lb N/A and 2 lb atrazine/A. Alfalfa was grown in 1983-85 and received 6 T manure/A in the fall of 1985.

A randomized, complete-block design with 4 replications was established at this site in mid-April, 1987 and was continued in 1988. Twelve N treatments were established for a total of 48 plots. Each plot measures 20' wide by 65' long.

Spring chiseling was conducted on October 28, 1987. The preplant anhydrous ammonia treatments were applied immediately afterward. A field cultivator was used as secondary tillage just prior to planting.

Corn (Pioneer 3790) was planted at 30,200 plants/A on May 2. Lasso (3 lb/A) and Bladex (2½ lb/A) was applied preemergence. Counter (8 oz/1000') was used to control corn rootworms. The chisel plowed plots were cultivated to remove weeds. Sidedress applications of N as anhydrous ammonia were applied at the 6 to 7-leaf stage (June 8) and the 8 to 9-leaf stage (June 17).

Plant and soil sampling procedures were identical to those used in Olmsted Co. Stainless steel and PVC suction lysimeters installed in 1987 at the 5' depth in six treatments (24 plots) were sampled on April 18, May 13, Aug. 17, Oct. 5, and Nov. 18 to determine NO_3 and pesticide concentrations in the extracted soil water.

RESULTS AND DISCUSSION

Olmsted Co.

Corn grain yields in 1988 were increased significantly by both the fertilizer and manure N treatments (Table 1). The addition of 75 lb N/A increased yield by 60 bu/A resulting in very high fertilizer N efficiency. The 150-lb N rate applied preplant (PP) gave the optimum yield among the fertilizer treatments. Yields were about 8 bu/A higher with the two hog manure treatments, but this difference was not significantly (P = 95% level) above the 150-lb N/A PP treatments. Corn yields with the fall and split 150-lb treatments were not significantly different from the 150-lb PP treatment. There was no significant yield difference between the chisel and no tillage systems. Average 2-year yields showed greatest economic return to the 150-lb PP application with no advantage to higher rates, fall application or split treatments.

Table 1. Effect of N treatments on the 1988 corn grain yields and NO_3-N concentrations in the water at 5' in Olmsted Co.

		Treatment		Grain Yield		Nitrate-N[3/] Conc. in Water	
No.	Tillage	N Rate	Time/Method	1988	1987-88	5'	7.5'
		lb N/A		---- bu/A -----		--- mg/L ---	
1	Chisel	0	-----	79.9	94.6	1	4
2	Chisel	75	Spr., preplant	139.7	161.0	6	7
3	Chisel	150	Spr., preplant	153.5	176.9	12	9
4	Chisel	225	Spr., preplant	153.4	168.7	18	8
5	Chisel	150	Fall, post tillage	153.9	174.8	24	-
6	Chisel	150 + NI[1/]	Fall, post tillage	156.8	174.0	22	-
7	Chisel	150 split	50% Spr., preplant 50% SD, 8-leaf	152.6	172.8	10	-
8	No tillage	150	Spr., preplant	155.0	176.7	14	-
9	Chisel	175[2/]	Spr., disked in	161.7	184.5	41	10
10	Chisel	230[2/]	Spr., disked in	161.0	185.2	63	5
	Significance Level (%):			99			
	BLSD (.05) :			15.2			
	CV (%) :			7.7			

1/ N-Serve
2/ Applied liquid swine manure at rates of 6600 and 9500 gal/A, respectively. Total N rates were 280 and 360 lb N/A or approximately 175 and 230 lb "available" N/A.
3/ Oct. 5, 1988

Nitrate-N concentrations in the soil water extracted from the 5-foot depth were correlated linearly with the spring-N rate (Table 1). Concentrations below 10 mg/L were found only with the 0 and 75-lb N rates, but economical return was also considerably less with the treatments. The split N application resulted in a similar NO_3-N concentration as the spring preplant application. Fall application, regardless of the inclusion of N-Serve, resulted in NO_3-N concentrations almost twice as high as with the spring applications. There appeared to be no difference between tillage systems. Highest NO_3-N concentrations occurred with realistic application rates of liquid hog manure. Nitrate leaching from the treatments had not reached the 7.5-foot depth at the end of the two growing seasons probably because of the dry conditions in 1988. It should be cautioned that these 5-foot NO_3-N concentrations may not represent the concentrations entering the aquifer because of dilution; however, they do provide an indication as to the environmental sensitivity of the treatments.

Corn yields in the pesticide study were not influenced statistically at the P = 90% level by tillage system because of the high variability (CV = 13%) (Table 2). The apparent 10 to 18 bu/A reduction with the ridge-till and no tillage (NT) systems could have been due to the ridging operation which may have pruned some roots and to some weeds in the NT system.

Table 2. Effect of tillage treatments on the 1988 corn yields in Olmsted Co.

Tillage	Grain Yield 1988	Grain Yield 1987-88 Avg.
	bu/A	bu/A
Moldboard plow	158.0	171.0
Chisel plow	158.0	170.6
"Ridge till"[1/]	147.8	162.8
No tillage	140.4	156.7
Significance Level (%):	47	
BLSD (.05) :	-	
CV (%) :	13.	

1/ First ridged in June, 1987.

Corn was planted on a 1½ acre area which is being saved for "future" investigations. Neither fertilizer N nor pesticides were applied. The corn was cultivated twice to control weeds as best possible. Corn yields averaged only 8 bu/A primarily due to weed pressure (early season moisture stress) and insufficient N. It is interesting to note the 72 bu/A difference between this site and the 0-lb N plots that were kept weed-free by herbicides.

Goodhue Co.

Grain yields were increased significantly over the control (both chisel and no tillage) by all of the N treatments (Table 3). Yields were optimized with the 100-lb spring PP treatment. The highest yield, although not statistically speaking, was obtained with the 150-lb PP treatment containing N-Serve. There was no difference between the two tillage systems. None of the split and sidedress treatments enhanced yields over the spring PP anhydrous applications.

Two-year average grain yields also show: (1) optimum N rate to be 100 lb/A, (2) no improvement in yield with either split or sidedress N application, and no difference between the two tillage systems except at the 0-lb N rate where there was a slight advantage for chisel plowing.

Nitrate-N concentrations in the soil water extracted from the 5-foot depth on Sept. 30 varied considerably and did not appear to relate well to N treatment (Table 3). This was probably due to the dry conditions and the incomplete number of samples obtained.

Table 3. Corn yield and NO_3-N concentation in the soil water at 5' as affected by N treatments in Goodhue Co. in 1988.

No.	N rate	Application time	Tillage[1/]	Grain Yield 1988	Grain Yield 1987-88 Avg.	Nitrate-N[3/] Conc.in water at 5'
	lb/A			----- (bu/A)	-----	mg/L
1	0	-----	Chisel	68.3	103.0	8
2	50	Spr. preplant (PP)	"	106.8	138.6	-
3	100	"	"	113.8	149.9	12*
4	150	"	"	114.5	149.4	12
5	200	"	"	118.6	154.0	-
6	0	-----	No Tillage	67.5	91.6	-
7	100	Spr. preplant (PP)	" "	112.4	150.0	7
8	150	"	" "	115.5	152.8	15
9	200	"	" "	115.2	153.4	-
10	50 + 50	Spr. PP + SD 9-lf	Chisel	111.4	145.6	-
11	50 + 100	" "	"	116.5	149.4	-
12	100 + 50	" "	"	117.3	151.6	-
13	100	SD 6-lf	"	106.4	143.4	-
14	150	"	"	116.6	152.1	38*
15	150 + NI[2/]	Spr. PP	"	123.7	159.1	-
16	150 + NI	SD 6-lf	"	120.1	150.0	-
	Significance Level (%):			99		
	BLSD (.05) :			14.0		
	CV (%) :			9.6		

1/ Chiseling was done in April, 1987.
2/ NI = N-Serve
3/ Sept. 30, 1988
* Avg. of only 2 samples

Winona County

Corn grain yields were very poor at this site due to the dry and hot weather (Table 4). Yield responses to the applied N were inconsistent and highly variable. There did not appear to be an advantage for the split or sidedress N treatments over the spring preplant treatment. No difference was observed between tillage systems.

Two-year average yields show: (1) no difference between the two tillage systems, (2) no advantage for the split and sidedress applications, and (3) a very slight but inconsistent response to fertilizer N at this site which was in alfalfa from 1983-85. Nitrate-N concentrations in the soil water at 5' after two years of experimentation still are at 14 mg/L where no N has been used. Concentrations ranged between 26 and 46 mg NO_3-N/L for the treatments that received fertilizer N, but there was no relationship to N rate. These high values must be a result of the previous alfalfa crop which received manure in 1985.

Table 4. Effect of N treatments on the corn grain yield and NO_3-N concentrations in the soil water at 5' in Winona County in 1988.

Treatment				Grain Yield		Nitrate-N[2/] Conc.in water
No.	N Rate	Time	Tillage[1/]	1988	1987-88 Avg.	at 5'
	lb N/A			------- bu/A	------	mg/L
1	0	-----	Chisel	72.1	128.9	14
2	50	Spr. preplant (PP)	"	73.9	131.8	-
3	100	" "	"	81.8	135.2	36
4	150	" "	"	84.9	137.8	37
5	200	" "	"	97.7	144.6	27
6	0	-----	No Tillage	68.0	129.0	-
7	100	Spr. preplant (PP)	" "	80.3	135.0	46
8	150	" "	" "	69.9	126.9	-
9	200	" "	" "	86.8	135.5	26
10	50 + 50	Spr. PP + SD 9-1f	Chisel	86.8	138.4	-
11	50 + 100	" " "	"	85.4	139.4	36
12	150	SD 6-1f	"	76.4	132.6	42
	Significance Level (%):			95		
	BLSD (.05) :			21.5		
	CV (%) :			15.		

1/ Chiseling was done in October, 1987.
2/ Oct. 5, 1988

SUMMARY

The following summarizes the yield results from the second year of these studies:

1) N rate was optimized at 150 lb/A for third year corn while at a second site 100 lb N/A was optimum.
2) Yields were slightly but not significantly higher with the manure treatments.
3) No apparent yield advantages were found with split or sidedress applications of N at any of the three sites.
4) There was no yield difference between the no tillage and chisel tillage systems at any of the three sites.
5) Previous crop and manure history apparently impacts corn yield and N management at the Winona Co. site.
6) The role of alfalfa and manure contributions to available N for succeeding corn crops needs to be carefully examined and understood before improved N management is a reality on these soils.
7) Nitrate-N concentrations in the soil water at 5' (below the root zone) provide a good basis upon which to compare the environmental risks associated with various N management systems.

ACKNOWLEDGEMENT

This interdisciplinary investigation would not have been possible without the fine cooperation and dedication of the farmer-cooperators and the participation of the Soil Conservation Service and the Minnesota Extension Service. Sincere appreciation is also extended to the Minnesota Valley Testing Lab who graciously conducted the manure analyses.

TILLAGE SYSTEMS FOR CORN AND SOYBEAN CROP SEQUENCES

Waseca, 1988

G. W. Randall, B. W. Anderson and R. R. Allmaras[1/]

ABSTRACT: A study was started in 1986 to determine the effect of tillage on corn and soybean production when grown in rotation compared to a continuous monoculture. Yield results in 1988 were highly variable due to the heat and moisture stress. Although both corn and soybean yields were substantially higher with NT compared to MP and CP tillage, these differences were not statistically significant at the 90% level. Corn and soybeans in rotation yielded 16 and 20% higher, respectively, than did the continuous monoculture systems. Tillage x crop sequence interactions were not significant for either crop.

Corn-soybean rotations have often been compared to continuous corn and soybean monocultures using a particular tillage system. Seldomly, however, have these comparisons been made over a range of primary tillage systems. The purpose of this study is to determine the effect of tillage on corn and soybean production when grown in a monoculture compared to a rotation.

Experimental Procedures

A study had been established on this Webster clay loam site in the fall of 1980 to determine the relationship between primary tillage and the incidence of corn and soybean diseases in continuous corn, continuous soybeans and a corn-soybean rotation. The tillage systems were fall moldboard plow (MP), fall chisel plow (CP), and no tillage (NT). After this 5-yr study was completed in 1985, the initial tillage plots and some of the monoculture plots were kept intact to take advantage of the past tillage and cropping history. Some of the monoculture plots were changed to a corn-soybean sequence so that there are now four cropping systems over each tillage system. The cropping systems are continuous corn (C-C), corn-soybean (C-Sb), soybean-corn (Sb-C), and continuous soybeans (Sb-Sb). Each treatment is replicated four times in a split-plot design with tillage as the main plot and crop system as the subplot.

Fall tillage was performed in October, 1987 after stalk chopping all corn plots. Spring secondary tillage consisted of disking the CP plots and field cultivating the MP and CP plots on April 21.

Nitrogen was broadcast applied as ammonium nitrate prior to secondary tillage to all 1988 corn plots at a rate of 200 lb N/A regardless of previous crop. Broadcast P and K were not applied because of high soil test P and K levels. Starter fertilizer was not used.

Corn (Pioneer 3737) was planted on May 4 at a rate of 28,400 ppA with a John Deere Max-Emerge II 4-row planter equipped with bubble coulters. Counter (1 lb ai/A) was applied to all corn plots at the time of planting. Weeds were chemically controlled with a combination of 3½ qts. Lasso and 3 qts Bladex/A applied preemergence on May 11. Row cultivation was performed on May 31 in the MP and CP corn plots.

Soybeans (Hardin) were planted in 30" rows with the aforementioned planter at a rate of 9 beans/foot on May 16. Weeds were controlled with a preemergence application of Lasso (3½ qts/A) + Amiben (6 qts/A) on May 20. The MP and CP soybean plots were cultivated on June 10.

A modified JD 3300 plot combine was used to harvest both the corn and soybeans. Corn and soybean yields are expressed at 15.5 and 13.5% moisture, respectively.

All wheel traffic during the season was confined to the same inter-row areas that were trafficked at the time of planting. This resulted in wheel traffic on one side of each row with the other side non-compacted by machinery operations.

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Results and Discussion

Corn yields were quite poor and highly variable due to the extreme heat and dry conditions throughout most of the growing season (Table 1). When averaged over crop sequence, NT yields were 38% and 17% higher than with CP or MP tillage, respectively. These yield differences, however, were not statistically significant at the 90% level due to the high CV (16%) and the highly significant tillage x rep interaction. This interaction is demonstrated by CP yields ranging from 38 bu/A in rep 1 to 107 bu/A in rep 2 while NT yields ranged from 78 bu/A in rep 3 to 136 bu/A in rep 4. Yield variation with MP tillage was much smaller, ranging from 75 bu/A in rep 1 to 108 bu/A in rep 3. These extreme differences were largely due to small changes in microrelief which affected stored soil moisture within the experimental site and because the CP tillage blocks in reps 1 and 3 were on the south edge of the study. Since there was no crop for over 1/2 mile to the south, the hot and dry south winds appeared to have influenced these plots to a greater degree than the rest of the study. Crop sequence significantly influenced corn yield. Corn following soybeans yielded 16% higher than continuous corn. The tillage x sequence interaction was not significant.

Grain moisture was significantly higher with NT compared to the MP and CP systems and for continuous corn (Table 1). Final population was not influenced by either tillage or crop sequence.

Table 1. Corn grain yield and moisture content and final population as affected by tillage and crop sequence.

Tillage	Crop Sequence	Grain Yield	Grain Moisture	Final population
		bu/A	%	x 10^3
MP	C-C	77.0	17.6	28.4
"	C-Sb	96.9	16.6	28.7
CP	C-C	71.4	18.4	28.3
"	C-Sb	75.8	16.9	27.9
NT	C-C	94.4	20.2	28.2
"	C-Sb	109.2	18.0	29.2
FACTORIAL COMPARISONS				
Tillage				
MP		86.9	17.1	28.6
CP		73.6	17.7	28.1
NT		101.8	19.1	28.7
Signif. Level (%):1/		72	98	90
BLSD (.05) :			1.4	
Crop Sequence				
C-C		80.9	18.8	28.3
C-Sb		93.9	17.2	28.6
Signif. Level (%):1/		95	99	82
Tillage x Replication Interaction				
Signif. Level (%):1/		98	99	96
Tillage x Sequence Interaction				
Signif. Level (%):1/		43	92	51
CV (%) :		16.	2.5	1.8

1/ Probability level of significance.

Soybean yields were relatively better than corn but were also highly variable (Table 2). When averaged over crop sequence, the NT yields were 20% and 14% higher than CP and MP tillage, respectively. Similar to corn, these yield differences were not statistically significant due to the high CV (10%) and the significant tillage x rep interaction. Soybeans following corn yielded 20% more than did continuous soybeans. There was no significant tillage x sequence interaction. Soybean seed moisture at harvest was unaffected by tillage and crop sequence.

Table 2. Soybean seed yield and moisture content as affected by tillage and crop sequence.

Tillage	Crop Sequence	Yield	Moisture
		bu/A	%
MP	Sb-Sb	29.8	11.2
"	Sb-C	36.5	11.5
CP	Sb-Sb	27.8	11.4
"	Sb-C	35.0	11.3
NT	Sb-Sb	35.6	11.5
"	Sb-C	40.0	10.9
FACTORIAL COMPARISONS			
Tillage			
MP		33.1	11.4
CP		31.4	11.4
NT		37.8	11.2
Signif. Level (%):		72	86
Crop Sequence			
Sb-Sb		31.0	11.4
Sb-C		37.2	11.2
Signif. Level (%):		99	74
Tillage x Replication Interaction			
Signif. Level (%):		96	13
Tillage x Sequence Interaction			
Signif. Level (%):		29	97
CV (%) :		10.	2.6

THREE-YEAR SUMMARY

Corn yields from this completely weed-free site were approximately 15 bu/A higher for NT compared to either MP or CP regardless of crop sequence (Table 3). Corn yields following soybeans averaged approximately 10% higher than continuous corn regardless of tillage system. Soybean yields were not affected by tillage system. Soybeans following corn yielded approximately 16% higher than continuous soybeans when averaged over tillage systems.

Table 3. Three-year corn and soybean yield averages as influenced by tillage and crop sequence.

Tillage	Crop Sequence	Yield: Corn	Yield: Soybean
		bu/A	bu/A
MP	Cont. Corn	131.0	-
"	Corn-Soybean	146.5	48.9
"	Cont. Soybean	-	44.2
CP	Cont. Corn	132.5	-
"	Corn-Soybean	142.5	50.8
"	Cont. Soybean	-	42.5
NT	Cont. Corn	147.4	-
"	Corn-Soybean	161.5	51.7
"	Cont. Soybean	-	44.1

CONSERVATION TILLAGE FOR CORN AND SOYBEAN PRODUCTION[1/]

Waseca, 1988

G. W. Randall and J. B. Swan[2/]

ABSTRACT: This was the 14th year in a study to evaluate five primary tillage systems for corn and soybean production on a Nicollet-Webster soil complex. Corn grain yields were significantly higher with moldboard plow tillage compared to chisel plow, spring disk, or no tillage. Although yields from ridge tillage were 16.7 bu/A less than from moldboard plowing, they were not statistically different. No tillage yields were considerably less than the other tillage treatments primarily because of high grass pressure. Yields from the no tillage, chisel plow and spring disk systems were improved markedly where Poast herbicide had been applied previously to soybeans. Weed pressure was very low with the ridge plant and moldboard plow systems. Under the hot and dry conditions the lesser yields obtained with the conservation tillage (CT) systems were partially due to poor weed control (especially with no tillage) but may also have been due to poor, early season root development in the CT systems in this 14-year study.

With increasing emphasis on controlling erosion and minimizing energy requirements (time, labor, and fuel), tillage practices have changed markedly over the last decade. Many of tillage practices have come to be known as "conservation tillage". To fit this definition, a tillage practice must leave 30% of the soil surface covered with residue after planting. The primary purpose of this study is to evaluate five conservation tillage (CT) systems in a long-term corn-soybean sequence. A secondary objective is to determine the value of starter fertilizers in CT systems.

EXPERIMENTAL PROCEDURES

To evaluate some of these conservation tillage practices an experiment was started in 1975 with continuous corn grown on a Webster clay loam at the Southern Experiment Station. Five tillage treatments (no tillage, fall moldboard plow, fall chisel plow, ridge-plant and till-plant [flat]) were replicated four times. Each plot was 20' wide by 125' long. Tile lines spaced 75' apart run perpendicular to the rows in all plots. Beginning in 1979 all plots were split into two, 4-row plots -- one with starter fertilizer and the other without.

After 8 years of continuous corn, soybeans were planted in 1983 to begin a long-term corn-soybean rotation. Tillage and starter fertilizer treatments remained the same except the till-plant (flat) treatment was changed to a spring-disk (20" disk blade) treatment (Table 1). Because of increased pressure of the grass weeds in the no tillage treatment, all plots were split so that either the front or rear half received a postemergence application of Poast at a rate of ½ lb/A with 1 qt of oil concentrate in the years that soybeans were grown.

Ridges for the ridge plant treatment in 1988 were built in June, 1987. After the 1987 soybean harvest, the moldboard and chisel plow treatments were performed. On April 21 the moldboard and chisel plow treatments were field cultivated once and the spring disk treatment was disked twice. Ammonium nitrate was broadcast-applied at a rate of 150 lb N/A immediately before the secondary tillage. Ridges for 1989 soybeans were prepared on June 20.

Corn (Pioneer 3732) was planted in 30" rows at a rate of 29,900 plants/A on May 4. All treatments were planted with a John Deere 7100 planter equipped with 2" fluted coulters. B&H ridge cleaners were attached to the planter for the ridge-plant treatment. Ten gallons/A of 7-21-7 was used as the starter treatment.

Broadcast P and K were not applied for the 1988 soybean crop because of very high soil tests. Soil tests on this site in 1984 averaged: pH = 6.7, $Bray_1$ extractable P = 60 lb/A and exchangeable K = 424 lb/A. Chemical weed control consisted of 3 lb Bladex and 3½ lb Lasso/A applied preemergence (May 14). In order to evaluate the effectiveness of the preemergence herbicide application on weed control, a plastic sheet 18" wide and 6' long was placed between the 4th and 5th rows of each plot during herbicide spraying to prevent the application of herbicide onto the soil surface. Weed counts (grass and broadleaf) were taken on May 23 from sprayed and unsprayed areas and poast and non-poast

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1/ Funding provided by the Southern Experiment Station, Waseca.
2/ Professors, Southern Experiment Station and Department of Soil Science, respectively.

areas. Treatments 2, 3, 4, and 5 were cultivated on June 1. Weed control was quite good on all cultivated plots.

Surface residue coverage was measured by the line-transect method on April 18 prior to spring tillage and on May 16 after planting. Planting depth was determined by cutting off the coleoptile at the soil surface from all the plants in a 10-foot length of row in each tillage plot 27 days after planting. The seeds were then excavated and the length of the coleoptile to the seed was measured. Early plant growth (EPG) was determined by harvesting the above ground portion of 10 random plants per starter and non-starter plot 41 days after planting.

Corn leaf samples were taken on July 14 from all treatments except NT, which was sampled on July 21, by randomly sampling the leaf opposite and below the ear from the starter treatment within each tillage treatment. Yields were taken by combine harvesting the center two rows from each plot with a modified JD 3300 combine. Grain moisture and N concentrations were determined on each of these samples.

RESULTS

Grain yield and moisture differences among the tillage treatments were highly significant when averaged over starter fertilizer and previous Poast treatments (Table 1). Moldboard plow (MP) tillage resulted in significantly higher yields than the chisel plow (CP), spring disk (SD), and no tillage (NT) systems. Grain yield was significantly lower and grain moisture higher for NT compared to all other tillage systems. The highly significant interaction between tillage and Poast treatment for yield indicated that yields from the NT, CP and SD systems were increased significantly by the Poast treatments applied to soybeans in previous years (1983, 1985 and 1987). Yields with the MP and ridge-plant (RP) systems were not affected by the Poast treatments primarily because of excellent weed control with these tillage systems regardless of Poast application.

Starter fertilizer increased yields by 16% when averaged across all tillage and Poast treatments (Table 1). Even though a statistically significant interaction between tillage system and starter fertilizer did not exist (23% level), the 15% yield response for the MP system was considerably higher than the 2% for the RP system. This was in contrast to previous years when greatest response to starter fertilizer was with the RP, CP and NT systems. Grain moisture was decreased significantly (0.6 points) by the starter fertilizer but was unaffected by the previous Poast treatments.

Early plant growth was affected significantly by the tillage systems (Table 2). Plants were largest with the MP and RP systems, were intermediate in size with the CP and SD systems and were significantly smaller with NT. Starter fertilizer increased early plant weight when averaged across tillage systems. The interaction between tillage and starter fertilizer was not significant (33% level). Final population was not affected by tillage or starter fertilizer.

Grain N was not influenced by tillage or starter fertilizer (Table 2). However, N removal in the grain (product of grain N concentration and grain yield) was affected significantly by both tillage and starter fertilizer. This effect was due largely to the yield differences among the treatments, which resulted in lowest N removal with the NT system and the plots without starter fertilizer.

Residue measurements taken prior to planting showed significant differences among the treatments for percent of the soil surface covered with residue from the previous crops (Table 3). The treatments ranked NT >SD > RP = CP> MP. After planting, surface residue measurements were taken both within the row and randomly across the plot area. All tillage treatments showed significantly more residue than the MP treatment. However, only the NT system exceeded 30% and therefore met the definition of "conservation tillage". Within the row measurements showed similar residue amounts compared to random across-the-plot measurements for all tillage systems.

Planting depth was affected significantly by the tillage systems (Table 3). This was consistent with most previous years. The variability in the seeding depth as measured by standard deviation and range in depths indicates least variability with the CP and SD systems and greatest variability with the NT system. Seed placement average between 2.2" and 2.5" for the MP, CP, RP and SD tillage systems compared to 1.6" for the NT system. These differences point out the need for careful adjustments of the planter even when following soybeans.

Table 1. Influence of tillage methods, starter fertilizer and previous Poast herbicide treatment on corn production at Waseca in 1988.

Tillage	Treatment: Starter fertilizer [1/]	Treatment: Poast herbicide [2/]	Grain: Moisture	Grain: Yield
			%	bu/A
No tillage	S	P	22.9	50.1
"	S	NP	22.7	36.5
"	NS	P	24.5	31.9
"	NS	NP	24.2	27.4
Fall plow, f. cult.	S	P	19.5	119.5
" "	S	NP	18.6	117.0
" "	NS	P	19.7	95.8
" "	NS	NP	19.4	109.2
Fall chisel, d., f. cult.	S	P	19.5	109.2
" "	S	NP	20.0	82.0
" "	NS	P	20.2	88.5
" "	NS	NP	21.1	65.4
Ridge plant	S	P	19.4	93.0
" "	S	NP	19.2	96.8
" "	NS	P	19.2	95.2
" "	NS	NP	19.3	89.9
Spring disk (2x)	S	P	19.9	109.3
" "	S	NP	21.0	76.0
" "	NS	P	20.2	105.2
" "	NS	NP	21.3	55.6
Individual Factors				
Tillage				
No tillage			23.6	36.5
Fall plow			19.4	110.4
Fall chisel			20.2	86.3
Ridge plant			19.2	93.7
Spring disk (2x)			20.6	86.5
Significance Level (%): [3/]			99	99
BLSD (.05) :			1.0	22.2
Starter Fertilizer				
Starter			20.3	89.0
No starter			20.9	76.4
Significance Level (%): [3/]			99	99
Poast Herbicide				
Poast			20.5	89.8
No Poast			20.7	75.6
Significance Level (%): [3/]			62	99
Interactions			Significance Levels (%)	
Tillage x SF			82	23
Tillage x Poast			93	99
SF x Poast			41	7
Tillage x SF x Poast			2	27
CV (%)			4.6	22.

1/ S = starter fertilizer used and NS = no starter fertilizer used.
2/ P = Poast herbicide used and NP = no Poast herbicide used in 1987.
3/ Probability level of significant difference between means.

Table 2. Influence of tillage methods and starter fertilizer on corn production at Waseca in 1988.

Treatment: Tillage	Starter fert.[1/]	Early plant growth	Final population	Grain N	Grain N Removal
		g/plant	$x10^3$	%	lb/A
No tillage	S	6.1	26.1	1.66	38.8
No tillage	NS	4.7	28.0	1.67	25.4
Fall plow, f. cult.	S	16.2	29.0	1.62	91.1
Fall plow, f. cult.	NS	14.7	28.6	1.70	77.1
Fall chisel, f. cult.	S	11.5	28.8	1.66	84.8
Fall chisel, f. cult.	NS	9.2	29.5	1.70	70.1
Ridge plant	S	12.2	28.5	1.67	72.1
Ridge plant	NS	11.8	28.9	1.67	74.2
Spr. disk	S	9.3	28.8	1.65	85.2
Spr. disk	NS	8.1	28.9	1.60	79.2
INDIVIDUAL FACTORS					
Tillage					
No tillage		5.4	27.0	1.66	32.1
Fall plow		15.5	28.8	1.66	84.1
Fall chisel		10.4	29.2	1.68	77.5
Ridge plant		12.0	28.7	1.67	73.2
Spr. disk		8.7	28.9	1.63	82.2
Signif. Level (%):		99	59	15	99
BLSD (.05)		2.0			18.8
Starter fertilizer					
Starter		11.1	28.3	1.62	74.4
No starter		9.7	28.8	1.68	65.2
Signif. Level (%):		99	79	67	99
Till x SF IA					
Signif. Level (%):		33	47	87	69
CV (%) :		12.	4.4	2.8	13.

1/ S = starter fertilizer used and NS = no starter fertilizer

Table 3. Influence of tillage methods for corn following soybeans on surface residue, seeding depth and leaf N at Waseca in 1988.

Treatment	Surface Residue: Before planting	After Planting: Across plot	After Planting: Within row	Planting Depth: Average	Planting Depth: S	Planting Depth: Range	Leaf nitrogen
	%	%	%	mm	mm	mm	%
No tillage	90	88	90	42	7.6	28-54	2.32
Fall plow	4	1	1	62	7.2	51-76	2.49
Fall chisel	18	7	7	64	5.8	55-78	2.44
Ridge plant	22	14	10	55	7.1	43-67	2.55
Spr. disk	60	14	9	59	5.9	47-69	2.38
Signif. Level (%):	99	99	99	99			48
BLSD (.05) :	9	6	4	12			-
CV (%) :	17.	18.	14.	13.			7.8

Nitrogen concentration of the earleaf at silking was not influenced significantly by tillage (Table 3).

The rate of seedling emergence was determined by counting the number of plants that had spiked thru in 100-feet of row/plot from the 10th to the 19th day after planting. Emergence, as a percent of final stand, shown in Table 4 indicates most rapid emergence with the RP system. Emergence was delayed about 1 to 2 days with the MP, CP and SD systems and about 3 days with the NT systems. These differences continued through about the 6 to 8-leaf stage, but by silking phenological differences among the RP, MP, CP and SD were not evident. The NT system, however, continued to be about 7 days behind at silking and reached physiological maturity a few days after the other tillage systems.

Table 4. Influence of tillage methods on the emergence progress of corn following soybeans at Waseca in 1988.

	Days Post Planting								
Treatment	10	11	12	13	14	15	16	17	19
	% emerged								
No tillage	0	0	8	22	44	74	89	97	100
Fall plow	0	15	55	76	86	90	94	96	100
Fall chisel	0	6	46	73	89	94	98	99	100
Ridge plant	2	38	82	90	96	99	100	100	100
Spring disk	0	8	44	69	84	94	96	98	100

Weed counts (broadleaf and grass) were taken between the 4th and 5th rows from 1 ft^2 sections/plot from both the previous (1987) Poast and non-Poast sections 12 days after preemergence herbicide application (Table 5). Weed pressure from broadleaf weeds was not great, as broadleaf weed counts were low from both herbicide treated and untreated areas. Grasses were controlled extremely well in the MP and RP systems and to a lesser degree with CP tillage. Grass weed control was least adequate with the NT tillage system. Under these dry conditions, the Lasso + Bladex combination had little overall effect on grass weed control at this time.

Table 5. Weed populations on May 23 as affected by tillage and herbicide for corn following soybeans at Waseca in 1988.

	Herbicide1/		No Herbicide	
Treatment	Grasses	Broadleaves	Grasses	Broadleaves
	plants/10 sq. ft.2/			
No tillage	1400	0	1427	10
Fall plow	20	10	30	0
Fall chisel	250	0	81	10
Ridge plant	50	0	40	0
Spring disk	620	0	719	0

1/ 3½ lb Lasso and 3 lb Bladex/A, preemergence
2/ Average over 4 replications and 2 counts/rep.

Grass counts from these 1 ft^2 areas were also taken for both the Poast and non-Poast areas that had been treated in 1983, 1985 and 1987. The purpose of these measurements was to evaluate the effect of these previous Poast applications on the grass pressure. Data shown in Table 6 indicate: (1) a tremendous affect of tillage on grass density, (2) some improvement in weed control with the preemergence herbicide, and (3) a marked decrease in weed pressure resulting from the previous applications of Poast. This resulted in the highly significant tillage x Poast interaction for corn yield shown in Table 1. Even though most farmers would use a herbicide program for general weed control somewhat similar to the Lasso + Bladex program, it is quite apparent that post emergence applications of materials such as Poast in the soybean phase of this crop sequence would be especially helpful for long-term grass management in the NT and SD tillage systems.

Table 6. Grass populations on May 23 as affected by previous Poast applications and tillage.

Treatment	Poast[1/]		No Poast	
	Preemerg	No Preemerg	Preemerg	No Preemerg
	Grasses/10 sq. ft.[2/]			
No Tillage	670	800	1130	2060
Fall Plow	10	20	30	40
Fall Chisel	30	80	460	1540
Ridge Plant	0	10	100	70
Spr. Disk (2 X)	130	140	1110	1290

1/ Applied in 1983, 1985 and 1987.
2/ Avg. of 4 replications and 2 counts/rep.

SUMMARY - 1987

This was the third crop of corn grown after soybeans in this long-term study with continuous corn from 1975 through 1982, soybeans in 1983, 1985 and 1987 and corn in 1984 and 1986. Surface residues prior to planting were greater than 50% with the NT and SD systems and remained above 30% after planting with the NT system. Plant emergence was fastest with RP, delayed by about 1 to 2 days with the MP, CP and SD systems, and by about 3 days with NT. Weed pressure was reduced some with the Lasso + Bladex preemergence application. Lowest weed pressure was noted with the RP and MP systems. Highest weed counts, primarily grasses, were found with the NT and SD systems. Previous applications of Poast to soybeans greatly reduced grass pressure in the CP, SD and NT systems. Early plant growth was greatest for the MP system and least for NT. Phenological plant development throughout the season continued to be a couple of days behind for the NT plants compared to plants grown on the other tillage systems. Leaf N was not affected by tillage or starter fertilizer. Yields were highest for MP, intermediate for RP, CP and SD, and lowest for the NT system. Soil profile investigations in mid-July indicated very limited soil water throughout the top 36" with all tillage systems and particularly poor rooting systems for the RP and NT tillage systems. Starter fertilizer increased yields by 16% when averaged over tillage systems. However, yield increases due to starter were greatest with the NT, CP and MP systems.

FOURTEEN-YEAR YIELD SUMMARY

Grain yields from the five tillage systems where starter fertilizer was used from 1975-1982 are shown in Table 7. The 8-year average yield shows a 5.3 bu/A yield advantage for the moldboard plow over the ridge-plant system. Some of this difference can be attributed to the 17 bushel advantage in 1980 for moldboard plowing. The chisel plow and till-plant (flat) systems showed intermediate yields while lowest yields were obtained with no tillage. Weed control was excellent in all treatments except no tillage. Postemergence herbicides were applied to no tillage in 1979 and 1980 and did provide better weed control.

Four-year data (1979-82) indicate some advantage for the use of starter fertilizer with the chisel plow (6 bu/A), ridge-plant (5 bu/A) and no tillage systems (5 bu/A). No reason can be given for the obvious difference in response to starter fertilizer between the no tillage and till-plant (flat) systems when both treatments represent the most severely reduced tillage systems.

Yields with no tillage continue to be significantly below the other tillage systems since converting to a corn/soybean sequence (Table 7). Corn yields in this sequence have not been different among the MP, CP, RP and SD systems when starter fertilizer has been used. Without starter fertilizer, yields from the CP, RP and SD systems have averaged about 9% less than from the MP system. Soybean yields in this sequence averaged about 6% higher with the moldboard plow system compared to the CP, RP, or SD systems with virtually no difference among the latter three systems.

Table 7. Influence of tillage methods and starter fertilizer on long-term corn and soybean yields at Waseca.

Treatment		Cont. Corn Yield		Soybeans	Corn
Tillage	Starter	1975-82	1979-82	1983,85 & 87	1984,86 & 88
		bu/A			
No tillage	Yes	129.2	140.6	34.5	111.5
"	No		136.0	34.3	98.8
Fall plow	Yes	154.5	170.9	51.0	145.6
"	No		170.8	50.2	141.2
Fall chisel	Yes	144.4	161.8	47.7	136.0
"	No		155.5	45.5	124.5
Ridge plant	Yes	149.2	161.5	46.9	137.4
"	No		156.4	47.2	129.4
Till plant (flat) 1/	Yes	144.9	154.8	46.8	139.7
"	No		157.4	47.1	132.1

1/ This treatment was converted to a spring disk (2x) beginning with the 1983 crop.

DECLINE RATES OF SOIL TEST P AND K IN A CORN-SOYBEAN ROTATION[1/]

1988

G. W. Randall and S. D. Evans[2/]

ABSTRACT: Decline rates of soil test P and K are being measured following 12 years of various application rates of P and K at two locations. Soil test P and K did not decline in 1988, probably because of low crop demand due to the hot and dry conditions. Soybean yields were increased about 10% by increasing P up to a soil test of 40 lb P/A at Waseca but did not increase with higher P levels. Soil test K, ranging from 235 to 325 lb K/A at Waseca, did not influence yield. Soybean yields were very low at Morris and were not affected by soil test P level.

With good fertilization practices over the last 20 to 30 years, many farmers throughout the Cornbelt have built their P and K soil tests to high and very high levels. Studies conducted over the last 12 years have not shown corn and soybean yield increases from additional broadcast P and K at these high to very high test levels. Consequently, a number of farmers have curtailed P and K fertilization on these high testing soils. Two commonly asked questions in this scenario are: (1) How fast will my soil test drop if I don't continue to add fertilizer P and K? and (2) At what test level should I begin to add P and K to maintain fertility at an optimum level for efficient and economical production? The purposes of this study are to determine (1) the decline rates of soil test P and K and (2) the optimum soil test level which should be maintained for economical corn and soybean production.

EXPERIMENTAL PROCEDURES

High rates of P and K were applied over a 12-year period (1973-84) in studies at the Southern Experiment Station at Waseca (Table 2) and the West Central Experiment Station at Morris (Table 3). These rates created a wide range of soil test values upon which we can evaluate the decline rates of soil test P and K when no additional fertilizer is added. Treatments 2, 3, and 4 have not received additional P since 1984 while treatments 6 and 7 at Waseca have not received K. The K treatments were not included at Morris because of very high native soil test K levels. Treatment 5, which had a moderately high level of fertilization prior to 1985, continues to receive P and K, and thus, serves as the high fertility control.

The P and K materials (0-46-0 and 0-0-60) were broadcast on the soil surface and incorporated by moldboard plowing the corn residue in the fall of 1987. Specific experimental procedures used for soybean at the two locations are presented in Table 1. Management practices providing for optimum yields were employed at each location. Starter fertilizer was not used.

Table 1. Experimental procedures for soybean on the high P and K rate study at the two branch stations in 1988.

	Location	
Variable	Morris	Waseca
Planting date	5/3	5/19
Row spacing	30"	13"
Planting rate (plants/A)	10 beans/ft	3-4 beans/ft
Variety	Evans	Hardin
Herbicide	3# Lasso + 2.5# Amiben/A (Bdct)	3.5# Lasso + 3# Amiben/A (Bdct)
Harvest date	9/9	10/5
Soil type	Aastad clay loam	Webster clay loam

1/ Funding provided by the TVA - National Fertilizer Development Center.
2/ Soil scientists and professors at the Southern Experiment Station, (Waseca) and West Central Experiment Station (Morris), respectively.

RESULTS AND DISCUSSION

Total phosphate (P_2O_5) and potash (K_2O) applied over the 12-yr period ranged from 0 to 1200 lb/A (Tables 2 and 3). These application rates plus the 1985-86 rates resulted in highly significant differences in soil test P at both locations and in soil test K at Waseca. At Waseca soil test P ranged from 17 to 121 lb P/A (Table 2). Soil test P did not change compared to 1987, but soil test K was generally 10 to 20% higher. This may have been due to the very dry conditions or to the fact that soybeans were grown in 1988 compared to corn in 1987. Soybean yields were increased significantly by P but plateaued at soil P levels higher than 40 lb/A. No reason can be given for the slightly lower yield of treatment 7.

At Morris, Bray P_1 ranged from 17 to 66 lb/A while Olsen's $NaHCO_3$ test ranged from 8 to 45 lb P/A (Table 3). Due to the extremely dry conditions, yields were very low and soil test P and K levels remained similar to those found in 1987.

Table 2. Soil test values, soybean moisture, and soybean yield as influenced by 15 years' application of P and K at Waseca.

	P and K Treatments		Soil Test 2/			Soybean	
No.	Total 1973-84	1985-87 1/	pH	P	K	Moisture	Yield
	----- lb P_2O_5 + K_2O/A -----			--- lb/A ---		%	bu/A
2	0 + 1200	0 + 100	6.7	17	316	11.8	35.8
3	600 + 1200	0 + 100	6.4	45	309	11.3	40.1
4	1200 + 1200	0 + 100	6.7	82	278	11.2	39.7
5	600 + 1200	100 + 100	6.7	85	327	11.4	41.4
6	1200 + 0	100 + 0	6.7	121	235	11.3	40.5
7	1200 + 600	100 + 0	6.6	120	237	10.7	37.1
	Signif. Level (%):		53	99	99	93	96
	BLSD (.05) :		-	11	32	-	4.0
	CV (%) :		3.1	8.3	6.4	3.3	5.1

1/ Treatments applied each Fall.
2/ Samples were taken in October before 1988 treatments were applied.

Table 3. Soil test values, soybean moisture, and soybean yield as influenced by 15' years' application of P and K at Morris.

	P and K Treatments		Soil Test 2/				Soybean	
No.	Total 1973-84	1985-87 1/	pH	P_1	P_{Ol}	K	Moisture	Yield
	---- lb P_2O_5 + K_2O/A -----			------ lb/A	-------		%	bu/A
2	0 + 1200	0 + 100	7.7	17	8	406	11.1	8.0
3	600 + 1200	0 + 100	7.6	38	24	380	10.3	8.3
4	1200 + 1200	0 + 100	7.7	66	45	369	10.4	9.3
5	600 + 1200	100 + 100	7.7	58	41	363	10.8	9.0
	Signif. Level (%):		94	99	99	41	8	19
	BLSD (.05) :			16.	14.			
	CV (%) :		22.	22.	30.	12.	16.	79.

1/ Treatments applied each Fall.
2/ Samples were taken in October before 1988 treatments were applied.

CONCLUSIONS

Long-term (12-yr) P additions to these two soils created a wide range in soil test P levels. Soybean yields were optimized over the no P treatments at soil test P levels of 40 lb/A at Waseca. Yields were not affected by K at Waseca or by P at Morris, primarily because of the very dry conditions. Soil test P levels at both locations were similar to 1987; however, soil test K was 10 to 20% higher at Waseca in 1988. Additional years will be needed to more accurately determine the decline rates.

WATER QUALITY RESEARCH WITH NITROGEN AT THE HERMAN ROSHOLT WATER QUALITY RESEARCH FARM, WESTPORT, MN 1988 [1]
Small plot phase.

G.L. Malzer and T.J. Graff [2]

Abstract: The objective of the small plot water quality reseach phase is to evaluate and quantitate the impact of a variety of agricultrual practices on crop nitrogen utilization efficiency and the potential impact on water quality. Currently agricultrual practices such as crop rotation, tillage, and fertilizer N management including, rates, sources, time of application, methods of application and use of nitrification inhibitors are being evaluated. Due to the hot, dry summer, relativily few differences in crop production were noted due to management practices. Corn grain yields aveaged 5 bu/a higher when the preceding crop was soybeans rather than corn. Corn grain yields utilizing a traditional chisel-plow tillage systems was 7-11 bu/a higher than ridge-till systems. Early N applications in 1988 were superior to split or late N applications. Nitrogen rates in excess of 120 kg/ha resulted in excess nitrate - N present in the soil profile at the end of the growing season. This excess nitrate has a high potential of being moved down toward the groundwater before the next growing season.

In 1987 three phases of nitrogen (N) research were started at the Herman Rosholt Water Quality Research Farm at Westport, MN. The three phases of research included a lysimeter phase, a large plot groundwater phase and a small plot N management/crop production phase. Each phase will be reported separately.

The soil at the Rosholt farm is an Estherville sandy loam with 38-76 cm of sandy loam soil overlying glacial outwash composed mainly of coarse sand and gravel. Because of the coarse nature of these soils and the low water holding capacity, they are frequently irrigated to attain high yields. The higher yield potential along with higher fertilizer inputs, low water holding capacity, and shallow underlying aquifer create conditions which could result in groundwater contamination with nitrate N. Improper fertilizer N management can result in reduced yields, reduced fertilizer use efficiency, decreased profits, and increased groundwater contamination. The purpose of this phase of research was to determine the impacts of different N and crop management practices on crop yield, N utilization and their resulting impacts on groundwater quality.

Experimental Procedures

Two separate N experiments were established at the Rosholt farm in 1988.

Experiment 1 consisted of 25 N treatments randomized within a split-split plot design with three replications. The main plot consisted of two cropping sequences (continuous corn and corn following soybeans) with the sub-plots being tillage (ridge till and chisel plow). Ridges were constructed the previous growing season in 1987. In 1988 the entire experiment was planted to corn. The 25 N treatments within each sub-plot consisted of a control (zero N) plus four N rates (60, 120 180, and 240 kg/ha), two nitrification inhibitors (none and N-Serve) and three times/methods of application (all N early-4 leaf growth stage, all N late-8 leaf growth stage, and split with 2/3 N early and 1/3 late). All fertilizer N treatments were applied as anhydrous ammonia. The nitrification inhibitor N-Serve was applied with an in-line injection pump which inserted the chemical in front of a bidirectional flow integrator and the manifold. N-Serve was applied at a rate of 0.56 kg/ha active ingredient.

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1. Funding provided by the University of Minnesota Agricutrual Experiment Station and the Center for the Impacts of Agicultral Practices on Water Quality.
Appreciation is also expressed to Pioneer Hybrid International for suppyling seed corn.

2. Associate Professor and Asst. Scientist, respectively, Dept. of Soil Science. University of Minnesota.

Soil samples were taken from 0-30 and 30-60 cm depth from 13 of the 25 treatments on April 12th before planting and on October 3rd after harvest. The soil samples were analyzed for ammonium and nitrate concentration and the data is reported in tables 4 and 5. Only fall samples were taken if soybeans were the previous crop.

Experiment 2 consisted of 16 N treatments randomized within a split plot design with three replications. The main plots variable was tillage (ridge till and chisel plow). The 16 N treatments within each sub-plot consisted of two N rates (120 and 180 kg/ha), two N sources (anhydrous ammonia and urea) and two nitrification inhibitor treatments (with and without) at two times of application (early-4 leaf and late-8 leaf). Nitrification inhibitor treatments consisted of 0.56 kg/ha a.i. of N-Serve applied with anhydrous ammonia or 10% DCD-N with urea. The DCD urea was supplied by Tennessee Valley Authority-National Fertilizer Development Center. Urea treatments were injected at a depth of 15 cm and positioned approximately 15 cm away from the row similar to the anhydrous ammonia treatments.

Experiments 1, and 2: Corn (Pioneer 3902 - 90 day R.M.) was planted on April 28 in 0.76 m rows at a population of 78,600 seeds/ha using a four-row Buffalo planter. Starter fertilizer was applied at the rate of 93.5 l/ha of 7-22-5 as a band below the seed. A tank mix of Dual (1.96 kg/ha), Bladex (1.96 kg/ha) and Roundup (2.24 kg/ha) was applied on May 6th for weed control. Because of poor weed control the area was resprayed with a tank mix of Bladex 90 DF(2.0 kg/ha), and Prowl (1.1 kg/ha) on May 23rd. For additional weed control the experiments were cultivated twice. The first cultivation was on June 4th, and second on June 18th, ridges were also built on June 18th. Nitrogen treatments were applied on June 2nd (early-4 leaf) and on June 16th (late-8 leaf). The irrigation program (traveling boom) was started on May 18th and continued through July 29th with 31.8 cm of water being applied through irrigation. An additional 17.9 cm of water was obtained during the growing season as rainfall.

Grain yields were obtained on September 26th by hand harvesting 9.3 m^2 of plot area. All grain yields were adjusted to 15.5% moisture.

General Results

Experiment 1 Because of the hot temperatures experienced in 1988 along with bird damage, few treatments averaged over 130 bu/a. When no fertilizer N was applied corn yields ranged from 70-110 bu/a depending on previous crop and tillage system. When no fertilizer N was applied corn yields were 16 bu/a higher with the chisel tillage system and 42 bu/a higher on the ridge-till system when the previous crop was soybeans rather that corn. This large advantage to the corn following soybean rotation was reduced when fertilizer N was applied. Across all treatment comparisons, however, corn yields were 5 bu/a higher following soybeans than following corn. Tillage system also influenced final grain yield. Although the ridge-till treatments provided better yields than the chisel tillage system when no fertilizer N was applied following soybeans this did not continue with all comparisons. Across the entire experiment corn grain yields were 7 and 11 bu/a higher utilizing a chisel system of tillage in 1988 rather than ridge tillage for corn following corn and corn following beans respectively.

Yield increases were obtained with fertilizer N up to rates of 120 kg/ha (108 lbs/a). The hot dry summer created conditions for some very interesting responses to fertilizer management. Fertilizer use efficiency would normally increase by delaying the time of fertilizer N application thereby minimizing N loss. In 1988 highest yields were obtained when the fertilizer was applied early (4-leaf) rather than in split or 8-leaf applications. This did, however, appear to be more pronounced with corn-corn rather than soybeans-corn. The lack of a yield response when the timing of fertilizer N was changed would indicate that N losses were not large during the 1988 growing season. A significant yield increase (4-5 bu/a) was obtained with the use of N-Serve. Since N-Serve is a chemical additive used with fertilizer to minimize N loss from soil, and the amount of N loss was low in 1988, the reason for a respose is not well understood at this time.

The concentration of nitrate-N in the surface 0.6 m of soil in the spring of 1988 was high if the fertilizer N treatment in 1987 was above 120 kg/ha (108 lbs/a). This would support the fact that winter recharge of the aquifer and leaching of nitrate-N through the soil during the late fall, winter, and early spring were minimal in 1987-1988. The soil nitrate-N concentration following harvest were generally lower than that found before planting. This reduced concentraion of nitrate-N may be due to either efficient utilization of the N by the plant or movement of the N below the 0-0.6 m sampling region. Since yields were not high it would seem feasible that at least a portion of the nitrate moved deeper into the soil profile during the growing season. The highest rate of fertilizer N tended to have higher concentrations of nitrate-N in the soil profile when it followed soybeans with chisel plow tillage.

<u>Experiment 2</u> The fertilizer N rates of 120 and 180 kg/ha were at or above the necessary rate to obtain optimum yields. Differences between various fertilizer N management options were therefore minimal. There was no treatment effect due to tillage, N source, N rate, or time of application.

Table 1. Influence of N-rates, nitrification inhibitors, method of application and tillage on continuous corn grain yields, Westport,MN 1988.

Total N-Rate kg/ha	Early N	Inh.	Late N	Tillage	Grain Bu/A	Grain % N	Grain mt/ha	N-Removal kg/ha
Control	-----	---	-----	C	78.4	1.33	4.93	55.76
60	60	---	-----	C	102.5	1.63	6.45	88.87
60	-----	---	60	C	122.0	1.62	7.67	104.57
60	40	---	20	C	113.5	1.70	7.14	102.38
60	60	NS	-----	C	108.4	1.66	6.82	95.45
60	-----	NS	60	C	117.3	1.62	7.38	100.98
60	40	NS	20	C	120.6	1.74	7.59	111.21
120	120	---	-----	C	117.9	1.65	7.42	103.40
120	-----	---	120	C	102.4	1.77	6.45	95.93
120	80	---	40	C	121.9	1.74	7.67	112.71
120	120	NS	-----	C	105.9	1.75	6.67	98.23
120	-----	NS	120	C	120.4	1.72	7.57	110.08
120	80	NS	40	C	109.4	1.73	6.88	100.29
180	180	---	-----	C	106.8	1.83	6.72	103.69
180	-----	---	180	C	117.2	1.72	7.37	106.64
180	120	---	60	C	106.2	1.79	6.68	100.48
180	180	NS	-----	C	116.2	1.67	7.31	102.56
180	-----	NS	180	C	113.3	1.72	7.13	103.54
180	120	NS	60	C	105.4	1.74	6.63	97.33
240	240	---	-----	C	127.7	1.70	8.04	115.35
240	-----	---	240	C	108.4	1.71	6.82	98.00
240	160	---	80	C	108.7	1.73	6.84	99.53
240	240	NS	-----	C	109.4	1.78	6.88	103.34
240	-----	NS	240	C	117.3	1.55	7.38	96.26
240	160	NS	80	C	126.0	1.66	7.93	110.86
Control	-----	---	-----	R	69.8	1.38	4.39	50.99
60	60	---	-----	R	99.5	1.70	6.26	89.64
60	-----	---	60	R	92.9	1.80	5.85	88.73
60	40	---	20	R	98.8	1.62	6.22	84.70
60	60	NS	-----	R	110.2	1.67	6.94	96.82
60	-----	NS	60	R	107.7	1.82	6.77	103.78
60	40	NS	20	R	100.3	1.71	6.31	90.50
120	120	---	-----	R	109.3	1.72	6.88	99.45
120	-----	---	120	R	105.2	1.73	6.62	96.41
120	80	---	40	R	110.2	1.71	6.93	99.70
120	120	NS	-----	R	122.4	1.74	7.70	112.50
120	-----	NS	120	R	122.5	1.75	7.71	113.20
120	80	NS	40	R	116.6	1.76	7.33	108.45
180	180	---	-----	R	121.8	1.77	7.66	113.82
180	-----	---	180	R	80.0	1.66	5.03	70.60
180	120	---	60	R	99.1	1.82	6.24	95.43
180	180	NS	-----	R	104.4	1.86	6.57	102.51
180	-----	NS	180	R	104.0	1.73	6.55	95.58
180	120	NS	60	R	102.7	1.80	6.46	97.98
240	240	---	-----	R	113.4	1.74	7.13	104.45
240	-----	---	240	R	98.0	1.77	6.16	91.99
240	160	---	80	R	103.7	1.78	6.53	97.55
240	240	NS	-----	R	119.1	1.78	7.49	112.15
240	-----	NS	240	R	94.5	1.82	5.94	91.34
240	160	NS	80	R	107.2	1.70	6.75	96.82

Table 1. continued: Continuous Corn Split Plot Statistical Analysis

	Grain		Grain	N-Removal
Tillage	Bu/A	% N	mt/ha	kg/ha
Chisel	113.5	1.70	7.14	102.56
Ridge Till	106.0	1.74	6.66	98.08
P-Value	99	95	99	99
N-Rate X Method X Inhibitor				
N-Rate kg/ha				
60	107.8	1.69	6.78	96.46
120	113.7	1.73	7.15	104.19
180	106.4	1.75	6.69	99.18
240	111.1	1.72	6.99	101.46
P-Value	99	99	99	99
BLSD (.05)	3.4	0.02	0.21	2.75
Method				
1. 4 leaf	112.2	1.72	7.05	102.63
2. 8 leaf	107.7	1.72	6.77	97.975
3. Split 2/3 1/3	109.4	1.73	6.88	100.37
P-Value	99	38	99	99
BLSD (.05)	3.1		0.19	2.47
Inhibitor				
None	107.8	1.72	6.78	98.50
N-Serve	111.7	1.72	7.02	102.15
P-Value	99	30	99	99
N-Rate X Method	99	99	99	99
N-Rate X Inhibitor	35	68	35	90
Method X Inhibitor	99	45	99	98
N-Rate X Method X Inhibitor	99	94	99	99
N-Rate X Method X Inhibitor X Tillage				
N-Rate X Tillage	99	73	99	97
Method X Tillage	99	93	99	99
Inhibitor X Tillage	96	92	96	99
N-Rate X Method X Tillage	86	99	86	99
N-Rate X Inhibitor X Tillage	79	55	79	60
Method X Inhibitor X Tillage	53	45	53	74
N-Rate X Method X Inhibitor X Tillage	99	79	99	99

Table 2. Influence of N-rates, nitrification inhibitors, method of application and tillage on corn grain yields, corn following soybeans. Westport,MN 1988.

Total N-Rate kg/ha	Early N	Inh.	Late N	Tillage	Grain Bu/A	% N	Grain mt/ha	N-Removal kg/ha
Control	-----	---	-----	C	94.7	1.52	5.96	76.53
60	60	---	-----	C	122.4	1.80	7.70	116.97
60	-----	---	60	C	113.4	1.78	7.13	106.82
60	40	---	20	C	111.8	1.75	7.03	103.43
60	60	NS	-----	C	127.6	1.73	8.03	116.60
60	-----	NS	60	C	118.1	1.73	7.43	107.93
60	40	NS	20	C	109.4	1.71	6.89	99.20
120	120	---	-----	C	118.2	1.76	7.43	110.15
120	-----	---	120	C	102.6	1.66	6.46	90.02
120	80	---	40	C	132.4	1.60	8.33	112.42
120	120	NS	-----	C	127.9	1.64	8.04	111.04
120	-----	NS	120	C	129.7	1.63	8.16	111.52
120	80	NS	40	C	128.0	1.73	8.05	117.47
180	180	---	-----	C	99.6	1.72	6.27	90.79
180	-----	---	180	C	130.8	1.62	8.23	112.62
180	120	---	60	C	130.8	1.57	8.19	108.56
180	180	NS	-----	C	120.4	1.68	7.58	106.99
180	-----	NS	180	C	124.3	1.69	7.82	111.12
180	120	NS	60	C	122.3	1.61	7.69	104.40
240	240	---	-----	C	119.6	1.78	7.53	112.94
240	-----	---	240	C	114.7	1.68	7.21	102.08
240	160	---	80	C	130.3	1.66	8.20	114.27
240	240	NS	-----	C	134.5	1.61	8.46	114.67
240	-----	NS	240	C	97.9	1.69	6.16	87.61
240	160	NS	80	C	116.9	1.60	7.36	99.10
Control	-----	---	-----	R	112.5	1.47	7.08	87.52
60	60	---	-----	R	112.8	1.63	7.10	97.16
60	-----	---	60	R	106.0	1.62	6.67	91.01
60	40	---	20	R	117.3	1.69	7.38	104.99
60	60	NS	-----	R	103.8	1.78	6.53	97.66
60	-----	NS	60	R	108.3	1.69	6.81	97.17
60	40	NS	20	R	115.1	1.74	7.24	105.60
120	120	---	-----	R	122.6	1.63	7.71	105.37
120	-----	---	120	R	85.4	1.71	5.37	77.30
120	80	---	40	R	106.2	1.69	6.68	95.33
120	120	NS	-----	R	104.2	1.73	6.56	95.20
120	-----	NS	120	R	123.3	1.54	7.76	99.92
120	80	NS	40	R	125.8	1.58	7.92	105.42
180	180	---	-----	R	113.4	1.67	7.13	100.33
180	-----	---	180	R	102.1	1.82	6.42	98.44
180	120	---	60	R	92.7	1.65	5.83	81.43
180	180	NS	-----	R	108.9	1.80	6.85	104.05
180	-----	NS	180	R	101.4	1.73	6.38	93.36
180	120	NS	60	R	108.0	1.81	6.79	103.75
240	240	---	-----	R	100.1	1.73	6.30	91.69
240	-----	---	240	R	101.3	1.68	6.37	90.05
240	160	---	80	R	105.2	1.70	6.62	94.65
240	240	NS	-----	R	122.1	1.71	7.68	110.59
240	-----	NS	240	R	106.3	1.83	6.69	103.17
240	160	NS	80	R	122.1	1.65	7.69	106.54

Table 2. continued: Corn Following Soybeans Split Plot Statistical Analysis

	Grain		Grain	N-Removal
<u>Tillage</u>	Bu/A	% N	mt/ha	kg/ha
Chisel	120.1	1.68	7.55	107.02
Ridge Till	108.9	1.70	6.85	97.92
P-Value	97	82	97	98
<u>N-Rate X Method X Inhibitor</u>				
<u>N-Rate kg/ha</u>				
60	113.8	1.72	7.16	103.71
120	117.2	1.65	7.37	102.59
180	112.8	1.69	7.09	101.31
240	114.2	1.69	7.18	102.27
P-Value	71	96	71	38
BLSD (.05)		0.04		
<u>Method</u>				
1. 4 leaf	116.1	1.71	7.30	105.13
2. 8 leaf	110.3	1.69	6.94	98.75
3. Split 2/3 1/3	117.1	1.67	7.36	103.53
P-Value	99	91	99	99
BLSD (.05)	3.9		0.25	2.97
<u>Inhibitor</u>				
None	112.1	1.69	7.05	100.36
N-Serve	116.9	1.69	7.35	104.58
P-Value	99	3	99	99
N-Rate X Method	97	48	97	99
N-Rate X Inhibitor	93	76	93	82
Method X Inhibitor	38	20	38	22
N-Rate X Method X Inhibitor	99	90	99	99
<u>N-Rate X Method X Inhibitor X Tillage</u>				
N-Rate X Tillage	82	99	82	59
Method X Tillage	11	70	11	25
Inhibitor X Tillage	82	99	82	99
N-Rate X Method X Tillage	99	46	99	99
N-Rate X Inhibitor X Tillage	94	99	94	99
Method X Inhibitor X Tillage	99	99	99	95
N-Rate X Method X Inhibitor X Tillage	35	99	35	45

Table. 1 and 2 continued: Split plot statistical analysis for corn-corn and corn following soybeans, Westport MN 1988

	Grain Bu/A	Grain % N	Grain mt/ha	N-Removal kg/ha
<u>Crop</u>				
Corn-Corn	109.7	1.72	6.90	100.32
Corn-Soybeans	114.5	1.69	7.20	102.47
P-Value	99	82	99	95
<u>Tillage</u>				
Chisel	116.8	1.69	7.35	104.79
Ridge Till	107.4	1.72	6.76	98.00
P-Value	99	99	99	99
Crop X Tillage	65	73	65	86
<u>N-Rate X Method X Inhibitor</u>				
<u>N-Rate</u>				
60	110.8	1.70	6.97	100.08
120	115.4	1.69	7.26	103.39
180	109.6	1.72	7.08	101.87
240	112.7	1.70	7.08	101.87
P-Value	99	97	99	97
<u>Inhibitor</u>				
None	110.0	1.70	6.91	99.43
N-Serve	114.3	1.71	7.19	103.37
P-Value	99	25	99	99
<u>Method</u>				
1. 4 leaf	114.2	1.72	7.18	103.88
2. 8 leaf	109.0	1.70	6.85	98.36
3. Split 2/3 1/3	113.2	1.70	7.12	101.95
P-Value	99	86	99	99
N-Rate X Inhibitor	74	83	74	86
N-Rate X Method	96	70	96	95
Method X Inhibitor	86	22	86	91
N-Rate X Method X Inhibitor	99	85	99	91
<u>N-Rate X Method X Inhibitor X Crop</u>				
N-Rate X Crop	44	99	44	99
Inhibitor X Crop	34	18	34	28
Method X Crop	87	92	87	53
N-Rate X Inhibitor X Crop	81	84	81	83
N-Rate X Method X Crop	93	96	93	99
Method X Inhibitor X Crop	72	50	72	63
N-Rate X Method X Inhibitor X Crop	99	98	99	99
<u>N-Rate X Method X Inhibitor X Tillage</u>				
N-Rate X Tillage	82	96	82	67
Inhibitor X Tillage	95	98	95	99
Method X Tillage	97	70	97	96
N-Rate X Inhibitor X Tillage	60	70	60	77
N-Rate X Method X Tillage	94	55	94	99
Method X Inhibitor X Tillage	96	80	96	84
N-Rate X Method X Inhibitor X Tillage	95	76	95	95
<u>N-Rate X Method X Inhibitor X Tillage X Crop</u>				
N-Rate x Tillage X Crop	96	99	96	86
Inhibitor X Tillage X Crop	17	36	17	5
Method X Tillage X Crop	91	94	91	95
N-Rate X Inhibitor X Tillage X Crop	92	94	92	96
N-Rate X Method X Tillage X Crop	95	98	95	97
Method X Inhibitor X Tillage X Crop	99	99	99	90
N-Rate X Method X Inh. X Till X Crop	83	94	83	77

Table 3. Influence of N-rates, N-forms, nitrification inhibitors, time of application and two tillage systems on grain yields at Westport, MN. 1988

N-Rate Kg/ha	N-Form	Inh.	Time	Tillage	Grain Bu/A	Grain % N	Grain mt/ha	N-Removal kg/ha
120	AA	---	1	C	115.3	1.69	7.25	102.92
120	AA	NS	1	C	118.5	1.66	7.45	104.01
120	UREA	---	1	C	119.1	1.75	7.49	110.51
120	UREA	DCD	1	C	112.6	1.66	7.08	98.88
120	AA	---	2	C	122.6	1.64	7.71	105.81
120	AA	NS	2	C	113.7	1.73	7.15	104.02
120	UREA	---	2	C	113.3	1.67	7.13	100.01
120	UREA	DCD	2	C	112.0	1.69	7.05	100.31
180	AA	---	1	C	138.7	1.67	8.72	122.96
180	AA	NS	1	C	114.1	1.75	7.18	105.50
180	UREA	---	1	C	101.0	1.75	6.35	93.03
180	UERA	DCD	1	C	113.8	1.64	7.16	99.02
180	AA	---	2	C	122.7	1.75	7.72	113.94
180	AA	NS	2	C	96.4	1.73	6.06	88.31
180	UREA	---	2	C	112.0	1.72	7.04	101.75
180	UREA	DCD	2	C	113.5	1.67	7.14	100.27
120	AA	---	1	R	93.3	1.72	5.87	84.87
120	AA	NS	1	R	116.1	1.66	7.30	102.19
120	UREA	---	1	R	110.4	1.66	6.94	97.39
120	UREA	DCD	1	R	115.3	1.75	7.25	106.98
120	AA	---	2	R	123.6	1.71	7.78	112.01
120	AA	NS	2	R	121.4	1.70	7.63	108.92
120	UREA	---	2	R	117.3	1.72	7.38	106.41
120	UREA	DCD	2	R	113.2	1.69	7.12	101.33
180	AA	---	1	R	124.7	1.77	7.84	117.14
180	AA	NS	1	R	103.7	1.78	6.52	97.54
180	UREA	---	1	R	122.9	1.62	7.73	105.61
180	UREA	DCD	1	R	125.4	1.72	7.88	114.08
180	AA	---	2	R	108.2	1.74	6.81	99.74
180	AA	NS	2	R	96.1	1.73	6.05	88.02
180	UREA	---	2	R	128.1	1.64	8.05	111.16
180	UERA	DCD	2	R	110.4	1.77	6.94	103.28

Table 3. continued: Split Plot Statistical Analysis

	Grain Bu/A	Grain % N	Grain mt/ha	N-Removal kg/ha
Tillage				
Chisel	114.9	1.69	7.23	103.20
Ridge Till	114.3	1.71	7.19	103.54
P-Value	35	46	35	17
N-Form X Inh. X Time X N-Rate				
N-Form				
Anhydrous Ammonia	118.7	1.71	7.46	107.42
Anhydrous Ammonia + N-Serve	110.0	1.71	6.91	99.81
Urea	115.5	1.69	7.26	103.23
Urea + DCD	114.5	1.69	7.20	103.02
P-Value				
Inhibitor				
Without	117.0	1.70	7.36	105.32
With	112.2	1.70	7.06	101.41
P-Value	99	27	99	99
Time				
1. 4 leaf 6/2/88	115.2	1.70	7.25	103.91
2. 8 leaf 6/16/88	114.0	1.70	7.17	102.83
P-Value	53	10	53	52
N-Rate kg/ha				
120	114.8	1.69	7.22	102.90
180	114.4	1.71	7.20	103.83
P-Value	17	76	17	45
N-Form X Inh.	97	10	97	98
N-Form X Time	50	5	50	47
N-Form X N-Rate	76	89	76	7
Inh. X Time	98	36	98	95
Inh. X N-Rate	99	31	99	99
Time X Rate	99	22	99	99
N-Form X Inh X Time	15	23	15	10
N-Form X Inh X Time X N-Rate	99	30	99	1
N-Form X Inh. X Time X N-Rate X Tillage				
N-Form X Tillage	99	49	99	99
Inh. X Tillage	72	80	72	96
Time X Tillage	89	6	89	86
N-Rate X Tillage	74	8	74	67
N-Form X Inh. X Tillage	99	99	99	57
N-Form X Time X Tillage	99	69	99	92
N-Form X N-Rate X Tillage	99	37	99	99
Inh. X Time X Tillage	77	70	77	95
Inh. X N-Rate X Tillage	97	81	97	78
Time X N-Rate X Tillage	99	40	99	99
N-Form X Inh. X Time X Tillage	68	67	68	93
N-Form X Inh. X Time X N-Rate X Tillage	68	47	68	93

Table 4. Influence of N-rates, nitrification inhibitors, method of application and tillage in continous corn on soil ammonium and soil nitrate from spring and fall soil samples depth 1 (0-30 cm) and depth 2 (30-60cm) Westport MN.

Total N-Rate	Early N	Inh.	Late N	Tillage	Depth	Ammonium Spring	Ammonium Fall	Nitrate Spring	Nitrate Fall
kg/ha						------PPM------		-----PPM-----	
Control	-----	---	-----	C	1	---	2.7	---	4.8
					2	---	2.0	---	3.1
60	60	---	-----	C	1	2.0	3.3	10.7	5.6
					2	2.1	2.4	7.7	6.0
60	-----	---	60	C	1	2.3	2.8	11.0	5.1
					2	2.3	2.4	5.5	4.7
120	120	---	-----	C	1	2.3	3.1	11.3	7.3
					2	1.6	2.5	12.3	6.5
120	-----	---	120	C	1	2.4	3.4	9.3	6.6
					2	1.8	2.5	9.0	8.2
180	180	---	-----	C	1	2.4	2.9	13.7	7.9
					2	1.8	3.4	20.0	8.5
180	-----	---	180	C	1	2.1	3.4	10.1	6.9
					2	1.8	3.0	12.5	10.6
180	120	---	60	C	1	2.0	3.1	11.6	7.0
					2	1.6	2.6	13.9	10.0
180	180	NS	-----	C	1	3.4	5.0	14.6	10.1
					2	7.0	3.5	19.2	11.2
180	-----	NS	180	C	1	1.7	3.2	10.7	6.2
					2	2.0	2.5	11.7	8.6
180	120	NS	60	C	1	1.9	5.7	11.9	11.4
					2	1.6	3.1	9.4	13.7
240	240	---	-----	C	1	5.1	4.0	20.0	13.7
					2	2.4	3.0	37.6	12.9
240	-----	---	240	C	1	2.1	2.9	14.8	7.0
					2	1.8	2.3	20.3	7.3
Control	-----	---	-----	R	1	---	2.8	----	3.7
					2	---	2.0	----	3.4
60	60	---	-----	R	1	1.8	3.2	11.6	6.1
					2	1.9	2.2	9.5	4.0
60	-----	---	60	R	1	1.9	3.6	11.9	6.5
					2	2.6	2.8	6.7	5.2
120	120	---	-----	R	1	2.1	4.9	17.2	10.5
					2	2.0	2.7	12.4	7.3
120	-----	---	120	R	1	2.3	3.4	12.7	5.7
					2	1.6	2.4	9.7	7.7
180	180	---	-----	R	1	2.0	3.0	11.9	11.3
					2	2.1	2.1	24.7	8.3
180	-----	---	180	R	1	2.0	5.5	18.9	5.6
					2	2.2	2.8	26.8	5.7
180	120	---	60	R	1	2.0	3.5	17.7	6.2
					2	2.3	2.3	24.5	5.1
180	180	NS	-----	R	1	1.9	4.6	15.8	20.9
					2	1.6	5.6	16.5	28.6
180	-----	NS	180	R	1	1.8	3.2	12.3	11.0
					2	1.7	2.4	8.5	6.9
180	120	NS	60	R	1	1.8	4.4	11.9	9.9
					2	2.0	2.8	9.2	6.7
240	240	---	-----	R	1	3.2	2.9	15.1	8.3
					2	2.2	2.7	33.2	7.3
240	-----	---	240	R	1	2.1	3.1	24.3	6.9
					2	2.2	2.6	20.5	19.1

Table 5. Influence of N-Rates, nitrification inhibitors, methods of application and tillage in corn following soybeans on soil ammonium and soil nitrate form fall soil samples depth 1 (0-30 cm) and depth 2 (30-60 cm) Westport, MN 1988.

Total N-Rate	Early N	Inh.	Late N	Tillage	Depth	Ammonium	Nitrate
kg/ha						------PPM--------	
Control	-----	---	-----	C	1	3.0	5.8
					2	2.3	3.9
60	60	---	-----	C	1	2.8	5.9
					2	2.2	5.3
60	-----	---	60	C	1	2.7	4.8
					2	2.3	3.7
120	120	---	-----	C	1	4.3	17.3
					2	2.1	13.2
120	-----	---	120	C	1	3.1	4.9
					2	2.2	4.2
180	180	---	-----	C	1	3.8	6.9
					2	3.6	13.0
180	-----	---	180	C	1	4.1	8.8
					2	2.8	7.8
180	120	---	60	C	1	3.1	6.5
					2	2.4	5.8
180	180	NS	-----	C	1	3.0	5.4
					2	2.9	6.5
180	-----	NS	180	C	1	2.7	5.4
					2	2.8	4.4
180	120	NS	60	C	1	3.8	12.9
					2	4.0	13.3
240	240	---	-----	C	1	4.6	16.1
					2	2.3	13.5
240	-----	---	240	C	1	5.6	21.6
					2	4.2	32.7
Control	-----	---	-----	R	1	3.2	4.2
					2	2.9	4.5
60	60	---	-----	R	1	2.8	5.6
					2	2.5	4.4
60	-----	---	60	R	1	3.5	7.3
					2	2.4	5.2
120	120	---	-----	R	1	3.2	6.9
					2	2.7	6.3
120	-----	---	120	R	1	2.8	6.6
					2	2.4	8.2
180	180	---	-----	R	1	3.1	6.0
					2	2.4	8.4
180	-----	---	180	R	1	3.0	6.8
					2	2.2	7.7
180	120	---	60	R	1	3.1	6.8
					2	2.2	10.7
180	180	NS	-----	R	1	3.4	7.1
					2	2.4	7.1
180	-----	NS	180	R	1	3.8	7.6
					2	2.5	7.4
180	120	NS	60	R	1	4.2	6.0
					2	2.6	4.8

INFLUNCE OF NITROGEN RATE AND CROP ROTATION ON GRAIN YIELD AND NITRATE-NITROGEN MOVEMENT THROUGH SOIL [1]

Large plot research phase Westport, MN. 1988

J. Neiber, D. Steele, G.L. Malzer, D. Clay and T.J. Graff [2]

Abstract: Several sampling devices, including suction lysmeters, glass blocks, sheet metal containers, and wick samplers, were installed in 1987 and 1988. Corn grain yield increases to N fertilization over 160 lbs/a were minimal in both 1987 and 1988. Increasing the rate of N fertilization on continous corn from 160 to 214 lbs N/a/yr resulted in increased concentrations of NO_3-N in soil water at the 4 ft depth toward the end of 1988. Other sampling devices were installed too late in 1988 to obtain useable results.

In 1987 three phases of nitrogen (N) research were started at the Herman Rosholt Water Quality Farm at Westport, MN. The three phases of research included a lysimeter phase, a large plot groundwater phase and a small plot nitrogen management/crop production phase. This report is a summary of the results obtained from the large plot groundwater phase.

The purpose of this phase of research was to determine the impacts of N rate and crop management practices on both the crop yield, N utilization and movement of nitrate-N through the soil profile to the groundwater.

Experimental Procedures

In 1987 six large plots (approximately one acre were established at the Rosholt farm. The experiment area consisted of three treatments with two replications. Two treatments are continuous corn with N rates of 160 and 214 lbs N/a. The third treatment is in a corn following soybeans rotation with 160 lbs N/a applied during the corn year. In 1987 all treatments were planted to corn. In 1988 soybeans were planted into the corn-soybean rotation treatment. Nitrogen was applied as anhydrous ammonia in split application of two-thirds of the N rate which was applied with a nitrification inhibitor (N-Serve) at an early growth stage 4-leaf (June 2), and one-third at the 8-leaf growth stage (June 16). N-Serve was applied only at the 4-leaf stage utilizing an in-line injection pump which inserted the chemical in front of a bidirectional flow integrator and the manifold. N-Serve was applied at a rate of 0.5 lbs. a.i./a.

Corn (Pioneer 3902 - 90 day R.M.) was planted on April 28 in 30 inch rows at a population of 29,900 seeds/A using a four-row Buffalo planter. Starter fertilizer was applied at the rate of 10 gal/A of 7-22-5 as a band below the seed. A tank mix of Atrazine (1.0 #/A), Lasso (3.0 #/A) and Dicamba (.25 #/A) was used on May 6th for weed control on corn treatments.

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Soybeans (Pioneer 9061) were planted on May 24th in 30 inch rows with the same buffalo planter at a seeding rate of 192,000 seeds/a (60 lbs/a). A tank mix of Lasso (2.0 lbs/a) plus Amiben (2.5 lbs/a) was applied May 26 for weed control on the soybean treatments.
The irrigation program (traveling boom) was started on May 18th and continued through July 29th with 12.55 inches of water being applied through irrigation and an additional 7.06 inches of water coming through rainfall during the growing season.

Grain yields were obtained on September 26th by hand harvesting 800 ft^2 of plot area. Corn grain yields were adjusted to 15.5% moisture. Soybean yields were obtained on September 27th by hand harvesting 400 ft^2 of plot area and were adjusted to 13% moisture. Grain yields results are in table 1.

Chemical movement through soils to groundwater

To follow the movement of nitrate-N through soils to the groundwater several types of soil water sampling devices have been installed. These include suction lysimeters, glass blocks, sheet metal, wick samplers, and wells. The wells were installed by the United States Geological Survey, and data from the wells will not be presented at this time.

Glass block samplers are made from glass building blocks,(12" X 12"X 4" - L X W X D). Holes were drilled into the blocks to allow water to enter and permit access for removing the water collected. Three glass blocks were installed in plots at a soil depth of 18-24 inches (depth where soil becomes very coarse). Three blocks were installed side by side, one directly under a crop row and one on either side.

Suction lysimeters were installed at depths of 4 and 7 feet during 1987. The ceramic cup of the suction sampler was cast into a silica slurry which hardens in the soil to insure continuous contact between the soil and the ceramic cup. Outflow tubes were run to the surface for sampling. This type of sampler allows for the collection of soil water samples at the aforementioned depths. Concentrations of nitrate-N in soil water samples utilizing this technique are presented in table 2.

Sheet metal samplers consist of 18-guage sheet metal, cut, bent, and spot welded into a trough-like collection box. The samplers are 30" long 12" wide and 3" deep and made watertight by soldering along seams. Holes were drilled into the top of the sampler to allow entry of water. Access tubes were installed to the soil surface to facilate extraction of the water collected.

Wick samplers a one-half inch glass plate, 12 inches X 30 inches. A hole was drilled in the center of the glass plate and a 2 inch lenght of PVC pipe was attached to it. A braided glass rope was inserted through the PVC pipe and onto the glass plate. The strands of glass rope were unraveled over the surface of the glass plate and epoxied to the edges of the plate, forming a spider web-like pattern. The glass rope thus acted as a wicking device to draw water from the surface of the plate into a one gallon collection jar. These also have outflow tubes going to the surface. The sheetmetal and wick samplers were installed at approximately the same depth as the glass blocks.

General Results: Preliminary results would suggest that there was no yield advantage to the application of fertilizer N over 160 lbs/a in 1987 and only a modest increase in 1988. The concentration of nitrate-N in soil solutions at the four and seven ft. depth should be viewed cautiously since 1987 and 1988 were the years of installation. Increased concentrations of nitrate-N were detected at the 4 ft. depth approximately two months after N application. Concentations of nitrate appeared to increase gradually with time. Higher rates of fertilizer N resulted in higher concentrations of NO_3-N toward the end of 1988.

Table 1. Corn grain and soybean yields from the large plot area Westport MN. 1988.

Corn Yields

Total N-Rate	Early N	Late N	Crop Rotation	Bu/A 15.5%		Grain % N		N-Removal Grain #/a	
lbs/a				1987	1988	1987	1988	1987	1988
160	105	55	Corn-Corn	120.5	109.0	1.69	1.71	96.3	88.2
214	140	74	Corn-Corn	123.4	118.4	1.69	1.74	98.3	97.5
160	105	55	Corn-Soybean	124.5	-----	1.55	----	91.3	----

Soybean Yields 1988

Bu/A at 13 % miosture 51.6

Table 2. Nitrate-N concentration of soil solution from 4 and 7 foot suction lysimeters 1988.

Treatments	Corn-Corn 160 lbs/a		Corn-Corn 214 lbs/a		Corn-Soybean 160 lbs/a	
Depth ft	4	7	4	7	4	7
Date(M/D/Y)	ppm NO_3-N					
7/2/87	5.5	11.5	7.7	9.7	7.6	13.8
7/6/87	6.7	9.8	8.9	9.3	7.6	11.8
7/10/87	7.1	10.5	7.2	9.9	9.4	11.8
7/24/87	14.6	13.1	13.5	11.7	19.0	11.8
8/7/87	14.1	13.8	20.1	12.5	22.2	13.0
8/25/87	13.2	15.0	21.8	14.4	22.0	14.7
9/16/87	----	----	22.2	14.9	24.1	16.2
4/4/88	----	----	----	----	19.1	----
4/7&8/88	----	----	----	----	39.3	----
4/27/88	----	----	----	----	21.8	22.7
8/12/88	23.2	38.0	15.3	22.6	18.7	----
10/3/88	25.3	21.4	45.9	24,4	21.7	18.1
10/25/88	31.3	26.7	53.4	45.3	43.4	26.1

---- = no sample

1/ Fertilizer N applied only in 1987

TILLAGE, N RATE AND NITRIFICATION INHIBITOR INFLUENCE ON CORN PRODUCTION AND NO_3 LEACHING[1]

D.E. Clay, G.L. Malzer, and J.L. Anderson[2]

ABSTRACT. Course textured soils in central Minnesota are frequently irrigated and fertilized with N to obtain maximum corn (Zea mays L.) yields. If excessive N fertilizer or over irrigation occurs then NO_3 leaching may be a potential health problem. The objective of this research was to determine the impact of different tillage systems, N rates, and nitrification inhibitor (DCD) on corn yield, N utilization and efficiency. Over the 2 years of the study corn yield and NO_3 concentration in the percolated water increased with N rate. Tillage treatment did not influence corn yield or NO_3 leaching. Nitrification inhibitor reduced NO_3 leaching into the ground water and did not have a impact on corn yields.

In central Minnesota course textured soils are frequently irrigated and fertilized with N to obtain maximum corn (Zea mays L.) yields. When excessive amounts of water or N fertilizer are applied to cropland NO_3-N leaching may pose a potential health problem. Nitrate leaching may be reduced by: (i) improved N and water management and/or (ii) improved N fertilizer recommendations. The objective of this research was to determine the impact of different tillage systems, N rates, and a nitrification inhibitor on corn yield, N utilization and efficiency, and NO_3-N leaching under a irrigated system in central Minnesota.

EXPERIMENTAL PROCEDURES

In 1975, 30 non-weighing lysimeters were installed on the Rosholt farm at Westport Minnesota. Each lysimeter was 5.75 ft in diameter and 4 ft deep and constructed of 12-gauge galvanized steel coated with coal tar epoxy-enamel. At the bottom of each lysimeter a sintered stainless steel filter candle was installed and connected to the soil surface by polyethylene tubing. Soil at the experimental site was a Estherville sandy loam (Typic Hapludolls) and was used to fill the lysimeters by depth.

Prior to the initiation of this experiment the experimental site had been under 2 years of dryland no-tillage soybean (Glycine max) production. Selected chemical and physical characteristics are shown in Table 1. Irrigation was provided to all plots through a drip-type irrigation system. Drippers were 30 inches apart on a 0.5 inch plastic irrigation line. An irrigation line was placed along each row of corn (Zea mays L.). Water was pumped through the irrigation system at 13.8 kPa pressure. Emission rate for each dripper was 0.35 gal/h. Each lysimeter contained 4 drippers. Irrigation water (1 inch) was applied when less than 2 inches of water were available in the soil profile. Irrigation water was metered through 3 main irrigation lines.

Corn (Pioneer 3790) was planted in the spring of 1987 and 1988 at a density of 27,000 seeds/A. Starter fertilizer (0-26-26) was banded below the seed at the rate of 35 lb/A. The crop rotation was corn-corn-soybeans. Soil temperature, wind speed, rainfall, and air temperatures were measured at regular intervals each day over the 2 growing seasons. This is the second year of the three year study.

A factorial arrangement of treatments were 2 tillage treatments (roto-tillage and no-tillage), 3 rates of urea (0, 70, and 140 lb urea-N/A) and 3 blocks. Dicyandiamide (DCD), a nitrification inhibitor, was applied at rates of 0 or 10% of the applied N to the 140 lb N/A treatments.

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[1]Funding provided by the Center for the Impact of Agricultural Practices on Water Quality.
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Corn was harvested from a 30 ft row at the silking stage and 60 ft row following black layer in both 1987 and 1988. Subsamples from the stover, cob and grain components were analyzed for total Kjeldahl N. Corn yields (grain) are reported at 15.5% moisture.

Following rainfall events water that had collected on the bottom of the lysimeters was removed, amount determined, and analyzed for NO_3-N.

RESULTS

Corn grain yields increased with N fertilizer in both 1987 and 1988 (Table 2). However, the application of 140 lbs. N/A when compared to the 70 lb N/A did not result in a significant increase in corn grain yield. Corn yields in either 1987 or 1988 were not observed to be influenced by tillage treatment or nitrification inhibitor.

Nitrogen uptake increased with N fertilizer in both 1987 and 1988. Maximum N uptake in the roto-tillage treatment was observed at the 140 lb N/A treatment in both 1987 and 1988. In the no-tillage treatment in 1987 increasing the N fertilizer rate beyond 70 lb N/A was not detected to increase N uptake. However, in 1988 for the no-tillage treatment increasing the N rate up to 140 lb N/A increased N uptake.

Inorganic N in the spring of 1987 ranged from 40 to 70 lb N/A in the surface 12 inches of soil (Table 3). These relatively high levels of inorganic N may have resulted from 2 previous years of soybeans. Inorganic N in the surface 12 inches of soil in the spring and fall of 1988 increased with N rate (Table 3). Highest inorganic N levels were observed in soil fertilized with urea treated with DCD while the lowest levels were observed in the unfertilized soil.

Water percolation through the profile did not occur in 1987 and most of 1988 growing seasons. However, in August through October in 1988 7.7 inches of rain fell resulting in 0- to 5-inches of water percolating through the lysimeters (Table 4). Total amount of NO_3 leached or water percolation through the profile was not influenced by fertilizer or tillage treatment. However, NO_3-N concentration in the percolating water was increased with N rate. Treatment of urea with a nitrification inhibitor reduced NO_3-N concentrations in the percolating water.

Nitrate movement through the soil profile was correlated to the amount of percolated water. As the amount of percolated water increased the NO_3-N concentration decreased (Fig. 1), and total amount of NO_3-N increased (Fig. 2).

DISCUSSION

The lack of corn grain yield response from treatment of urea with DCD must be considered as a product of climatic conditions. Over the two years of the study rainfall was much lower than normal resulting in little NO_3 leaching. If NO_3 does not leach then yield increases would not be expected. Dicyandiamide (DCD) was effective at reducing nitrification in that inorganic N levels in the surface soil was increased in the fall of 1988, and NO_3-N concentration of percolating water was reduced.

Nitrate concentration of the percolating water can be reduced by increasing the amount of water percolating through the profile. As the amount of water percolation increases N loss also increases. Corn yields often times are correlated to N fertilizer rate. However, maximum corn yields may be obtained at relatively low N fertilizer rates as observed in this study.. This can occur if residual N does not leach, and/or N mineralization from the organic matter was greater than expected. Applying higher than required N fertilizer levels to insure optimum yields may increase the potential for NO_3-N leaching. Under the climatic conditions observed in this experiment a substantial amount of inorganic N was contained in the soil at planting which did not leach. In order to reduce the potential for NO_3 leaching and minimize fertilizer cost the N management system should be adaptive to take advantage of these conditions.

Table 1. Some chemical and physical properties of the Estherville sandy loam.

Soil depth	Gravel	Sand	Silt	Clay	Organic matter	pH
in			%			
0-6	0.8	57.9	23.8	18.3	4.8	5.7
6-15	8.0	69.0	16.8	14.1	1.1	5.8
15-30	5.4	66.8	16.1	17.1	0.7	6.2

Table 2. Corn grain yield and N uptake during 1987 and 1988.

Tillage	N rate	grain yield 1987	grain yield 1988	N uptake 1987	N uptake 1988
	lb N/A	---- bu/A ----		---- lb/A ----	
Roto-till	0	130	47	98	42
	70	161	101	154	87
	140	174	127	184	141
	140DCD	169	127	183	148
No-till	0	125	53	91	41
	70	158	101	150	89
	140	163	119	168	122
	140DCD	150	111	150	108
LSD (0.05)		25	19	27	19
Tillage					
Roto-till		159	155	101	105
No-till		149	140	96	90
LSD (0.05)		NS	NS	NS	NS
N rate					
	0	127	95	50	42
	70	160	152	101	88
	140	170	176	123	132
	140DCD	160	167	119	128
LSD (0.05)		17	18	13	19

Table 3. Inorganic N from the surface 12 inches at 2 date during the 1988 growing season.

Tillage	N rate	4/16/87	4/12/88	9/18/88
		Sampling dates		
	lb N/A	-------- lb N/A 12" --------		
Roto-till	0	47	29	24
	70	45	37	28
	140	46	50	48
	140DCD	49	74	89
No-till	0	48	33	25
	70	64	27	34
	140	47	58	56
	140DCD	46	60	60
LSD (0.05)		NS	20	18
Tillage				
Roto-till		46	48	47
No-till		51	45	44
LSD (0.05)		NS	NS	NS
N rate				
	0	48	31	25
	70	55	32	31
	140	47	54	52
	140DCD	48	67	75
LSD (0.05)		NS	15	16

Table 4. The influence of tillage, N rate, and nitrification inhibitor on water percolation and NO_3-N concentration in the soil solution between August and October in 1988.

Tillage	N rate	NO_3-N leached	water leached	NO_3-N concentration
		lb N/A	in	ppm NO_3
Roto-till	0	4.6	3.0	7.5
	70	7.9	3.1	12.1
	140	4.4	1.3	25.5
	140DCD	3.7	1.4	12.3
No-till	0	5.0	3.3	6.4
	70	8.9	3.3	14.2
	140	8.2	1.6	25.9
	140DCD	5.0	1.7	16.0
LSD(0.05)		NS	NS	11.1
Tillage				
Roto-till		5.2	2.2	14.4
No-till		6.8	2.5	15.6
LSD(0.05)		NS	NS	NS
N rate				
	0	4.8	3.2	7.0
	70	8.4	3.2	13.2
	140	6.3	1.4	25.7
	140DCD	4.4	1.6	14.2
LSD(0.05)		NS	NS	8.9

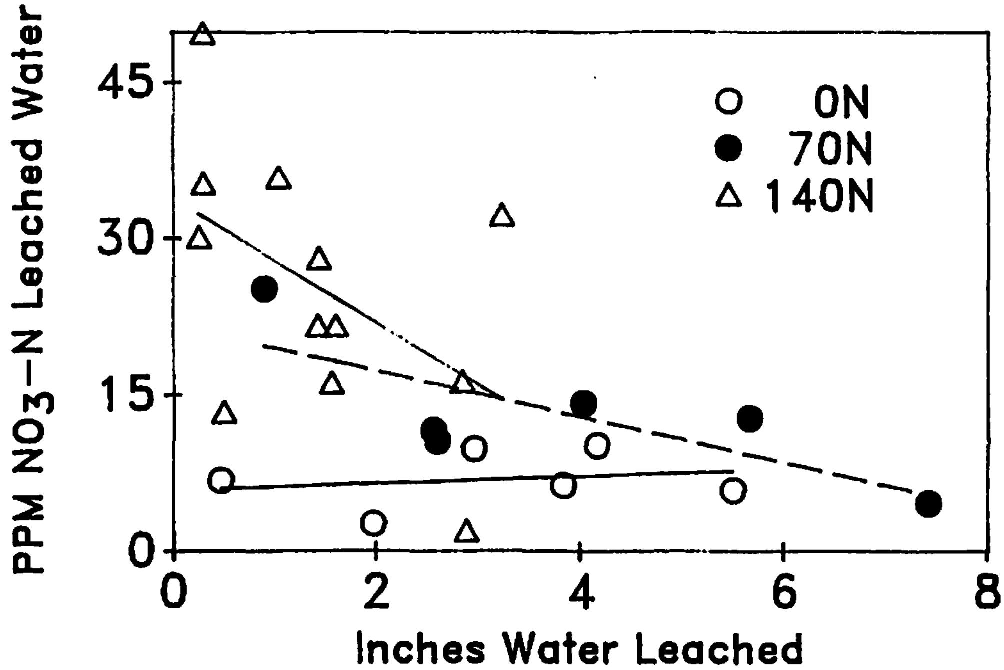

Fig. 1 The relationship between percolated water and NO_3-N concentration for 3 N rates.

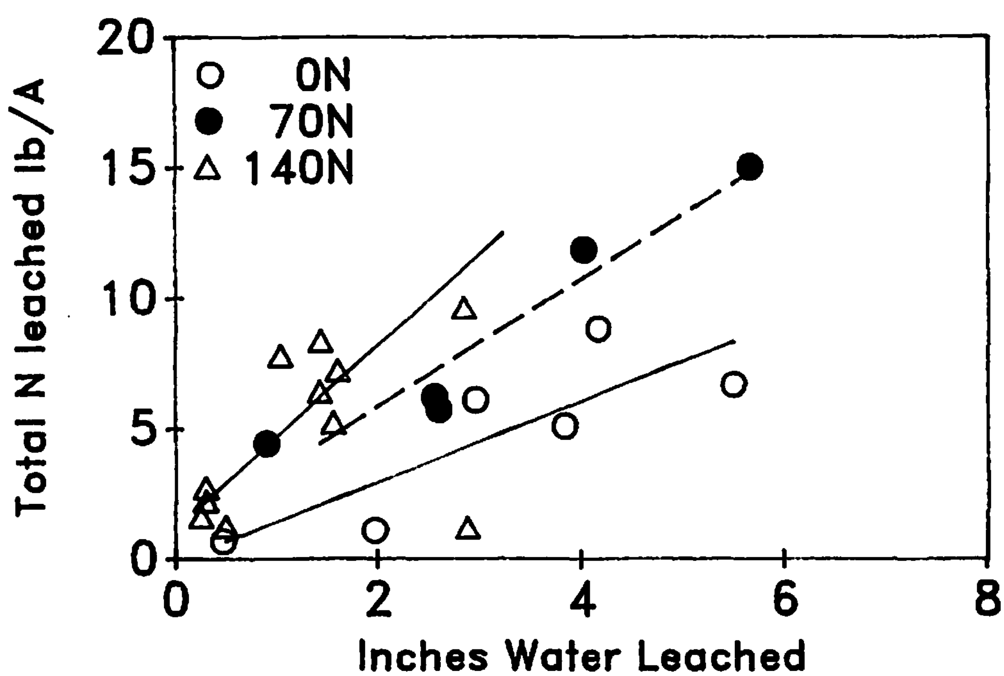

Fig. 2 The relationship between percolated water and total NO_3-N leached for 3 N rates.

PRELIMINARY STUDY ON THE IMPACT OF NBPT ON CORN PRODUCTION[1]

D.E. Clay and G.L. Malzer[2]

ABSTRACT. Ammonia volatilization from surface applied urea reduces N fertilizer efficiency, and thus, may reduce crop yields. The objective was to determine if N-(n-butyl)thiophosphoric triamide (NBPT) has the potential in Minnesota to reduce N loss and increase corn yields. N-(n-butyl)thiophosphoric triamide reduced the rate of urea hydrolysis which in turn reduced NH_3-N volatilization loss. However, results of this one year field study indicated that urea treatment with NBPT did not influence corn grain yield or N uptake. The lack of a yield increase was attributed to the lack of N fertilizer response and low corn grain yields.

Volatilization losses of NH_3 from surface applied urea may reduce N fertilizer efficiency. Reduced fertilizer efficiency may reduce crop yields or increase fertilizer requirements. N-(n-butyl)thiophosphoric triamide (NBPT) may reduce the rate of urea hydrolysis, which in turn may reduce the amount of NH_3 volatilized. The objectives of this study were to determine if NBPT has the potential in Minnesota to reduce N loss and increase corn grain yields.

EXPERIMENTAL PROCEDURES

Field and laboratory studies were conducted on Estherville sandy loam (coarse loamy over sandy, mixed mesic, Typic Hapludolls). The field experiments were conducted at Westport Minnesota. Seven treatments with three replications were arranged in a randomized block design. The treatments consisted of factorial combinations of 2 N rates (67 and 135 lb N/A) and 3 NBPT rates (0, 0.0025, and 0.005 lb NBPT/lb fertilizer) plus a 0 N control. Fertilizer treatments were surface banded on 2 June when corn was at the 4 leaf growth stage. Fertilizer band was placed approximately 3 inches away from the corn plant. Corn grain was hand harvested from 100 ft^2 area on 15 September. Grain yields were adjusted to 15.5% moisture. Subsamples of corn grain were dried, ground, and analyzed for Kjeldahl N.

The previous crop was Soybeans. A traveling boom was used to apply 12.6 inches of water between June and August while 7.1 inches of water fell as rainfall in August and September. The experimental area was chisel plowed on 20 April and planted with corn (Pioneer 3902) on 28 April in 30 inch rows at a density of 29,900 seeds/A. Liquid starter (7-22-5) fertilizer was banded below the seed at the rate of 6, 9 and 4 lb of N, P, and K, respectively.

To determine the influence of NBPT on urea hydrolysis a incubation experiment was conducted using soil samples collected from the 0- to 6-inch soil depth on 2 June from the field experimental plots. Soil was incubated at field moisture capacity and 77°F with urea (1000 ug N/g of soil) and with (10 ug NBPT/g of soil) or without NBPT. The soil was analyzed for urea at 1, 2, 3, 7 and 10 day.

To determine if the potential exist for NH_3-N volatilization in the field a experiment was conducted next to the field experiment. The field site was prepared for the experiment by thoroughly wetting the soil profile with a sprinkler and allowing the profile to drain for 24 hours. Following excess water drainage a plastic cylinder 15 cm high with a diameter of 24 cm was pushed 14 cm into the wet soil. Fertilizer treatments were urea or urea plus NBPT. Fertilizer treatments were dissolved in 100 mL of water. Urea was sprinkled over the bare soil surface within the cylinder at the rate of 1800 lb N/A to simulate the fertilizer concentration in a surface band having a application rate of 180 lb N/A. The inhibitor (NBPT) was applied at the rate of 0.9 lb/A.

[1]Funding provided by EniChem Americas Inc., and the Center for the Impacts of Agricultural Practices on Water Quality.
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Caps, fitted to the cylinders, were placed over the cylinders for a period of 20 minutes every 3 hours over a 4 day period. Air was drawn through the cylinders, at this time, and passed through boric acid to collect volatilized NH_3-N. The boric acid solutions were titrated with 0.01 M H_2SO_4 to determine volatilized NH_3-N.

RESULTS AND DISCUSSION

Neither N rate or NBPT treatment influenced corn yields, N uptake, moisture percentage of the grain at harvest (Table 1). The lack of differences was attributed to abnormally high temperatures reducing corn grain yields.

The incubation study indicated that treatment of urea with NBPT reduced the rate of urea hydrolysis (Fig. 1). The reduced rate of urea hydrolysis reduces both NH_4-N and NH_3-N in the soil solution. Reduction in the NH_4-N and NH_3-N concentration in the soil solution should reduce the potential for NH_3-N to be volatilized. Treatment of urea with NBPT reduced ammonia volatilization in the field over the 4 days of the study (Fig. 2). Treatment of the urea with NBPT reduced the amount of volatilized NH_3 from 10 to 20% to less than 1% of the applied fertilizer. Maximum NH_3 volatilization in untreated urea occurred 2 days following application. Volatilization from NBPT treated urea was increasing as the experiment proceeded.

Although treatment of urea with NBPT did not increase corn yield, field and laboratory experiments indicates that NBPT does have the potential to reduce NH_3-N volatilization from urea.

Table 1. Corn grain yields, N uptake, and percentage moisture of the grain as influenced by N rate and NBPT hydrolysis inhibitors.

		Grain Yield at	Grain		
N Rate	NBPT	15.5% moisture	N	N Uptake	moisture
lb/A	%	bu/A	%	lb/A	%
0	0.0	102	1.68	81	16
67	0.0	109	1.62	81	17
135	0.0	100	1.69	79	17
67	0.25	100	1.60	74	16
135	0.25	117	1.54	85	15
67	0.50	111	1.54	81	15
135	0.50	115	1.56	84	16
LSD (0.05)		NS	NS	NS	NS
P-value		30	38	24	70
N Rate					
67		106	1.59	79	16
135		111	1.59	83	16
LSD (0.05)		NS	NS	NS	NS
P-value		26	9	38	0
Inhibitor Rate					
0		105	1.65	80	17
0.25		108	1.57	80	15
0.50		113	1.55	83	15
LSD (0.05)		NS	NS	NS	NS
P-value		16	64	6	9

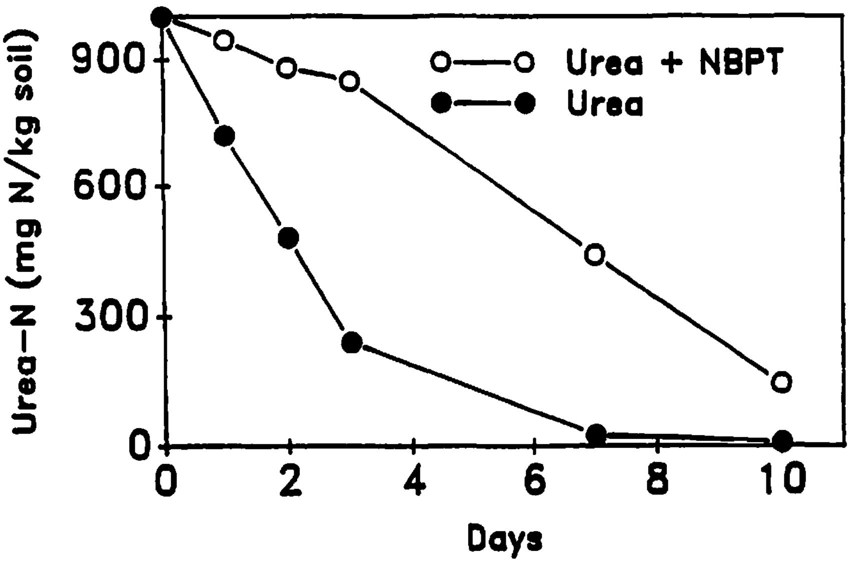

Fig. 1. The influence of NBPT on urea hydrolysis.

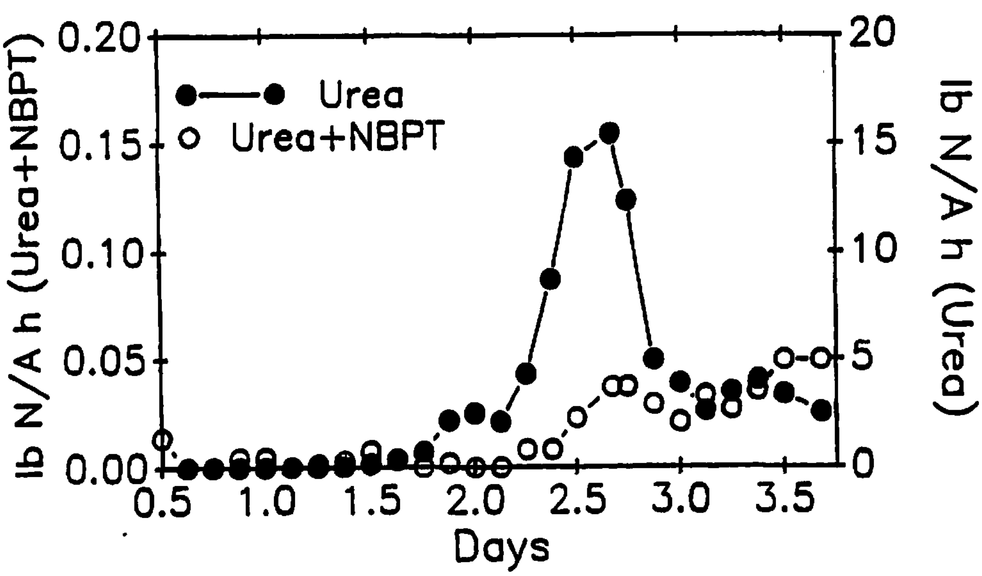

Fig. 2. Ammonia volatilization from urea and urea treated with NBPT applied to bare soil over 4 days.

LAND TREATMENT OF SEWAGE SLUDGE INCINERATOR ASH[1]

C. Rosen, and R. Polta[2]

ABSTRACT: This experiment was conducted at the Rosholt Research farm in Westport, MN to evaluate the use of sewage sludge incinerator ash as a phosphorus source for corn production. Three rates of phosphate fertilizer (70, 140, and 280 lb P_2O_5/A) were compared with equivalent rates of P supplied by ash based on the citrate soluble P test. Early plant (8-12 leaf) dry weight significantly increased with both ash and fertilizer compared to the control. At equivalent P rates, response was greater with the fertilizer compared to the ash. Final grain yield was not affected by either amendment. Tissue analysis revealed that both P sources increased P levels in the plant; however, at equivalent P rates, response was greater with the fertilizer source compared to the ash source. Although ash was a good source of Zn, movement of this element was apparent through the soil profile. Other heavy metals such as Cd, Pb, Ni, and Cr did not move out of the top 6" nor did they accumulate in the corn grain, stover, or cob.

Incineration of sewage sludge is a common means of reducing the volume of municipal waste material. As landfill usage is being reduced, disposal of the resulting ash is becoming more of a problem. Finding an environmentally acceptable disposal method for incinerator ash is important as increasing quantities of sewage sludge wastes are burned. Sewage sludge incinerator ash contains many elements that are essential for plant growth. In particular, high concentrations of phosphorus, calcium and magnesium have been reported in previous studies. However, this ash also contains heavy metals such as cadmium, lead, zinc, copper, and others which can pose problems to plants and animals in high concentrations. When properly managed, recycling incinerator ash nutrients by land spreading may provide a disposal method that is beneficial to both incinerator operators and crop producers. The purpose of this study was to determine whether sewage sludge ash can be used as a soil amendment/fertilizer without lowering crop quality or polluting the environment. Results reported here are from the second year of a three year study.

Materials and Methods. A field experiment was initiated in May 1987 at the Rosholt Research Farm in Westport, MN. This site was selected because irrigation was available and soil test P was at a level where a response to applied phosphorus might be expected. The soil is characterized as a Estherville sandy loam with an initial pH of 5.7 and Bray P1 of 35 lb/A.

Ash was collected from the Metropolitan Waste Water Treatment Plant in St. Paul in April 1987 and stored in 5 gallon covered plastic containers. A complete elemental analysis of the material was presented in detail last year (see 1988 Bluebook). Briefly, the ash is 8.8% P_2O_5 based on the citrate acid soluble P test and has a calcium carbonate equivalent of 13.7%. Particle size analysis revealed that 99% passed through a 60 mesh screen and 88% passed through a 100 mesh screen.

Treatments consisted of a control, three rates of phosphate fertilizer (0-46-0: 70, 140 and 280 lb P_2O_5/A) and three equivalent rates of sewage sludge incinerator ash based on available phosphate. Treatments were applied to the same plots at the same rates as in 1987. Loading rates of Cd, Ni, Cr, and Pb based on the digest analysis and application rates were less than the annual maximum application rates set by the Minnesota Pollution Control Agency. A Gandy fertilizer spreader was used to broadcast applications of 0-0-60 (200 lbs/A) and 45-0-0 (195 lbs/A). Sludge ash and phosphate fertilizer were applied by hand. The entire plot area was disked to a depth of 4-6". A randomized complete block design with four replications was used. Field corn (Funks G-4100 hybrid) was planted on April 28, 1988 at a population of 32,000 in 30" rows along with a furrow application of Counter insecticide. Each plot consisted of four 30' rows. Irrigation supplemented rainfall to provide approximately 1" of water per week. Suction cup lysimeters

[1] Funding for this project was provided by the Metropolitan Waste Control Commission.

[2] Extension Soil Scientist, Soil Science Department, University of Minnesota, and Director of Research and Development, Metropolitan Waste Control Commission, respectively.

were installed in all treatments in reps 1 and 3 on May 20 at a depth of 18". Water samples were collected on June 9, August 25, and September 15 approximately 3 or 4 days after at least 1" of rainfall or irrigation was supplied. On June 15, 8 whole plants were sampled from each plot at the ends of the two middle rows. At this sampling, plant development corresponded to the 8-10 leaf stage. The entire plot was sidedressed with 34-0-0 (295 lbs/A) with a Gandy on June 15. Ear leaf samples were collected from each plot at the mid-silking stage (July 20). Plots (20' from the middle two rows) were harvested for grain plus cob and stover yields on September 9. Subsamples of stover and grain plus cob were collected for moisture determinations, shelling percentage, and elemental analyses. All plant samples were ground in a Wiley mill to pass through a 30 mesh screen. Multiple element analysis using ICP procedures were performed on ashed samples dissolved in 2 N HCl. Following Kjeldahl digestion, total nitrogen in plant tissues was determined using conductimetric procedures.

Soil samples were collected on September 15 at 3 depths: 0-6", 6-12", and 12-24". Samples were air dried, ground using a rolling pin and extracted with 1 N nitric acid. Multiple elements were determined using ICP procedures. Available nutrients were determined using the following extractants: Bray P1 extractant, Olsen P, ammonium acetate, and DTPA. Soil pH was determined on a 1:1 soil - water extract.

Results

Soil and Water Samples. Elemental analyses of the water collected in the suction cup lysimeters are presented in Table 1. Because of the dry year, some lysimeters were often dry. Therefore, data presented are sometimes based on only one sample. For phosphorus and all heavy metals, except nickel, concentrations were generally below detection limits of the ICP spectrophotometer. Nickel levels tended to increase at the second and third sampling date, but these increases did not appear to be related to treatment. Other elements such as Cu, Zn and B were at background levels. One exception was zinc at the last sampling date and at the highest ash rate was nearly 5 times higher than the other treatments. However, even at this higher Zn concentration, it was still 30 times lower than the allowable limit for Zn in safe drinking water (< 5 ppm). None of the other elements determined exhibited trends with increasing ash or fertilizer treatments.

As expected, extractable P increased with increasing ash and fertilizer rate in the 0-6" depth (Tables 2a and 2b). Nitric acid extracted more P from the soil amended with ash than with fertilizer, while there was no difference between the two amendments when the Bray P extractant was used. In contrast, Olsen P extractant extracted more P from soil amended with fertilizer than with ash. Soil pH was not significantly affected by ash or fertilizer treatments. Ammonium acetate and nitric acid extractable Na increased slightly with increasing ash rates. Nitric acid extractable Mg, Ca, Al, Fe, Zn, Cu, Ni, Cr, and Cd increased with ash applications. Of particular interest is the DTPA or 'plant available' metals. Ash amendments significantly increased DTPA extractable Zn, Cu, and Cd in the top 6".

In the 6 - 12" depth, Bray and Olsen extractable P increased with both amendments (Table 3a). In contrast, there was no difference in nitric acid extractable P (Table 3b). DTPA extractable Zn and Cu and nitric acid extractable Cu tended to increase with increasing ash applications.

In the 12 -24" depth, Bray and Olsen extractable P increased with both amendments (Table 4a) with no differences in nitric acid extractable P (Table 4b). DTPA and nitric acid extractable Zn increased with increasing ash rates. These results indicate that zinc is moving to some extent through the soil profile.

Yield Data. Both triple superphosphate fertilizer and ash significantly increased early plant dry weight compared to plants growing in the check plot (Table 5). This early plant response to P fertilizer is common in corn grown in cool soils. At the final harvest, however, none of the treatments significantly increased grain or stover yield over the check plot. The reason for lack of yield response to applied phosphorus is that soil P in the plow layer was at a higher level than the initial soil tests indicated. The check plots were actually in a range where response to applied P is not likely. Another factor that might be involved is that corn yields were low considering that irrigation was used. Consequently, the demand for P would not be as great had yields been higher. The cause for low yields was undoubtedly due to the hot and dry period when plants were silking. In either case, the results do indicate that application of ash does not detrimentally affect yield.

Tissue Analyses. Fertilizer and ash treatments increased tissue P concentrations in corn sampled at the 8 - 10 leaf stage (Table 6). Even though rates of ash were adjusted to equivalent rates of available P in fertilizer using the citrate acid test, corn grown in plots supplied with fertilizer source was superior to the ash source in supplying P. Both Cu and Zn concentrations tended to increase with ash applications; however, both of these nutrients are essential for plant growth and levels reported are well below those considered toxic to plants or animals. The other heavy metals, Pb, Ni, Cr, and Cd were generally at background levels. Concentrations of Pb in whole plant samples from some of the lower ash treatments were higher than those in the control or P fertilizer treatments. This trend did not continue in tissue sampled later in the season.

Ear leaves sampled at silking increased in P with fertilizer and ash applications (Table 7). As in whole plant samples, the increase was greater in the 0-46-0 plots than with the ash plots. Phosphate fertilizer increased Mn, but decreased Fe, Cu, and Zn concentrations compared to the ash treatments. Other heavy metals were not consistently affected by fertilizer or ash treatments.

Concentrations of P increased in stover to a greater extent in plants supplied with 0-46-0 than in plants supplied with ash (Table 8). Stover K tended to increase in ash plots but not P fertilizer plots. Levels of Zn and Cu in stover were highest in the control plots although ash treatments tended to increase stover Zn and Cu compared to fertilizer treatments. The only elements significantly affected in cob tissue were Zn and Cu where fertilizer decreased and ash increased levels of these elements (Table 9). Levels of N, P, K, Mg, and Mn in grain increased with fertilizer and ash treatments compared to those in the control plots (Table 10). Levels of these elements tended to be greater with the fertilizer than with the ash treatments. Grain Cu decreased with increasing P fertilizer rate. Concentrations of Pb, Ni, Cr, and Cd in stover, cob, and grain tissue were either at background levels or below detection limits of the ICP.

General Discussion. Even though no differences in corn yields due to treatments were detected, the results do show that ash treatments are not detrimental to yield or quality in the short term. The positive response to P from fertilizer and ash at the early plant stage is encouraging. From tissue analysis results, phosphate availability at equivalent rates does not appear to be as good from the ash source as from fertilizer source. This may be due to lower P solubility in the ash compared to the fertilizer which may not be readily detected by the available (citrate soluble) P test. The Olsen P soil test seemed to predict response to the ash amended soils better than the Bray P1 or Nitric acid extractants. Ash appears to be a good source of Zn, a nutrient which can be limiting when high rates of P fertilizer are used. Further experiments on this same site are required to evaluate longer term effects of incinerator ash on element movement in the soil profile as well as effects on element uptake and yield response by the crop.

Table 1. Elemental composition of lysimeter water as affected by fertilizer or ash treatments at three sampling dates.

Treatment lb P_2O_5/A	P Source	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
June 9		ppm														
Control	--	<0.57	5.9	165.7	42.5	0.42	<0.01	13.5	0.09	<0.01	0.01	0.04	<0.13	<0.05	0.02	<0.01
70	Fert.	<0.57	13.3	238.2	64.0	0.61	<0.01	18.4	0.20	0.02	0.01	0.04	<0.13	<0.05	<0.01	<0.01
140	Fert.	0.74	1.3	139.8	15.8	0.87	0.12	5.3	0.18	0.09	0.02	0.03	<0.13	0.10	<0.01	<0.01
280	Fert.	0.62	3.6	139.4	34.2	0.32	<0.01	11.5	0.11	<0.01	0.02	0.04	<0.13	<0.05	<0.01	<0.01
70	Ash	<0.57	13.8	244.2	62.5	0.52	<0.01	18.1	0.16	<0.01	0.01	0.04	<0.13	<0.05	0.02	<0.01
140	Ash	<0.57	9.8	204.0	56.9	0.47	<0.01	14.1	0.16	<0.01	0.01	0.04	<0.13	<0.05	0.02	<0.01
280	Ash	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
August 25																
Control	--	<0.57	4.6	595.0	156.4	0.68	<0.01	9.9	0.01	0.05	0.04	0.05	<0.13	0.24	<0.01	<0.01
70	Fert.	<0.57	7.4	775.8	200.6	0.77	<0.01	13.8	0.02	<0.01	0.02	0.04	<0.13	0.44	0.02	<0.01
140	Fert.	<0.57	8.2	706.6	184.6	0.80	<0.01	14.1	0.01	0.04	0.04	0.04	<0.13	0.20	<0.01	<0.01
280	Fert.	<0.57	5.7	500.4	127.1	0.64	<0.01	14.1	0.02	0.04	0.02	0.04	<0.13	0.28	<0.01	<0.01
70	Ash	<0.57	10.2	1107.4	290.1	0.64	<0.01	18.3	0.07	0.09	0.04	0.04	<0.13	0.80	<0.01	<0.01
140	Ash	<0.57	4.3	445.6	116.6	0.66	<0.01	9.2	0.01	<0.01	0.02	0.04	<0.13	0.12	<0.01	<0.01
280	Ash	<0.57	6.5	858.7	220.6	0.78	<0.01	17.1	0.04	0.04	0.04	0.04	<0.13	0.13	<0.01	<0.01
September 15																
Control	--	<0.57	3.0	674.2	182.0	0.72	<0.01	9.3	0.01	0.04	0.02	0.02	<0.13	0.14	<0.01	<0.01
70	Fert.	<0.57	4.6	530.2	140.3	0.70	<0.01	12.3	0.01	0.03	0.01	0.03	<0.13	0.53	<0.01	<0.01
140	Fert.	<0.57	8.9	1064.2	264.2	0.68	<0.01	11.6	0.01	0.03	0.01	0.03	<0.13	0.20	<0.01	<0.01
280	Fert.	<0.57	4.6	441.7	118.7	0.64	<0.01	11.0	0.01	0.06	<0.01	0.03	<0.13	0.18	<0.01	<0.01
70	Ash	<0.57	6.9	942.6	259.2	0.71	<0.01	12.9	0.02	0.04	0.02	0.02	<0.13	0.34	0.02	<0.01
140	Ash	<0.57	4.6	564.4	152.1	0.74	<0.01	8.8	0.01	0.02	0.01	0.02	<0.13	0.16	0.02	<0.01
280	Ash	<0.57	3.8	716.7	193.7	0.80	<0.01	13.4	0.02	0.15	0.03	0.03	<0.13	0.20	<0.01	<0.01

Table 2a. Effect of sludge ash and phosphate fertilizer on soil pH Bray P1, Olsen P, Ammonium Acetate (NH_4OAc) extractable cations, and DTPA extractable micro elements (0-6" depth).

Treatment	P Source	pH	Bray P1	Olsen P	NH_4OAc Extractable K	Ca	Mg	Na	DTPA Extractable Fe	Mn	Zn	Cu	Pb	Ni	Cr	Cd
lb P_2O_5/A			ppm													
Control	-	5.5	18.3	6.3	124	1889	265	7.0	75.3	48.0	1.4	0.78	1.01	1.89	0.04	0.12
70	Fert.	5.3	33.8	12.2	131	1896	262	8.5	76.4	60.9	1.2	0.71	1.01	2.07	0.05	0.12
140	Fert.	5.3	61.0	26.6	129	1850	256	8.8	77.4	73.3	1.2	0.68	1.02	2.04	0.07	0.12
280	Fert.	5.4	96.3	39.3	151	1829	250	8.5	75.1	50.2	1.2	0.73	0.86	1.91	0.05	0.12
70	Ash	5.4	43.0	15.1	164	1832	254	7.9	77.4	64.6	1.6	1.19	1.01	2.09	0.06	0.16
140	Ash	5.5	98.8	20.8	130	1893	268	9.7	77.5	53.6	2.1	2.00	1.01	2.03	0.04	0.19
280	Ash	5.6	130.8	22.0	135	1949	292	10.4	71.1	49.9	3.1	3.05	1.18	2.15	0.06	0.24
Significance		NS	*	**	NS	NS	NS	**	NS	*	**	**	NS	NS	NS	**
BLSD (0.05)			72.7	6.3	-	-	-	1.6	-	18.4	0.4	0.31	-	-	-	0.02
Contrasts																
Ctrl vs Rest		NS	*	**	NS	NS	NS	**	NS	NS	*	**	NS	NS	NS	**
Fert vs Ash		*	NS	**	NS	NS	NS	NS	NS	NS	**	**	NS	NS	NS	**
Linear Fert.		NS	*	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	*	NS
Linear Ash		NS	**	**	NS	NS	NS	**	NS	NS	**	**	NS	*	NS	**
Quad Ash		NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 2b. Effect of sludge ash and phosphate fertilizer on 1N nitric acid extractable elements. (0-6" depth)

Treatment	Source	1 N Nitric Acid Extractable P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb P_2O_5/A		ppm														
Control	-	57	169	2604	442	1630	385	7	149	5.5	3.3	0.9	<1.66	3.86	0.86	0.23
70	Fert	67	184	2610	440	1623	382	8	165	5.6	3.4	1.2	<1.83	4.13	1.01	0.17
140	Fert	108	176	2576	434	1682	423	10	183	5.5	3.3	0.9	<1.96	3.89	1.02	0.19
280	Fert	143	199	2514	405	1657	408	8	159	6.1	3.1	1.0	1.93	3.48	0.91	0.18
70	Ash	99	222	2594	418	1662	372	8	174	6.2	4.7	0.9	<1.61	3.79	0.99	0.30
140	Ash	161	157	2722	460	1760	430	11	164	7.9	7.1	0.9	3.40	4.03	1.43	0.50
280	Ash	267	309	2967	513	1893	485	14	180	11.0	11.6	1.0	3.34	4.51	2.06	0.56
Significance		**	NS	*	*	**	**	**	NS	**	**	NS	-	*	**	**
BLSD (0.05)		47	-	281	71	117	47	2	-	1.6	1.4	-	-	0.6	0.2	0.14
Contrasts																
Ctrl. vs Rest		**	NS	NS	NS	NS	NS	**	*	*	**	NS	-	NS	**	NS
Fert. vs Ash		**	NS	*	*	**	NS	**	NS	**	**	NS	-	NS	**	**
Linear Fert.		**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	*	NS	NS
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS
Linear Ash		**	NS	**	**	**	**	**	NS	**	**	NS	-	**	**	**
Quad Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 3a. Effect of sludge ash and phosphate fertilizer on soil pH, Bray P1, Olsen P, Ammonium Acetate (NH_4OAc) extractable cations, and DTPA extractable micro elements (6-12" depth).

Treatment	P Source	pH	Bray P1	Olsen P	NH_4OAc Extractable				DTPA Extractable							
					K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Ni	Cr	Cd
lb P/A		ppm														
Control	-	5.9	5.8	2.5	46	1634	265	5.8	24.4	11.0	0.2	0.53	<0.42	0.99	<0.02	0.03
70	Fert.	5.7	8.5	2.8	58	1740	282	6.9	38.0	25.3	0.5	0.62	0.47	1.46	<0.03	0.06
140	Fert.	5.7	12.3	5.0	48	1645	271	6.7	25.3	13.3	0.3	0.56	0.43	1.23	<0.02	0.04
280	Fert.	5.8	13.3	4.8	50	1671	270	6.7	24.7	10.6	0.2	0.56	0.39	1.00	<0.03	0.03
70	Ash	5.8	9.5	2.8	54	1745	274	6.5	28.4	15.5	0.3	0.58	<0.47	1.26	<0.03	0.04
140	Ash	5.9	10.3	3.5	47	1628	259	6.3	24.1	10.7	0.3	0.60	<0.37	1.04	<0.02	0.04
280	Ash	5.9	19.5	4.8	52	1722	280	6.7	26.7	13.6	0.5	0.81	0.40	1.27	<0.02	0.05
Significance		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	NS
BLSD (0.05)		-	7.3	-	-	-	-	-	-	-	-	-	-	-	-	NS
Contrasts																
Ctrl vs Rest		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	NS
Fert vs Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	NS
Linear Fert.		NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	NS
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	*	-	NS
Linear Fert.		NS	**	*	NS	NS	NS	NS	NS	NS	*	**	-	NS	-	NS
Quad Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	NS

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 3b. Effect of sludge ash and phosphate fertilizer on 1 N nitric acid extractable elements (6-12" depth).

Treatment	P Source	1 N Nitric Acid Extractable														
		P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb. P_2O_5/A		ppm														
Control	-	46	59	1946	518	1489	558	11	65	5.0	2.6	0.6	3.05	2.81	1.32	0.41
70	Fert.	29	62	2039	553	1523	539	12	60	6.3	3.0	0.6	4.27	2.73	1.27	0.30
140	Fert.	43	63	2133	558	1609	606	12	74	5.9	3.4	0.6	2.99	3.09	1.36	0.26
280	Fert.	39	59	1921	529	1497	573	11	60	4.3	2.9	0.6	2.72	2.74	1.28	0.34
70	Ash	45	74	2174	557	1654	598	11	73	6.7	3.3	0.7	2.87	3.00	1.39	0.30
140	Ash	59	69	1957	515	1541	570	13	67	4.5	3.4	0.6	3.24	2.74	1.35	0.31
280	Ash	59	66	2099	594	1624	679	13	72	5.8	4.1	0.7	4.78	3.16	1.60	0.38
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
BLSD (0.05)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Contrasts																
Ctrl vs Rest		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	*
Fert. vs Ash		**	**	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Linear Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS
Linear Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Quad Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 4a. Effect of sludge ash and phosphate fertilizer on soil pH, Bray P1, Olsen P, Ammonium Acetate (NH_4OAC) extractable cations, and DTPA extractable micro elements (12-24" depth).

Treatment	P Source	pH	Bray P1	Olsen P	NH_4OAc Extractable K	Ca	Mg	Na	DTPA Extractable Fe	Mn	Zn	Cu	Pb	Ni	Cr	Cd
lb. P_2O_5/A			ppm													
Control	-	6.9	5.0	2.3	39	1132	168	4.0	15.3	13.6	0.11	0.54	<0.25	0.58	<0.03	<0.03
70	Fert.	6.6	6.3	2.8	41	1163	175	4.0	17.3	16.2	0.10	0.56	<0.26	0.67	<0.03	<0.03
140	Fert.	6.8	8.3	3.8	47	1160	183	5.0	15.2	13.6	0.10	0.45	<0.25	0.55	<0.02	<0.03
280	Fert	6.7	13.5	5.3	43	1074	160	3.7	17.6	15.5	0.12	0.55	<0.24	0.63	<0.03	<0.03
70	Ash	6.9	6.8	2.3	42	1447	166	4.3	15.8	15.5	0.10	0.56	<0.24	0.63	<0.03	<0.03
140	Ash	7.3	7.3	2.8	35	1971	169	3.6	13.4	11.9	0.13	0.54	<0.22	0.48	<0.02	<0.03
280	Ash	6.7	16.8	4.5	45	1131	188	5.0	18.5	16.8	0.27	0.76	<0.25	0.95	<0.04	<0.03
Significance		NS	**	**	NS	*	NS	NS	NS	NS	**	NS	-	NS	-	-
BLSD (0.05)		-	5.0	1.3	-	618	-	-	-	-	-	-	-	-	-	-
Contrasts																
Ctrl vs Rest		NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	-
Fert. vs Ash		NS	NS	NS	NS	*	NS	NS	NS	NS	*	NS	-	NS	-	-
Linear Fert.		NS	**	**	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	-
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	-
Linear Ash		NS	**	**	NS	NS	NS	NS	NS	NS	**	*	-	NS	-	-
Quad Ash		NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	-	NS	-	-

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 4b. Effect of sludge ash and phosphate fertilizer on 1 nitric acid extractable elements (12-24" depth).

Treatment	P Source	1 N Nitric Acid Extractable P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb. P_2O_5/A		ppm														
Control	-	101	49	5045	1679	685	491	11	64	2.8	2.4	0.5	<2.24	2.16	0.74	0.20
70	Fert.	90	49	3050	1184	653	479	9	53	2.6	2.1	0.5	2.08	2.56	0.79	0.17
140	Fert.	92	52	6094	2911	638	476	11	65	2.6	1.7	0.5	2.34	2.34	0.82	0.28
280	Fert.	88	53	5684	2313	672	510	10	58	2.4	1.7	0.5	2.25	2.44	0.78	0.24
70	Ash	113	50	4644	1839	660	535	10	60	2.7	2.1	0.5	<2.61	2.07	0.73	0.25
140	Ash	108	48	17795	5372	623	596	15	89	2.6	2.0	1.0	2.57	2.99	0.89	0.17
280	Ash	125	60	2737	867	914	735	12	74	4.0	3.1	0.6	<1.76	3.13	1.06	0.21
Significance		NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	-	NS	NS	NS
BLSD (0.05)		-	-	-	-	-	-	-	-	1.1	-	-	-	-	-	-
Contrasts																
Crtl vs Rest		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS
Fert. vs Ash		*	NS	NS	NS	NS	NS	*	NS	NS	*	NS	-	NS	NS	NS
Linear Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS
Linear Ash		NS	*	NS	NS	**	NS	NS	NS	**	*	NS	-	NS	NS	NS
Quad Ash		NS	NS	**	*	NS	NS	*	NS	NS	NS	*	-	NS	NS	NS

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 5. Effect of sludge ash and phosphate fertilizer on whole plant dry weight at the 8-12 leaf stage, grain yield (dry weight basis), stover yield (dry weight basis).

Treatment	P Source	Early plant yield 8-12 leaf	Grain Yield	Stover Yield
lb P_2O_5/A		g dw	bu/A	T/A
Control	-	26.1	130.1	2.38
70	Fert.	37.3	127.8	2.70
140	Fert.	45.4	129.8	2.95
280	Fert.	53.4	125.7	2.82
70	Ash	33.2	130.9	2.86
140	Ash	35.3	130.8	2.66
280	Ash	46.2	128.9	2.65
Significance		*	NS	NS
BLSD (0.05)		16.8	--	--
Contrasts				
Ctrl. vs Rest		**	NS	NS
Fert. vs Ash		NS	NS	NS
Linear Fert.		**	NS	NS
Quad. Fert.		NS	NS	NS
Linear Ash		**	NS	NS
Quad. Ash		NS	NS	NS

NS = Non significant, * = Significant at 5%, ** = Significant at 1%

Table 6. Effect of sludge ash and phosphate fertilizer on the elemental composition of whole plants sampled at the 8-12 leaf stage.

Treatment	P Source	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb P_2O_5/A		%					ppm										
Control	-	3.77	0.28	3.70	0.57	0.40	117	150	12	196	60	8.3	9.5	1.15	0.64	0.75	0.32
70	Fert.	3.95	0.34	3.64	0.55	0.41	100	145	10	199	58	8.3	9.9	1.08	0.62	0.74	0.32
140	Fert.	3.83	0.33	3.66	0.54	0.38	94	143	10	197	53	7.6	10.0	2.04	0.86	1.01	0.33
280	Fert.	3.64	0.34	3.70	0.55	0.39	97	139	11	200	48	6.8	10.1	1.08	0.73	0.85	0.46
70	Ash	3.76	0.30	3.77	0.53	0.40	97	132	13	183	60	8.3	9.3	3.11	0.75	0.68	0.37
140	Ash	3.73	0.29	3.80	0.55	0.40	112	146	11	183	64	8.6	9.1	2.22	0.78	0.77	0.41
280	Ash	3.53	0.32	3.57	0.56	0.41	121	157	10	184	60	8.8	10.2	1.51	0.83	0.90	0.46
Significance		NS	**	NS	NS	NS	NS	NS	NS	NS	*	*	NS	**	NS	NS	NS
BLSD (0.05)		-	0.04	-	-	-	-	-	-	-	12	1.6	-	1.17	-	-	-
Contrasts																	
Ctrl. vs Rest		NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fert. vs Ash		NS	**	NS	NS	NS	NS	NS	NS	NS	**	*	NS	**	NS	NS	NS
Linear Fert.		NS	**	NS	NS	NS	NS	NS	NS	NS	*	*	NS	NS	NS	NS	NS
Quad. Fert.		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Linear Ash		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad. Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS

NS = Non significant, * = Significant at 5%, ** = Significant at 1%

Table 7. Effect of sludge ash and phosphate fertilizer on elemental composition of the ear leaf sampled during initial silking.

Treatment	P Source	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb P_2O_5/A		--------	---- %	----	--------		------	------	------	------	------	---- ppm	------	------	------	------	------
Control	-	2.66	0.23	1.82	0.83	0.43	28	530	59	232	49	5.3	9.0	1.76	0.64	0.41	0.29
70	Fert.	2.70	0.25	1.85	0.85	0.38	24	481	52	248	39	4.4	10.1	1.09	0.53	0.47	0.13
140	Fert.	2.66	0.28	2.05	0.88	0.40	29	482	60	301	37	3.9	10.1	1.21	0.71	0.54	0.10
280	Fert.	2.68	0.34	1.92	0.85	0.38	31	451	56	286	29	3.1	8.9	1.40	0.81	0.46	0.16
70	Ash	2.70	0.25	2.01	0.79	0.37	29	509	56	255	48	5.0	10.1	1.56	0.74	0.49	0.15
140	Ash	2.74	0.25	1.91	0.80	0.40	26	507	62	220	49	6.3	9.2	2.06	0.95	0.54	0.23
280	Ash	2.68	0.26	1.92	0.86	0.43	32	534	61	216	51	5.9	9.5	1.45	0.56	0.41	0.15
Significance		NS	**	NS	NS	NS	NS	NS	NS	NS	**	**	NS	NS	NS	NS	NS
BLSD (0.05)		-	0.02	-	-	-	-	-	-	-	8	1.1	-	-	-	-	-
Contrasts																	
Ctrl. vs Rest		NS	**	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
Fert. vs Ash		NS	**	NS	NS	NS	NS	*	*	*	**	**	NS	NS	NS	NS	NS
Linear Fert.		NS	**	NS	NS	NS	*	*	NS	NS	**	**	NS	NS	NS	NS	NS
Quad. Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
Linear Ash		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad. Ash		NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS

NS = Non significant * = Significant at 5% ** = Significant at 1%

Table 8. Effect of sludge ash and phosphate fertilizer on elemental composition of stover at harvest.

Treatment	P Source	N	K	Ca	Mg	P	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb. P_2O_5/A		--------	%	--------		------	------	------	------	------	------	ppm	------	------	------	------	------
Control	-	0.61	1.77	0.52	0.36	526	71	211	44	175	28	4.1	7.3	<1.1	<0.5	0.61	<0.1
70	Fert.	0.91	1.87	0.59	0.32	650	74	222	45	194	22	3.2	7.5	<1.1	<0.6	0.70	<0.1
140	Fert.	1.02	1.89	0.65	0.29	987	87	243	49	208	16	2.7	8.2	<1.1	<0.5	0.60	<0.1
280	Fert.	0.96	1.96	0.59	0.28	1405	91	222	42	166	12	1.1	7.5	<1.1	<0.5	0.60	<0.1
70	Ash	0.89	1.95	0.54	0.32	633	76	214	44	186	25	4.0	7.1	<1.1	<0.5	0.60	<0.1
140	Ash	0.79	1.72	0.47	0.29	544	79	192	40	145	25	3.5	7.2	<1.1	<0.5	0.56	<0.1
280	Ash	0.90	2.34	0.57	0.33	718	85	222	48	167	26	3.9	7.6	<1.1	<0.5	0.56	<0.1
Significance		NS	**	NS	NS	**	NS	NS	NS	NS	**	**	NS	-	-	NS	-
BLSD (0.05)		-	0.26	-	-	229	-	-	-	-	8	0.9	-	-	-	-	-
Contrasts																	
Ctrl vs Rest		**	NS	NS	*	**	NS	NS	NS	NS	*	*	NS	-	-	NS	-
Fert vs Ash		NS	NS	*	NS	**	NS	NS	NS	NS	**	**	NS	-	-	NS	-
Linear Fert.		NS	NS	NS	*	**	NS	NS	NS	NS	**	**	NS	-	-	NS	-
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-	NS	-
Linear Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-	NS	-
Quad Ash		NS	*	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	-	-	NS	-

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 9. Effect of sludge ash and phosphate fertilizer on the elemental composition of cob at harvest.

Treatment	P Source	N	K	P	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb. P_2O_5/A		— % —		ppm													
Control	--	0.51	0.47	409	204	841	5.8	18	2.9	23	72	4.7	3.7	<1.3	1.44	1.21	<0.09
70	Fert.	0.53	0.43	438	229	909	6.0	17	3.0	27	61	3.5	3.7	<1.4	1.10	1.16	<0.08
140	Fert.	0.56	0.45	455	236	806	6.1	18	3.8	28	48	3.0	3.7	<1.8	1.40	1.22	<0.09
280	Fert.	0.62	0.44	555	215	699	7.7	19	4.8	28	34	2.5	3.5	<1.7	1.05	1.03	<0.09
70	Ash	0.53	0.44	425	203	850	5.7	17	2.9	26	64	4.3	3.5	<1.9	1.33	1.21	<0.10
140	Ash	0.54	0.47	384	189	717	7.6	19	3.2	25	60	4.8	3.8	<2.2	1.35	1.28	<0.10
280	Ash	0.56	0.46	505	209	601	5.5	17	2.9	25	58	4.0	3.5	<1.5	1.26	1.13	<0.10
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	**	**	NS	-	NS	NS	-
BLSD (0.05)		-	-	-	-	-	-	-	-	-			-	-	-	-	-
Contrasts																	
Ctrl vs Rest		NS	NS	NS	NS	NS	NS	NS	NS	*	**	**	NS	-	NS	NS	-
Fert. vs Ash		NS	NS	NS	*	NS	NS	NS	*	NS	*	**	NS	-	NS	NS	-
Linear Fert.		*	NS	NS	NS	NS	NS	NS	**	*	**	**	NS	-	NS	NS	-
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	-
Linear Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	-
Quad Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS	-

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

Table 10. Effect of sludge ash and phosphate fertilizer on the elemental composition of grain at harvest.

Treatment	Source	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
lb. P_2O_5/A		— % —			ppm												
Control	-	1.47	0.26	0.33	40	1308	1.4	22	4.1	9.6	27	1.5	2.6	<1.7	<0.5	<0.2	<0.1
70	Fert.	1.68	0.30	0.34	39	1445	1.2	23	4.2	10.9	26	1.0	2.4	<1.5	<0.5	<0.2	<0.1
140	Fert.	1.71	0.35	0.38	41	1596	1.2	25	4.7	11.6	26	0.7	2.5	<1.2	<0.6	<0.2	<0.2
280	Fert.	1.68	0.38	0.40	42	1694	1.5	26	4.3	13.7	24	0.5	2.2	<1.6	<0.5	<0.3	>0.1
70	Ash	1.64	0.28	0.34	37	1330	1.2	22	3.1	10.3	26	1.0	2.4	<1.2	<0.5	<0.2	<0.1
140	Ash	1.58	0.29	0.35	41	1379	1.6	25	4.2	10.8	27	1.3	2.6	<1.7	<0.5	<0.2	<0.1
280	Ash	1.62	0.30	0.35	41	1411	1.7	23	6.1	10.5	26	1.2	2.5	<2.6	<0.5	<0.3	<0.1
Significance		**	**	**	NS	**	NS	NS	NS	**	NS	**	NS	-	-	-	-
BLSD (0.05)		0.10	0.04	0.03	-	212	-	-	-	2.1	-	0.4	-	-	-	-	-
Contrasts																	
Ctrl vs Rest		**	**	*	NS	*	NS	NS	NS	*	NS	**	NS	-	-	-	-
Fert. vs Ash		*	**	**	NS	**	NS	NS	NS	**	NS	**	NS	-	-	-	-
Linear Fert.		NS	**	**	NS	**	NS	*	NS	**	NS	**	*	-	-	-	-
Quad Fert.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	-	-	-	-
Linear Ash		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-	-	-
Quad Ash		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-	-	-

NS = Nonsignificant, * = Significant at 5%, ** = Significant at 1%

NITROGEN RATES FOR CORN PRODUCTION IN SOUTHEAST MINNESOTA

Tim Wagar, Greg Cremers, Andy Scobbie, and George Rehm[1/]

ABSTRACT: This study was conducted to measure the effect of legumes in rotation and history of manure use on the response of corn in southeastern Minnesota to N fertilization. Seven rates of fertilizer N (0, 40, 80, 120, 160, 200, 240 lb./acre) supplied as urea were applied to corn following varied histories of legumes in rotation and manure use. Treatments were repeated on the same plots at each site. The drought caused a substantial reduction in yield in 1988. Therefore, only limited information can be obtained from yields measured in 1988.

Stimulated by concerns for a quality environment, there has been a renewed interest in refining fertilizer nitrogen recommendations for corn production in southeast Minnesota. Special emphasis has been placed on giving proper credit for the amount of N supplied by manure as well as the N provided by the legume crops used in the rotation. Therefore, this study was conducted to document the effect of manure use and legume crops in rotation on the response of corn to use of fertilizer nitrogen.

EXPERIMENTAL PROCEDURE:

This study was initiated at 3 sites in Winona County in 1986. Differences in cropping history and manure use were used as criteria for site selection. Two of these original three sites were continued with treatments repeated in both 1987 and 1988. Three additional sites were added in 1987. Again, differences in manure use and cropping history were used as criteria for site selection. Treatments were repeated in 1988.

At each site, each year, urea (46-0-0) was applied to supply 0, 40, 80, 120, 160, 200, and 240 lb. N/acre. The urea was incorporated soon after application to prevent N loss. Treatments were arranged in a randomized complete block design with 4 replications.

Corn production practices acceptable for profitable yields were used at each location. Grain yields were harvested each fall and corrected to 15.5% moisture.

RESULTS AND DISCUSSION:

The grain yields measured at each site are summarized in the tables that follow. Grain yields at a site which had not been manured and had been in continuous corn for 9 years prior to 1986 were increased by the use of fertilizer N each year (Table 1).

Table 1. The effect of rate of fertilizer N on corn yield at a site where no legumes were used and no manure had been applied.

N Applied	1986	Year 1987	1988
lb./acre		bu./acre	
0	107.4	84.8	29.1
40	124.4	140.8	30.7
80	138.2	149.3	48.6
120	139.3	161.0	75.2
160	139.1	159.5	82.2
200	147.5	162.4	85.4
240	143.9	171.1	72.9

1/ Area Crops and Soils Agent, Assistant Scientist, Junior Scientist and Extension Specialist, respectively.

Each year, the most profitable yield was produced by the application of 120 lb. N/acre. This was true, even though the 1988 yields were reduced by the drought. The nitrogen fertilizer die not reduce corn yields in dry weather. In 1988, yields were more than doubled by the use of fertilizer N.

The second site chosen for this study in Winona County in 1986 had been planted to alfalfa and manure was applied to the alfalfa crop. The alfalfa was chiseled in the fall of 1985 and corn was planted in 1986. Yields from this site are summarized in Table 2.

Table 2. The effect of rate of fertilizer N on corn yield at a site where alfalfa was used in rotation and manure was applied to the alfalfa.

N Applied	Year 1986	1987	1988
lb./acre	- - - - - - - -	bu./acre	- - - - - - - -
0	214.6	197.5	100.3
40	223.2	197.4	123.4
80	209.3	196.1	124.2
120	210.5	198.7	133.9
160	207.3	195.5	128.4
200	211.6	191.2	122.1
240	213.7	196.6	127.1

At this site, there was no response to the N fertilizer applied in 1986 and 1987 even though yields were exceptionally good. There was apparently ample N for corn growth supplied from the combination of the previous alfalfa crop, the manure used and the soil organic matter.

There was a response to applied N in 1988. A rate of 120 lb. N per acre produced the most profitable yield. The use of this rate of N produced a 34 bu./acre increase in production. Even though the 1988 yield was reduced by drought, it was still profitable to use fertilizer N in 1988.

Grain yields from the sites established in 1987 and continued in 1988 are summarized in Table 3. In Houston County, the experimental site was in alfalfa in 1986 and no manure was applied. For the site in Olmsted County, manure had been applied to the alfalfa in 1986 prior to planting corn in 1987. In Rice County, the previous crop was alfalfa, but no manure had been applied.

Table 3. Effect of a previous crop of alfalfa and manure use on the response of corn to the application of fertilizer N.

	Site and Year					
N	Houston Co.		Olmsted Co.		Rice Co.	
Rate	1987	1988	1987	1988	1987	1988
lb./acre	- - - - - - - -	- - - - - - - -	- - - - - - - -	bu./acre	- - - - - - - -	- - - - - - - -
0	195.0	97.9	175.3	82.1	185.6	92.2
40	193.7	95.8	181.9	86.5	189.6	104.4
80	200.8	100.6	178.6	85.0	182.0	106.6
120	195.1	103.8	168.7	89.5	189.5	107.4
160	204.9	104.4	173.6	77.6	176.1	92.1
200	194.8	100.9	174.5	82.4	187.4	106.9
240	197.2	104.0	172.3	92.3	191.1	112.8

Grain yields were very good in 1987 at all sites; but there was no response to fertilizer N. Apparently, the N supplied by the previous alfalfa crop and the mineralization of soil organic matter was adequate for corn production in 1987.

Drought severely reduced the grain yields measured in 1988. The dry weather also caused a large amount of variability in the data and there was no significant response to the fertilizer N applied in 1988. Results may have been different if moisture had not limited yield.

The data collected from this study clearly show that the alfalfa in rotation as well as the animal manure applied can have a substantial effect on the response of corn to fertilizer N in southeast Minnesota. The challenge is to predict the amount of N that will be supplied by these two sources. This challenge will have to be met with future research.

EFFECT OF SOIL MINERAL N AND TIME OF SAMPLING FOR PREDICTING NITROGEN NEEDS OF CORN[1]

P. L. Kelly, G. L. Malzer and G. W. Randall[2]

ABSTRACT: A reliable nitrogen test for corn has yet to be developed in the high rainfall area of SE Minnesota. This study addresses an early season soil and plant nitrate test as a means of obtaining sidedress nitrogen fertilizer recommendations for corn. Results of this one year study indicate that although soil and plant sampling were successful in predicting grain yield, date of sampling and nitrogen source does influence the "critical" values of soil and plant nitrate concentrations.

A need exists for a diagnostic technique to determine the nitrogen (N) needs of corn in southeast Minnesota. This karst area of Minnesota is characterized by abundant rainfall which may leach N fertilizers to groundwater. Traditional fall and spring soil sampling for nitrates (NO_3^--N) are unreliable because of the risk of N loss between soil sampling and the time of greatest N uptake by corn.

There has been some success with young corn stalk NO_3^--N analysis as an indicator of the N status of the plant. Delayed sampling for N (6-lf stage) has the advantage of being close to the time of greatest N uptake by the corn plant and still allows for sidedress applications of N if needed.

If substantial amounts of N are present as soil NH_4^+-N (i.e. fertilizers, organic matter mineralization, legume fixation, manure, etc.) soil and plant tissue analysis for NO_3^--N may underestimate available N by not addressing soil NH_4^+-N.

The objectives of this study were to:

1) Relate soil NO_3^--N to stalk NO_3^--N concentrations.
2) Determine the effect of sampling time on stalk NO_3^--N.
3) Examine NH_4^+-N nutrition effects on stalk NO_3^--N.
4) Correlate stalk and soil NO_3^--N with grain yield.

EXPERIMENTAL PROCEDURES:

This one year study was conducted in 1988 on a Port Byron silt loam on the Lawler Farm in Olmsted County. Two years of unfertilized corn preceded the experiment on this very high phosphorus and high potassium testing site.

A randomized complete block design was used with four replications. The treatments consisted of two N sources: (1) a nitrate source, calcium nitrate: $Ca(NO_3)_2$ and (2) an ammonium source, urea with 10% Dicyandiamide (DCD10). Each N source was applied at five rates: 0, 40, 80, 120 and 160 lb N per acre (A). The N fertilizer was broadcast by hand to the fall chiseled soil and immediately incorporated with disking on April 25. Pioneer 3737 was planted on May 4th at 30,200 plants per acre in 30" rows with a JD Max-Emerge planter without starter fertilizer and with Counter insecticide. On May 16, 50% of the seedlings had emerged. Populations were recorded on June 20. Plant samples were taken 22 (V5) and 31 (V7) days

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1. Funding provided by the Center for the Impacts of Agricultural Practices on Water Quality and the Agricultural Experiment Station.
2. Graduate Assistant, Assoc. Professor, and Professor, respectively, Dept. of Soil Science, Univ. of Minnesota.

after emergence (DAE) with the previous day being warm and sunny. No measurable precipitation occurred between 13 and 34 DAE. These plant samples consisted of the basal two inches of stalk tissue removed from 8-10 plants from a predetermined area of each plot. Soil samples were taken in one foot increments to a depth of three feet at the same time and same designated place as the stalk sampling. The stalk and soil samples were then analyzed for soluble NO_3^--N. Grain and fodder were harvested at physiological maturity on September 20 from 20 feet of row. Grain yields were adjusted to 15.5% moisture. Soil sampling throughout the growing season showed most NO_3^--N accumulation in the top two feet due to below normal precipitation.

RESULTS AND DISCUSSION:

Stalk NO_3^--N concentrations were significantly greater when the N source was calcium nitrate for 22 and 31 DAE (Table 1). Soil NO_3^--N in the top three feet was also significantly greater with calcium nitrate. The amount of total N in the plant tissue was not significantly different at 22 DAE which indicates that the plants were able to obtain the N required for growth regardless of the form of N present. At 31 DAE, plant uptake of N was significantly less for the urea (DCD10) N source. Extended leaf heights of the plants taken at 31 DAE was not influenced by N source but dry weights and N concentrations were higher for calcium nitrate. Stalk NO_3^--N concentrations increased at the later date of sampling while soil NO_3^--N concentrations decreased. Soil NO_3^--N concentration did not decrease as rapidly over the ten day period with urea (DCD) as with $Ca(NO_3)_2$. Both stalk and soil NO_3^--N were responsive to the amount of N applied. As N rate increased both stalk and soil NO_3^--N increased. N uptake (g/plant) by the small plants increased with increasing N rate also.

Plant population was lower than expected due to surface crusting as a result of 1.55" of rainfall occurring shortly after planting (Table 2). Plant population was not affected by source nor rate of N. Total silage yields were greater for the calcium nitrate treatments. Grain yields for the two N sources were not significantly different at the .10 level but there was a trend toward greater yields for N applied in the nitrate form.

Fodder, silage and grain yields increased with increasing N rates. The highest yields were obtained at the 160 lb N per acre rate but due to the high CV these yields weren't significantly (95% level) higher than with the 80 lb N rate.

CORRELATION OF GRAIN YIELD WITH STALK NITRATE AND SOIL NITRATE

The Cate and Nelson Graphical Method is a simple procedure to partition yield values which are either responsive or non responsive to either soil or stalk NO_3^--N. The idea is to draw parallel lines to the x and y axes forming four quadrants within the scatter plot. The number of points in the lower left (responsive) and upper right (non responsive) quadrants are maximized. The point where these two lines cross indicates a "critical value" of soil or stalk NO_3^--N for a given grain yield.

In Figures 1-4, grain yield was plotted against soil and stalk NO_3^--N concentrations sampled 22 and 31 DAE. The four scatter plots have two graphical procedures associated with each. One graphical analysis was drawn with the calcium nitrate data (darkened circles) while a second was drawn with the urea (DCD10) data (triangles). The checks (empty circles) were included in both N sources. In all four figures or scatter plots the line parallel to the x axis was shared by both N sources. This line intersected the y axis at a grain yield of 123 bushels per acre.

In all four figures the urea (DCD10) N source had critical levels of stalk and soil NO_3^--N less than the calcium nitrate N source. The critical values of soil NO_3^--N sampled at 22 and 31 DAE was 38 and 6 lb N per acre less for the urea (DCD10) N source respectively. Stalk NO_3^--N concentrations for 22 and 31 DAE was .90 and .70 g NO_3^--N/kg DM greater for the calcium nitrate N source than the urea (DCD10) N source respectively. The differences between N sources tended to decrease with time of sampling.

CONCLUSIONS

The relationship between soil and stalk NO_3^--N concentrations appears to be very good. These "N tests" are responsive to the amount of spring applied broadcast N fertilizer present in the NO_3^--N form. Fertilizer applied in an ammonium form with a nitrification inhibitor may not entirely nitrify to nitrate at the time of sampling. By analyzing only the NO_3^--N fraction the contributions of other available N sources are not included. The rate of nitrification is heavily influenced by the weather and soil moisture conditions prior to sampling. Therefore, the probability exists of yearly weather induced fluctuations in these NO_3^--N critical values.

Table 1. The effect of N source and N rate on early stalk and soil nitrate analysis.

N Treatments		Stalk Nitrate		Soil Nitrate		Total N Uptake	
Source	Rate	22 DAE	31 DAE	22 DAE	31 DAE	22 DAE	31 DAE
	-lb/A-	---g/kg DM[1]---		----lbs/A----		---g/plant---	
---	0	.42	.75	50	35	.05	.20
$Ca(NO_3)_2$	40	3.23	3.49	96	92	.12	.48
"	80	5.20	5.84	173	132	.16	.55
"	120	5.84	6.01	202	112	.13	.54
"	160	6.20	7.57	275	182	.15	.58
Urea (DCD10)	40	1.70	2.14	65	56	.10	.31
"	80	2.53	3.11	74	61	.12	.42
"	120	3.90	4.25	100	96	.13	.44
"	160	4.30	5.21	115	92	.17	.58
Signif. Level (%):		99	99	99	99	99	99
BLSD (.05):		.97	1.07	110	72	.03	.17
CV (%):		20	19	56	48	18	25
INDIVIDUAL FACTORS							
Nitrogen Sources							
$Ca(NO_3)_2$		5.12	5.73	187	129	.14	.54
Urea (DCD)		3.11	3.68	88	76	.13	.44
Signif. Level (%):		99	99	99	99	82	97
Nitrogen Rate (lb/A)							
40		2.47	2.82	80	74	.11	.40
80		3.87	4.47	123	96	.14	.48
120		4.87	5.13	151	104	.13	.49
160		5.26	6.39	195	137	.16	.58
Signif. Level (%):		99	99	96	91	99	95
BLSD (.05):		.71	.77	87		.02	.14
INTERACTION		---significance level---					
Nitrogen Source x Rate		51	65	57	58	90	40

1. DM: dry matter.

Table 2. The effect of N source and N rate on population and yield.

N Treatments		Population	Yield		
Source	Rate	(thousands)	Fodder	Silage	Grain
	-lb/A-	-plants/A-	---tons DM/A--		-bu/A-
---	0	24.4	1.69	3.76	72.9
$Ca(NO_3)_2$	40	24.6	2.13	5.31	114.7
"	80	24.8	2.30	6.10	136.7
"	120	23.9	2.37	6.06	135.5
"	160	26.5	2.61	6.67	145.7
Urea (DCD10)	40	25.7	2.11	4.98	103.4
"	80	25.9	2.20	5.42	116.7
"	120	24.8	2.37	6.09	135.2
"	160	25.4	2.33	6.16	137.9
Signif. Level (%):		70	99	99	99
BLSD (.05):			.29	.73	23.1
CV (%):		5.8	9.0	9.4	13
INDIVIDUAL FACTORS					
Nitrogen Sources					
$Ca(NO_3)_2$		24.9	2.35	6.03	133.2
Urea (DCD10)		25.4	2.25	5.66	123.3
Signif. Level (%):		63	81	93	89
Nitrogen Rate					
40		25.2	2.12	5.15	109.1
80		25.4	2.25	5.77	126.8
120		24.4	2.37	6.08	135.4
160		25.9	2.48	6.42	141.8
Signif. Level (%):		75	98	99	99
BLSD (.05):		--	.23	.56	18
INTERACTION		------------significance level (%)----------			
Nitrogen Source x Rate		57	46	39	29

22 Days After Emergence

31 Days After Emergence

Figure 1

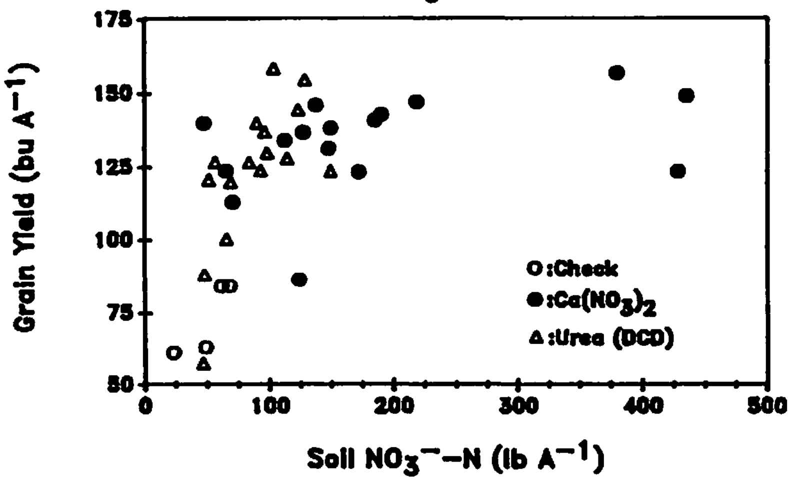


Figure 2

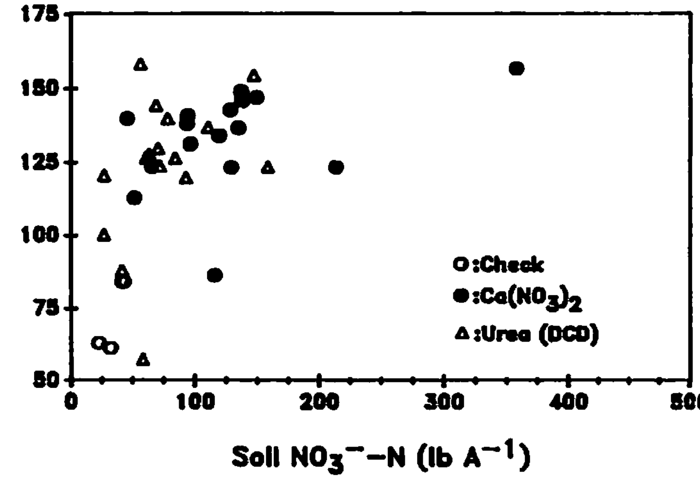


Figure 3

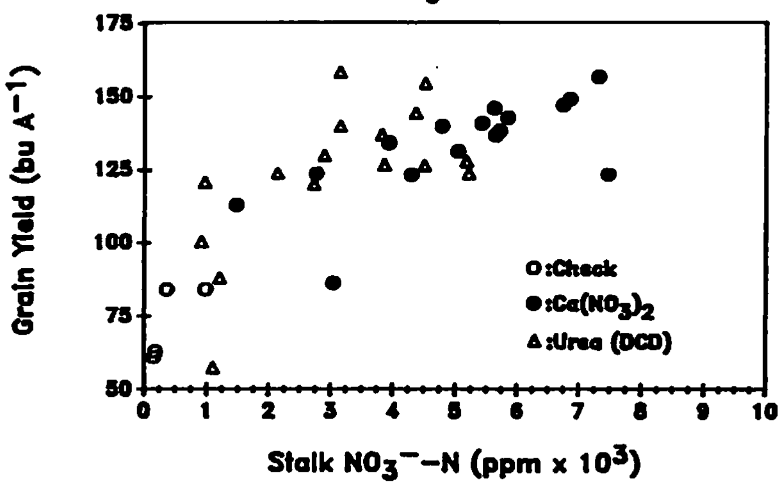
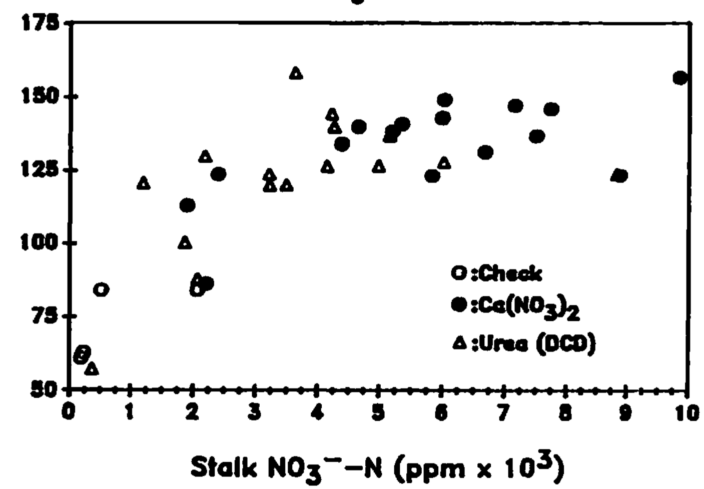


Figure 4



INFLUENCE OF NITROGEN AND POTASSIUM FERTILIZATION ON THE YIELD AND NUTRIENT ACCUMULATION OF FOUR DIFFERENT CORN HYBRIDS--1988 [1]

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ABSTRACT: How different corn hybrids utilize fertilizer and soil nutrients may impact the best fertilizer management that a producer should utilize. Previous research results would suggest that hybrids do vary in the total quantity and time period of nutrient absorption. The objective of this experiment are to evaluate the N accumulation patterens of different corn hybrids and to determine the impact of N rate, K rate, and nitrification inhibitors on yield and N utilization. Results from both Becker and Waseca support the yields and N utilization differences between hybrids. Numerous interactions of hybrid with N and K and nitrification inhibitors treatments would suggest that management treatements can impact the utilization efficiency of a given corn hybrid.

Two experimental locations were selected in 1986 and two experiments established at each location. The two locations were: 1. The Sand Plains Research farm, Becker, MN (irrigated) and 2. Southern Experiment Station, Waseca, MN (dryland). In 1986 a corn and soybean experiment was started at each location to provide for a future corn-soybean sequence. In 1987 nitrogen (N) and potassium (K) treatments were established at each location.

The objectives of these experiments were to: 1. Determine the nutrient accumulation patterns of different corn hybrids grown in a high yield envirnment, and 2. Evaluate the impact of N, and K, and the the use of nitrification inhibitors on the yields and nutrient utilization of different corn hybrids in a corn-soybean sequence.

Experimental Procedures

Becker: A total of 56 treatments with four replications were established on the corn experimental site. A split plot design was utilized with K as the main plot. N and hybrid treatments were randomized within the main plots. A modified factorial arrangement consisting of four corn hybrids (Pioneer 3732, Pioneer 3737, A632 x LH39, and DeKalb 484), three N rates (80, 160, and 240 lbs/A), two nitrification inhibitor treatments (w/wo N-Serve 0.5 lbs/A a.i.), and three K fertilizer rates (0, 100, and 200 lbs K/A) were utilized. To reduce the size of the experiment not all combinations of K were utilized with the 160 lbs/A N treatment.

Potassium treatments were broadcast before planting and incorporated by plowing. The four corn hybrids were planted on April 28th, at a population of 30,700 seeds/A in 30 inch rows. Starter fertilizer was applied as a side banded application of 160 lbs/A of 10-10-10. Weed control was accomplished by using Dual 8E (2.0 lbs/A a.i.) on April 29th and two cultivations one on May 23 and the other on June 3rd. Nitrogen treatments were applied as anhydrous ammonia on June 1st (4-5 leaf growth stage). The nitrification inhibitors were injected into the anhydrous ammonia flow stream and forced to passed through a bidirectional flow integrator prior to the manifold.

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Plant and soil samples were taken four times during the growing season. Plant samples were taken on June 22, July 11th, August 4th, and September 13. These dates corresponded to the 12-leaf, silking, predent, and physiological maturity, growth stages, respectively. Total plant material was removed from 20 ft^2 of plot area for each of the first three harvests and 100 ft^2 was sampled for the final sampling. For the first two harvests total dry matter production was determined and subsamples collected for N concentration and determination of total N uptake. Plant samples obtained during the third and fourth harvest were separated into grain and stover samples. Separate determinations were made for dry matter production and N concentrations. Grain yields were adjusted to 15.5% moisture. Soil samples were collected from all N combinations at the high K rate for two hybrids (Pioneer 3732 and A632 x LH39). Six to eight cores were taken from a depth of 0-1 ft through the anhydrous ammonia injection zone. All soil samples were analyzed for nitrate and ammonium N.

The irrigation program began on June 6th and continued through August 19th with a total of 16.9 inches being applied through an overhead solid set irrigation system. An additional 9.0 inches of water was obtained during the growing season as rainfall.

Waseca: The corn experiment at Waseca was similar to that established at Becker except only 40 treatments were evaluated. The experimental design was a split plot with four replications. Treatments included a factorial combination of four hybrids (Pioneer 3732, Pioneer 3475, LH74 X LH51, AND A632 X LH38), with two N rates (80 AND 160 lbs N/A), two K rates (0 and 100 lbs K/A), and two nitrification inhibitor treatments (w/wo N-Serve 0.5 lbs/A). Two controls both with no fertilizer N but w/wo K and one without was also included in the experiment.

Potassium treatments were applied in the fall of 1987. The four corn hybrids were planted on April 3rd at a population of 32,000 seeds/A in 30 inch rows. Weed control was accomplished with a tank mix of Lasso (3.5 lbs/A a.i.) and Bladex (3 lbs/A a.i.) on May 5th. Nitrogen treatments were applied as anhydrous ammonia on June 7th using procedures similar to that used at Becker.

Plant and soil samples were taken four times (June 24th, July 18th, August 10th, and September 12th), during the growing season. (This coincides with the comparable growth stages at the Becker location.) The same plant sampling procedures were used at Waseca as was described for Becker. Soil samples were collected from the zero K rate (all N combinations) for two of the hybrids (Pioneer 3732 and A632 x LH38) at each plant sampling.

<u>General Results</u>

The results from the Becker location are presented in tables 1-10, and a summary of the results from Waseca are presented in tables 11-23. The discussion presented here will not attempt to interpret all of the results. Major emphasis will be placed on the interpretations of the final yield and N utilization by the crop. A more thorough evaluation of the remaining data will be conducted at a later time.

Becker: Grain yields at this location were lower than average due to the high temperatures that were experienced during the 1988 growing season. Even though this location is irrigated water stress conditions were incountered due to the prolonged dry, hot season. Yields obtained from the four hybrids selected were significantly different. In 1987, P-3732 was one of the lowest yielding hybrids, while in 1988 it was one of the highest. P-3732 and DeKalb 484 were the highest yielding, P-3737 was intermediate and A632 x LH39 was the lowest yielding of the four hybrids tested. A significant yield increase was obtained when the fertilizer N rate was increased from 80 to 240 lbs/a. The magnitude of the yield increase was relatively modest averaging only 8 bu/a. There were, however, many significant N management hybrid interactions when the final yield was determined. A significant hybrid x N rate interaction in 1988 would suggest that P-3732 was more responsive to higher rates of fertilizer N than were the other hybrids examined. The hybrids also responded differently to the addition of K fertilizer. In general P-3732 and P-3737 were not influenced greatly with K addition, while the yields of A632 x LH39 and DeKalb 484 decreased with K fertilization. The use of a nitrification inhibitor tended to reduce yields if no fertilizer K was applied, but increased yields when fertilizer K was applied. This test area is moderate in soil test K and is irrigated so a reason for the negative response to K fertilization is not well understood at this time.

Waseca: Due to the hot, dry growing conditions in 1988 corn grain yields were well below normal at this locations. Final grain yield were significantly different between hybrids, with A632 x LH39 and P-3732 having the lowest yields, P-3475 being intermediate and LH74 x LH51 having the highest overall yields. The P-3475 hybrid tended to have the highest yield when no fertilizer N was applied. Numerous interactions would suggest that not all hybrids responded to the N, K, and nitrification inhibitor treatments in a similar manner. Most of the positive response to K fertilization could be attributed to P-3732 and A632 x LH39. A yield response to increasing N rate was observed through the highest rate of N, but LH74 x LH51 was the most responsive hybrid in the experiment. Although the main effect of nitrification inhibitor was not significant, interactions would suggest that N-Serve increased yields when low rates of N were applied (80 lbs/a), but decreased yields at the high fertilizer N rate when no K was applied. The addition of fertilizer K eliminated the yield depression that was obtained with the nitrification inhibitor at the high fertilizer N rate. The information obtained at both locations warrants continued evaluation.

Table 1. Influence of N-rate, K-rate and nitrification inhibitors on stover N content, total N removal and dry matter production on four corn hybrids. Becker, MN 1988.

N-Rate	Hybrid	Inh.	K-Rate	Whole Plant 12 Leaf Stover			Whole Plant Tasseling Stover		
#/A			#/A	T/A	% N	#/A	T/A	% N	#/A
80	Pioneer 3732	---	---	1.18	2.57	60.2	3.74	1.60	120.2
80		NS	---	0.98	2.85	56.2	3.12	1.49	92.6
80		---	100	1.12	2.72	61.0	3.62	1.67	120.1
80		NS	100	1.41	2.44	69.1	3.70	1.69	125.0
80		---	200	1.15	2.47	56.2	3.35	1.40	93.2
80		NS	200	1.14	2.42	55.0	3.28	1.68	109.3
160		---	200	1.17	2.77	64.6	3.66	1.55	113.1
160		NS	200	1.29	2.58	66.3	3.43	1.69	115.9
240		---	---	1.28	2.68	67.9	3.51	1.64	115.5
240		NS	---	1.12	2.59	58.0	3.35	1.60	106.9
240		---	100	1.24	2.32	57.6	3.43	1.66	114.1
240		NS	100	1.23	2.55	62.5	3.98	1.82	144.2
240		---	200	1.02	2.51	50.4	3.12	1.79	111.6
240		NS	200	1.10	2.58	57.1	3.17	1.82	113.6
80	Pioneer 3737	---	---	1.10	2.72	58.9	3.36	1.52	100.1
80		NS	---	1.15	2.96	67.4	3.50	1.70	118.5
80		---	100	1.28	2.53	65.1	3.42	1.73	119.0
80		NS	100	1.23	2.81	68.8	3.63	1.85	133.5
80		---	200	1.31	2.70	70.6	3.60	1.49	108.1
80		NS	200	1.11	2.72	60.2	3.25	2.07	137.7
160		---	200	0.96	3.20	60.0	2.83	1.82	102.7
160		NS	200	1.07	2.71	58.0	3.25	1.72	111.8
240		---	---	1.15	3.03	69.0	3.37	1.90	127.1
240		NS	---	1.25	3.00	75.4	3.31	2.10	139.8
240		---	100	1.14	2.76	62.2	3.53	2.21	157.6
240		NS	100	1.14	2.96	67.1	3.14	1.90	119.3
240		---	200	0.96	2.83	54.2	3.44	1.88	129.0
240		NS	200	1.12	2.88	64.8	2.87	1.79	102.2
80	A632 X LH39	---	---	1.20	2.86	68.6	3.70	1.73	128.6
80		NS	---	1.36	2.62	71.2	3.61	1.93	139.4
80		---	100	1.16	2.71	60.9	3.36	1.43	95.2
80		NS	100	1.08	2.53	53.6	3.03	1.51	91.3
80		---	200	1.21	2.52	60.7	3.60	1.80	129.2
80		NS	200	1.13	2.67	61.1	2.97	1.44	84.4
160		---	200	0.93	2.76	50.6	3.20	1.84	116.9
160		NS	200	0.91	2.77	49.4	3.08	2.07	126.7
240		---	---	1.04	2.77	57.1	3.06	1.72	106.8
240		NS	---	1.17	2.92	67.8	3.65	2.01	148.9
240		---	100	1.09	2.70	58.5	3.18	1.76	110.8
240		NS	100	1.14	2.79	63.6	3.01	1.86	110.6
240		---	200	0.86	2.91	49.6	2.70	1.94	106.8
240		NS	200	0.96	2.65	50.9	3.03	1.67	101.2
80	DeKalb 484	---	---	1.18	2.61	61.4	3.50	1.61	113.0
80		NS	---	1.21	2.56	61.8	3.82	1.79	136.8
80		---	100	1.11	2.67	59.2	3.42	1.70	116.4
80		NS	100	1.10	2.67	58.9	3.24	1.71	110.6
80		---	200	1.03	2.70	55.0	3.42	1.44	98.2
80		NS	200	1.17	2.68	63.1	3.50	1.67	115.3
160		---	200	1.00	2.73	54.0	3.35	1.53	101.1
160		NS	200	0.93	2.85	52.7	3.14	1.79	112.2
240		---	---	1.28	2.74	70.8	3.29	1.72	113.5
240		NS	---	1.03	2.92	59.3	3.68	2.01	147.3
240		---	100	1.15	2.82	64.7	4.11	1.91	157.6
240		NS	100	1.22	2.69	64.6	3.38	1.83	124.1
240		---	200	1.04	2.90	60.4	3.46	1.98	134.5
240		NS	200	1.22	2.54	61.5	3.32	1.89	124.9

Table 2. Influence of N-rate, K-rate and nitrification inhibitors on stover N content, total N removal and dry matter production on four corn hybrids at predent. Becker, MN 1988.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
#/A			#/A	Bu/A	--------------T/A-------------			
80	Pioneer 3732	---	---	89.7	2.12	3.56	0.72	6.40
80		NS	---	86.4	2.05	3.47	0.71	6.22
80		---	100	91.1	2.16	3.89	0.67	6.72
80		NS	100	95.4	2.26	4.35	0.69	7.29
80		---	200	91.0	2.15	3.63	0.69	6.47
80		NS	200	86.8	2.05	3.62	0.67	6.34
160		---	200	91.1	2.16	3.49	0.66	6.31
160		NS	200	88.2	2.09	3.78	0.71	6.58
240		---	---	104.6	2.48	3.30	0.78	6.56
240		NS	---	90.8	2.15	3.15	0.70	6.00
240		---	100	83.6	1.98	3.53	0.66	6.17
240		NS	100	97.8	2.32	4.35	0.76	7.43
240		---	200	70.7	1.67	3.14	0.58	5.40
240		NS	200	85.3	2.02	3.58	0.73	6.33
80	Pioneer 3737	---	---	99.1	2.35	3.45	0.62	6.41
80		NS	---	104.6	2.47	3.32	0.64	6.42
80		---	100	92.5	2.19	3.53	0.59	6.31
80		NS	100	95.4	2.26	3.40	0.62	6.28
80		---	200	86.4	2.05	2.98	0.52	5.54
80		NS	200	98.8	2.34	3.37	0.61	6.33
160		---	200	86.1	2.04	3.01	0.57	5.62
160		NS	200	95.6	2.26	3.14	0.62	6.03
240		---	---	101.0	2.39	3.44	0.68	6.51
240		NS	---	97.1	2.30	3.65	0.61	6.56
240		---	100	99.5	2.36	3.82	0.69	6.86
240		NS	100	87.5	2.07	3.21	0.55	5.84
240		---	200	109.5	2.59	3.26	0.71	6.57
240		NS	200	94.3	2.23	3.40	0.60	6.23
80	A632 X LH39	---	---	84.1	1.99	3.54	0.77	6.31
80		NS	---	94.0	2.22	3.43	0.72	6.38
80		---	100	85.6	2.03	3.82	0.73	6.58
80		NS	100	75.4	1.78	3.25	0.69	5.72
80		---	200	70.5	1.67	3.42	0.65	5.73
80		NS	200	93.3	2.21	3.94	0.78	6.93
160		---	200	80.2	1.90	3.32	0.77	5.99
160		NS	200	84.4	2.00	3.45	0.79	6.24
240		---	---	95.8	2.27	3.27	0.79	6.32
240		NS	---	89.3	2.13	3.38	0.73	6.24
240		---	100	79.2	1.87	3.39	0.67	5.94
240		NS	100	78.7	1.86	3.21	0.77	5.84
240		---	200	74.5	1.76	2.89	0.73	5.37
240		NS	200	72.2	1.71	3.28	0.62	5.61
80	DeKalb 484	---	---	89.5	2.12	3.60	0.66	6.38
80		NS	---	83.0	1.96	3.44	0.67	6.08
80		---	100	87.3	2.07	3.84	0.81	6.72
80		NS	100	79.4	1.88	3.61	0.72	6.23
80		---	200	79.4	1.88	3.72	0.69	6.29
80		NS	200	70.8	1.68	3.81	0.53	6.01
160		---	200	76.6	1.81	3.67	0.66	6.15
160		NS	200	79.9	1.89	3.11	0.66	5.67
240		---	---	87.5	2.08	3.31	0.73	6.12
240		NS	---	76.2	1.80	3.08	0.65	5.53
240		---	100	90.5	2.14	4.43	0.80	7.37
240		NS	100	82.0	1.94	3.57	0.64	6.15
240		---	200	81.9	1.94	3.37	0.70	6.01
240		NS	200	79.4	1.88	3.27	0.67	5.82

Table 3. Influence of N-rate, K-rate and nitrification inhibitors on grain, stover and cob N content and total N removal on four corn hybrids at predent. Becker, MN 1988.

N-Rate	Hybrid	Inh.	K-Rate	N-Concentration Stover	Grain	Cob	N-Removal Stover	Grain	Cob	Total
#/A			#/A	-----------	%	---------	-----------	#/A	-----------	
80	Pioneer 3732	---	---	1.15	1.45	0.63	91.4	61.5	8.9	151.9
80		NS	---	1.23	1.48	0.64	85.5	60.6	8.9	155.0
80		---	100	0.96	1.49	0.52	73.9	64.2	7.0	145.1
80		NS	100	1.06	1.52	0.55	90.4	68.5	7.5	166.5
80		---	200	1.19	1.48	0.57	85.5	63.7	7.9	157.1
80		NS	200	1.06	1.46	0.55	76.5	59.8	7.4	143.8
160		---	200	1.24	1.55	0.63	87.3	66.6	8.3	162.2
160		NS	200	1.03	1.55	0.62	77.7	64.8	8.7	151.3
240		---	---	1.19	1.50	0.54	79.1	74.3	8.4	161.9
240		NS	---	1.13	1.52	0.54	71.6	65.4	7.5	144.6
240		---	100	1.11	1.51	0.57	79.6	59.5	7.4	146.6
240		NS	100	1.26	1.56	0.55	110.2	72.0	8.4	190.6
240		---	200	1.10	1.60	0.67	67.9	53.3	7.7	129.0
240		NS	200	1.30	1.56	0.58	93.9	63.0	8.3	165.3
80	Pioneer 3737	---	---	1.19	1.53	0.45	82.2	71.6	5.5	159.3
80		NS	---	1.23	1.55	0.47	80.6	76.2	6.0	162.9
80		---	100	1.01	1.51	0.50	71.8	66.2	5.7	143.8
80		NS	100	1.07	1.62	0.43	72.8	72.9	5.3	151.2
80		---	200	1.10	1.55	0.42	64.4	63.3	4.3	132.1
80		NS	200	1.26	1.60	0.48	84.1	74.9	5.8	165.0
160		---	200	1.10	1.67	0.46	65.9	67.4	5.1	138.6
160		NS	200	1.19	1.69	0.49	75.2	76.4	6.1	157.7
240		---	---	1.18	1.72	0.55	80.9	82.0	7.2	170.3
240		NS	---	1.15	1.67	0.44	83.7	76.5	5.3	165.5
240		---	100	1.33	1.67	0.47	100.7	78.3	6.2	185.3
240		NS	100	1.21	1.65	0.49	76.7	68.2	5.4	150.3
240		---	200	1.14	1.65	0.47	75.1	85.4	6.6	167.2
240		NS	200	1.22	1.74	0.44	83.0	77.5	5.3	165.8
80	A632 X LH39	---	---	0.97	1.66	0.42	69.7	66.1	6.4	142.3
80		NS	---	1.13	1.76	0.45	77.6	78.4	6.4	162.6
80		---	100	1.25	1.63	0.45	96.4	65.3	6.5	168.6
80		NS	100	1.13	1.68	0.45	74.8	59.5	6.1	140.5
80		---	200	0.98	1.62	0.41	66.7	53.9	5.2	125.8
80		NS	200	1.10	1.63	0.41	86.6	71.9	6.4	165.0
160		---	200	1.02	1.81	0.48	67.0	68.7	7.4	143.2
160		NS	200	1.35	1.82	0.43	93.2	73.5	6.6	173.4
240		---	---	1.43	1.71	0.42	93.7	77.9	6.6	178.2
240		NS	---	1.08	1.83	0.40	72.8	77.8	5.9	156.7
240		---	100	1.26	1.85	0.44	85.3	69.2	5.8	160.4
240		NS	100	1.34	1.77	0.48	84.8	66.0	7.4	158.2
240		---	200	1.11	1.68	0.45	64.4	59.1	6.4	130.1
240		NS	200	1.40	1.91	0.53	91.6	65.0	6.6	163.3
80	DeKalb 484	---	---	1.19	1.56	0.53	84.9	66.1	6.8	158.0
80		NS	---	1.21	1.73	0.44	83.3	67.9	5.9	157.2
80		---	100	1.03	1.62	0.52	78.9	67.0	8.4	154.4
80		NS	100	1.00	1.60	0.48	71.8	59.8	6.9	138.6
80		---	200	1.26	1.61	0.47	93.8	60.3	6.5	160.7
80		NS	200	1.04	1.66	0.53	79.2	55.4	5.6	140.3
160		---	200	1.29	1.72	0.54	94.9	62.3	7.1	164.4
160		NS	200	1.13	1.77	0.57	69.8	66.8	7.4	144.2
240		---	---	1.35	1.72	0.43	89.3	71.2	6.2	166.8
240		NS	---	1.24	1.78	0.45	76.3	64.1	5.8	146.3
240		---	100	1.35	1.78	0.54	119.6	76.2	8.6	204.4
240		NS	100	0.97	1.73	0.49	68.9	67.1	6.2	142.3
240		---	200	1.18	1.79	0.47	79.5	69.3	6.6	155.5
240		NS	200	1.20	1.82	0.56	78.0	68.3	7.4	153.7

Table 4. Influence of N-rate, K-rate and nitrification inhibitors on stover N content, total N removal and dry matter production on four corn hybrids at physiological maturity. Becker, MN 1988.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Total
#/A			#/A	Bu/A	----------T/A-----------		
80	Pioneer 3732	---	---	172.0	4.07	3.25	7.32
80		NS	---	160.4	3.80	3.01	6.80
80		---	100	181.7	4.30	3.63	7.93
80		NS	100	181.3	4.29	3.39	7.69
80		---	200	164.5	3.89	3.33	7.22
80		NS	200	161.7	3.83	3.14	6.97
160		---	200	164.9	3.90	2.98	6.89
160		NS	200	174.2	4.12	3.63	7.76
240		---	---	173.2	4.10	3.36	7.46
240		NS	---	171.7	4.06	3.11	7.17
240		---	100	176.4	4.17	3.45	7.63
240		NS	100	185.9	4.40	3.88	8.28
240		---	200	181.0	4.28	3.28	7.57
240		NS	200	187.7	4.44	3.91	8.35
80	Pioneer 3737	---	---	179.6	4.25	2.75	7.00
80		NS	---	172.1	4.07	3.21	7.28
80		---	100	173.4	4.10	2.70	6.81
80		NS	100	173.0	4.10	2.81	6.91
80		---	200	161.2	3.81	2.57	6.38
80		NS	200	177.7	4.21	3.07	7.28
160		---	200	157.6	3.73	2.33	6.06
160		NS	200	172.6	4.08	2.60	6.68
240		---	---	189.6	4.49	3.07	7.55
240		NS	---	167.2	3.96	2.49	6.45
240		---	100	171.9	4.07	2.75	6.82
240		NS	100	166.6	3.94	2.52	6.46
240		---	200	166.7	3.94	2.61	6.55
240		NS	200	177.5	4.20	2.96	7.16
80	A632 X LH39	---	---	171.9	4.07	3.11	7.18
80		NS	---	186.0	4.40	3.29	7.69
80		---	100	165.7	3.92	2.92	6.84
80		NS	100	163.8	3.88	2.98	6.86
80		---	200	162.9	3.85	2.95	6.80
80		NS	200	166.5	3.94	2.93	6.87
160		---	200	162.2	3.84	2.72	6.56
160		NS	200	167.2	3.96	2.84	6.79
240		---	---	165.1	3.91	2.85	6.76
240		NS	---	151.3	3.58	2.68	6.26
240		---	100	163.6	3.87	3.05	6.92
240		NS	100	151.6	3.59	2.55	6.14
240		---	200	167.2	3.96	2.88	6.84
240		NS	200	169.8	4.02	2.88	6.75
80	DeKalb 484	---	---	178.1	4.22	2.73	6.72
80		NS	---	178.5	4.22	3.51	7.42
80		---	100	178.3	4.22	3.20	7.50
80		NS	100	173.9	4.12	3.28	7.37
80		---	200	159.5	3.78	3.25	6.83
80		NS	200	175.7	4.16	3.05	7.52
160		---	200	180.6	4.27	3.37	7.45
160		NS	200	175.8	4.16	3.18	6.93
240		---	---	201.5	4.77	2.77	8.15
240		NS	---	166.9	3.95	3.38	6.85
240		---	100	164.1	3.88	2.90	6.88
240		NS	100	173.8	4.11	2.99	7.15
240		---	200	173.9	4.12	3.04	7.25
240		NS	200	166.7	3.95	3.13	6.73

Table 5. Influence of N-rate, K-rate and nitrification inhibitors on grain and stover N content and total N removal on four corn hybrids at physiological maturity. Becker, MN 1988.

				N-Concentration		N-Removal		
N-Rate	Hybrid	Inh.	K-Rate	Stover	Grain	Stover	Grain	Total
#/A			#/A	-------%--------		----------#/A----------		
80	Pioneer 3732	---	---	0.49	1.28	31.4	104.0	135.4
80		NS	---	0.48	1.38	29.2	104.5	133.7
80		---	100	0.55	1.50	39.7	128.9	168.6
80		NS	100	0.52	1.35	35.4	115.8	151.2
80		---	200	0.50	1.38	33.2	107.2	140.4
80		NS	200	0.50	1.40	31.1	106.7	138.0
160		---	200	0.51	1.43	30.5	111.3	141.8
160		NS	200	0.55	1.47	39.7	121.1	160.8
240		---	---	0.55	1.31	37.0	106.8	143.8
240		NS	---	0.61	1.39	38.0	112.9	151.0
240		---	100	0.55	1.49	38.2	124.3	162.5
240		NS	100	0.63	1.46	48.7	128.3	177.1
240		---	200	0.54	1.40	35.2	119.9	155.2
240		NS	200	0.59	1.48	46.2	131.4	177.7
80	Pioneer 3737	---	---	0.45	1.35	24.6	114.1	138.7
80		NS	---	0.43	1.33	27.6	108.4	136.1
80		---	100	0.44	1.34	23.9	109.5	133.4
80		NS	100	0.41	1.42	22.9	116.2	139.1
80		---	200	0.44	1.39	22.0	105.3	127.4
80		NS	200	0.42	1.31	25.3	109.8	135.2
160		---	200	0.54	1.43	25.2	107.1	132.4
160		NS	200	0.56	1.46	29.2	118.8	148.0
240		---	---	0.57	1.50	34.8	134.0	168.9
240		NS	---	0.61	1.54	30.1	121.7	151.8
240		---	100	0.67	1.49	37.2	121.4	158.7
240		NS	100	0.66	1.53	32.8	120.4	153.2
240		---	200	0.53	1.50	27.1	118.0	145.2
240		NS	200	0.60	1.54	35.9	129.3	165.2
80	A632 X LH39	---	---	0.49	1.39	30.7	112.7	143.4
80		NS	---	0.43	1.45	28.3	127.4	155.6
80		---	100	0.50	1.45	29.2	113.5	142.8
80		NS	100	0.41	1.33	24.7	103.7	128.5
80		---	200	0.40	1.48	23.5	113.7	137.3
80		NS	200	0.37	1.45	21.8	114.0	135.9
160		---	200	0.50	1.52	26.8	116.7	143.6
160		NS	200	0.56	1.48	31.7	116.8	148.6
240		---	---	0.57	1.56	31.7	121.1	152.9
240		NS	---	0.52	1.59	27.5	114.4	141.9
240		---	100	0.52	1.62	31.5	125.1	156.7
240		NS	100	0.54	1.54	27.2	110.1	137.4
240		---	200	0.49	1.62	28.1	128.1	156.3
240		NS	200	0.52	1.64	27.8	131.6	159.4
80	DeKalb 484	---	---	0.39	1.42	27.0	119.4	146.5
80		NS	---	0.49	1.46	30.7	123.8	154.6
80		---	100	0.46	1.43	29.9	120.6	150.5
80		NS	100	0.46	1.38	29.6	113.7	143.4
80		---	200	0.39	1.37	23.5	103.0	126.5
80		NS	200	0.44	1.34	29.5	111.0	140.6
160		---	200	0.53	1.49	33.5	127.1	160.6
160		NS	200	0.49	1.57	26.9	130.4	157.3
240		---	---	0.52	1.63	35.5	155.4	190.6
240		NS	---	0.58	1.56	33.4	123.4	156.8
240		---	100	0.55	1.55	32.7	119.8	152.6
240		NS	100	0.52	1.52	31.6	125.4	157.0
240		---	200	0.49	1.47	30.4	120.7	151.2
240		NS	200	0.44	1.62	24.8	127.8	152.7

Table 6. Continued from table 1.

200 # K-Rate only RCB (Hybrid X N-Rate)	Whole Plant 12 Leaf Stover			Whole Plant Tasseling Stover		
Hybrids	T/A	% N	#/A	T/A	% N	#/A
Pioneer 3732	1.14	2.55	58.3	3.33	1.65	109.4
Pioneer 3737	1.09	2.83	61.3	3.20	1.79	115.3
632 X LH39	0.99	2.71	53.7	3.09	1.79	110.9
DeKalb 484	1.06	2.73	57.8	3.36	1.85	114.4
P-Value	83	99	77	81	89	20
BLSD (.05)		0.12				
N-Rate						
80	1.15	2.61	60.2	3.36	1.62	109.4
160	1.03	2.79	56.9	3.24	1.75	112.5
240	1.03	2.72	56.1	3.13	1.84	115.5
P-Value	99	96	61	85	99	41
BLSD (.05)	0.11	0.10			0.11	
Inhibitor						
None	1.05	2.74	57.2	3.30	1.70	112.0
N-Serve	1.09	2.67	58.3	3.19	1.77	112.9
P-Value	67	92	35	78	85	16
Hybrid X N-Rate	79	10	81	55	87	85
Hybrid X Inhibitor	7	15	5	2	86	61
N-Rate X Inhibitor	66	72	42	35	96	73
Hybrid X N-Rate X Inh.	22	98	18	80	97	89
Split Plot without the 160# N-Rate						
K-Rate						
0	1.16	2.77	64.4	3.47	1.75	122.2
100	1.17	2.66	62.3	3.44	1.76	121.8
200	1.09	2.66	58.2	3.25	1.73	112.5
P-Value	40	90	63	61	18	78
BLSD(.05)						
Hybrid X N-Rate X Inhibitor						
Hybrid						
Pioneer 3732	1.16	2.55	59.3	3.44	1.65	113.9
Pioneer 3737	1.16	2.82	65.3	3.36	1.84	124.3
A632 X LH39	1.11	2.72	60.3	3.24	1.73	112.8
DeKalb 484	1.14	2.70	61.7	3.51	1.77	124.3
P-Value	27	99	87	92	99	94
BLSD(.05)		0.8			0.08	
N-Rate						
80	1.17	2.65	61.8	3.44	1.65	114.0
240	1.12	2.74	61.5	3.33	1.84	123.7
P-Value	84	99	17	85	99	99
Inhibitor						
None	1.13	2.69	60.8	3.42	1.71	117.8
N-Serve	1.15	2.70	62.5	3.35	1.78	119.8
P-Value	49	24	61	66	96	42
Hybrid X N-Rate	71	89	53	58	38	45
Hybrid X Inhibitor	5	84	14	10	34	2
N-Rate X Inhibitor	36	4	37	47	89	45
Hybrid X N-Rate X Inhibitor	42	39	46	91	89	97
Hybrid X N-Rate X Inhibitor X K-Rate						
Hybrid X K-Rate	40	23	23	64	94	98
N-Rate X K-Rate	79	18	71	68	23	51
Hybird X N-Rate X K-Rate	59	27	51	8	94	50
Inhibitor X K-Rate	37	55	12	57	80	89
Hybrid X Inhibitor X K-Rate	84	14	51	89	99	99
N-Rate X Inhibitor X K-Rate	73	74	41	45	92	78
Hybrid X N-Rate X Inhibitor X K-Rate	26	50	17	4	25	22

Table 7. Continued from table 2.Predent 200 # K-Rate only RCB (Hybrid X N-Rate)	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
Hybrids	Bu/A	-------------T/A---------------			
Pioneer 3732	85.5	2.02	3.54	0.67	6.23
Pioneer 3737	95.1	2.25	3.19	0.60	6.05
A632 X LH39	79.2	1.87	3.38	0.72	5.97
DeKalb 484	78.0	1.84	3.49	0.65	5.99
P-Value	99	99	99	99	69
BLSD (.05)	3.9	0.09	0.22	0.03	
N-Rate					
80	84.6	2.00	3.56	0.64	6.20
160	85.3	2.01	3.37	0.68	6.07
240	83.5	1.97	3.27	0.66	5.91
P-Value	27	27	99	92	91
BLSD (.05)			0.18		
Inhibitor					
None	83.1	1.98	3.32	0.66	5.95
N-Serve	85.7	2.02	3.48	0.66	6.17
P-Value	90	90	96	25	96
Hybrid X N-Rate	99	99	92	98	99
Hybrid X Inhibitor	88	88	94	97	97
N-Rate X Inhibitor	82	82	66	69	47
Hybrid X N-Rate X Inh.	99	99	26	99	93
Split Plot without the 160# N-Rate					
K-Rate					
0	92.1	2.17	3.39	0.69	6.27
100	87.6	2.07	3.70	0.69	6.46
200	84.0	1.98	3.41	0.65	6.06
P-Value	99	99	62	92	62
BLSD(.05)	2.5	0.06			
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3732	89.4	2.11	3.63	0.69	6.44
Pioneer 3737	97.1	2.29	3.40	0.61	6.31
A632 X LH39	82.8	1.95	3.40	0.72	6.08
DeKalb 484	82.3	1.94	3.58	0.68	6.22
P-Value	99	99	99	99	99
BLSD(.05)	2.5	0.06	0.17	0.03	0.22
N-Rate					
80	87.9	2.08	3.58	0.69	6.33
240	87.9	2.08	3.42	0.68	6.19
P-Value	2	2	99	82	93
Inhibitor					
None	88.5	2.09	3.50	0.69	6.29
N-Serve	87.2	2.09	3.50	0.66	6.24
P-Value	80	80	2	95	51
Hybrid X N-Rate	61	61	94	43	96
Hybrid X Inhibitor	99	99	96	99	99
N-Rate X Inhibitor	99	99	4	89	73
Hybrid X N-Rate X Inhibitor	99	99	66	98	93
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	99	99	95	98	96
N-Rate X K-Rate	41	41	71	32	51
Hybird X N-Rate X K-Rate	99	99	44	93	61
Inhibitor X K-Rate	90	90	95	58	95
Hybrid X Inhibitor X K-Rate	98	98	92	94	96
N-Rate X Inhibitor X K-Rate	87	87	18	52	7
Hybrid X N-Rate X Inhibitor X K-Rate	99	99	24	99	80

Table 8. Continued from table 3. Predent 200 # K-Rate only RCB (Hybrid X N-Rate)	N-Concentration Stover	Grain	Cob	N-Removal Stover	Grain	Cob	Total
Hybrids	---------%---------			------------#/A-----------			
Pioneer 3732	1.15	1.53	0.60	81.4	61.9	8.0	151.4
Pioneer 3737	1.16	1.64	0.45	74.6	74.2	5.5	154.4
A632 X LH39	1.15	1.74	0.45	78.2	65.3	6.4	150.1
DeKalb 484	1.18	1.72	0.52	82.6	63.7	6.7	153.1
P-Value	15	99	99	86	99	99	19
BLSD (.05)		0.04	0.03		3.5	0.62	
N-Rate							
80	1.21	1.57	0.47	79.6	62.9	6.1	148.7
160	1.16	1.69	0.52	78.9	68.3	7.1	154.4
240	1.20	1.71	0.52	79.2	67.6	6.8	153.7
P-Value	96	99	98	3	99	99	68
BLSD (.05)	0.06	0.03	0.03		3.3	0.58	
Inhibitor							
None	1.14	1.64	0.50	76.0	64.4	6.6	147.1
N-Serve	1.18	1.68	0.51	82.4	68.1	6.8	157.4
P-Value	93	99	67	99	99	62	99
Hybrid X N-Rate	69	52	35	27	99	8	82
Hybrid X Inhibitor	99	84	85	99	94	2	99
N-Rate X Inhibitor	97	68	17	94	43	10	66
Hybrid X N-Rate X Inh.	90	75	65	83	99	93	98
Split Plot without the 160# N-Rate							
K-Rate							
0	1.18	1.63	0.48	80.8	71.1	6.7	158.7
100	1.14	1.63	0.49	84.8	67.5	6.8	159.2
200	1.16	1.64	0.49	79.4	65.3	6.5	151.2
P-Value	68	78	61	36	98	60	50
BLSD(.05)							
Hybrid X N-Rate X Inhibitor							
Hybrid							
Pioneer 3732	1.14	1.50	0.57	82.9	63.8	7.9	154.8
Pioneer 3737	1.17	1.61	0.46	79.7	74.4	5.7	159.9
A632 X LH39	1.18	1.72	0.44	80.3	67.5	6.3	154.3
DeKalb 484	1.16	1.69	0.49	83.6	66.1	6.7	156.5
P-Value	46	99	99	61	99	99	70
BLSD(.05)		0.02	0.02		2.2	0.4	
N-Rate							
80	1.11	1.58	0.48	79.7	65.6	6.5	152.0
240	1.21	1.69	0.49	83.6	70.3	6.8	160.8
P-Value	99	99	71	96	99	84	99
Inhibitor							
None	1.16	1.61	0.49	81.9	67.7	6.8	156.4
N-Serve	1.16	1.65	0.49	81.4	68.2	6.6	156.3
P-Value	1	99	14	19	42	77	6
Hybrid X N-Rate	85	95	48	26	92	33	69
Hybrid X Inhibitor	99	77	73	99	99	93	99
N-Rate X Inhibitor	74	56	20	58	99	60	93
Hybrid X N-Rate X Inhibitor	70	54	87	93	99	94	99
Hybrid X N-Rate X Inhibitor X K-Rate							
Hybrid X K-Rate	98	57	84	19	99	99	38
N-Rate X K-Rate	93	87	98	97	9	95	84
Hybird X N-Rate X K-Rate	87	71	74	73	99	32	47
Inhibitor X K-Rate	93	90	63	73	99	32	47
Hybrid X Inhibitor X K-Rate	92	99	70	99	99	70	99
N-Rate X Inhibitor X K-Rate	99	95	29	94	80	60	81
Hybrid X N-Rate X Inhibitor X K-Rate	99	84	70	98	81	81	99

Table 9. Continued from table 4.	Grain	Dry Matter Production		
200 # K-Rate only RCB (Hybrid X N-Rate)	Yields	Grain	Stover	Total
Hybrids Physiological Maturity	Bu/A	---------T/A-----------		
Pioneer 3732	172.3	4.07	3.37	7.45
Pioneer 3737	168.9	3.99	2.69	6.68
A632 X LH39	165.9	3.92	2.84	6.76
DeKalb 484	172.0	4.07	3.04	7.11
P-Value	99	99	99	99
BLSD (.05)	6.8	0.16	0.15	0.25
N-Rate				
80	166.2	3.93	3.05	6.98
160	169.4	4.00	2.88	6.89
240	173.8	4.11	3.03	7.14
P-Value	99	99	95	91
BLSD (.05)	5.0	0.11	0.16	
Inhibitor				
None	166.8	3.94	2.91	6.86
N-Serve	172.8	3.06	3.06	7.15
P-Value	99	99	98	99
Hybrid X N-Rate	99	99	92	98
Hybrid X Inhibitor	87	87	99	99
N-Rate X Inhibitor	41	41	5	20
Hybrid X N-Rate X Inh.	72	72	99	98
Split Plot without the 160# N-Rate				
K-Rate				
0	174.1	4.11	3.07	7.19
100	171.6	4.06	3.07	7.13
200	170.0	4.02	3.04	7.06
P-Value	48	48	9	26
BLSD(.05)				
Hybrid X N-Rate X Inhibitor				
Hybrid				
Pioneer 3732	174.8	4.13	3.39	7.53
Pioneer 3737	173.0	4.09	2.79	6.88
A632 X LH39	165.4	3.91	2.91	6.82
DeKalb 484	174.2	4.12	3.15	7.28
P-Value	99	99	99	99
BLSD(.05)	4.5	0.10	0.12	0.20
N-Rate				
80	171.6	4.06	3.11	7.17
240	172.1	4.07	3.01	7.08
P-Value	23	23	96	73
Inhibitor				
None	172.6	4.08	3.07	7.16
N-Serve	171.1	4.04	3.05	7.10
P-Value	54	54	43	57
Hybrid X N-Rate	99	99	99	99
Hybrid X Inhibitor	9	9	71	45
N-Rate X Inhibitor	96	96	89	95
Hybrid X N-Rate X Inhibitor	96	96	99	99
Hybrid X N-Rate X Inhibitor X K-Rate				
Hybrid X K-Rate	99	99	99	99
N-Rate X K-Rate	99	99	70	94
Hybird X N-Rate X K-Rate	90	90	10	60
Inhibitor X K-Rate	99	99	98	99
Hybrid X Inhibitor X K-Rate	90	90	80	89
N-Rate X Inhibitor X K-Rate	95	95	82	93

Table 10. Continued from table 5. 200 # K-Rate only RCB (Hybrid X N-Rate)	N-Concentration Stover	Grain	N-Removal Stover	Grain	Total
Hybrids Physiological Maturity	------%--------		----------#/A----------		
Pioneer 3732	0.52	1.42	36.0	116.3	152.3
Pioneer 3737	0.51	1.43	27.5	114.7	142.2
A632 X LH39	0.47	1.52	26.6	120.2	146.8
DeKalb 484	0.46	1.47	28.1	120.0	148.1
P-Value	99	99	99	87	95
BLSD (.05)	0.03	0.04	2.8		8.0
N-Rate					
80	0.42	1.38	26.3	108.9	135.2
160	0.52	1.47	30.4	118.7	149.2
240	0.52	1.53	31.9	125.8	157.8
P-Value	99	99	99	99	99
BLSD (.05)	0.03	0.03	2.5	4.3	5.5
Inhibitor					
None	0.48	1.45	28.3	114.9	143.2
N-Serve	0.50	1.47	30.8	120.7	151.6
P-Value	73	81	98	99	99
Hybrid X N-Rate	79	96	77	92	85
Hybrid X Inhibitor	27	76	97	46	78
N-Rate X Inhibitor	22	96	26	46	51
Hybrid X N-Rate X Inh.	62	13	98	7	65
Split Plot without the 160# N-Rate					
K-Rate					
0	0.50	1.44	31.1	119.0	150.1
100	0.52	1.46	32.2	118.5	150.8
200	0.47	1.45	29.1	117.4	146.5
P-Value	99	92	89	19	53
BLSD(.05)	0.02				
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3732	0.54	1.40	36.9	115.9	152.9
Pioneer 3737	0.51	1.43	28.7	117.3	146.1
A632 X LH39	0.47	1.50	27.7	117.9	145.7
DeKalb 484	0.47	1.47	29.9	122.0	151.9
P-Value	99	99	99	98	99
BLSD(.05)	0.02	0.03	1.7	4.3	4.9
N-Rate					
80	0.45	1.38	28.1	112.8	140.9
240	0.55	1.52	33.5	123.8	157.3
P-Value	99	99	99	99	99
Inhibitor					
None	0.50	1.45	30.7	118.6	149.4
N-Serve	0.50	1.45	30.8	118.0	148.9
P-Value	53	33	11	35	25
Hybrid X N-Rate	99	99	99	65	88
Hybrid X Inhibitor	93	27	94	29	72
N-Rate X Inhibitor	96	84	32	46	27
Hybrid X N-Rate X Inhibitor	98	3	99	95	99
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	55	99	98	99	99
N-Rate X K-Rate	40	28	13	98	93
Hybird X N-Rate X K-Rate	92	14	54	71	69
Inhibitor X K-Rate	73	99	91	99	99
Hybrid X Inhibitor X K-Rate	69	99	38	94	66
N-Rate X Inhibitor X K-Rate	30	95	77	99	99
Hybrid X N-Rate X Inhibitor X K-Rate	18	60	53	66	44

Table 11. Influence of N-rate, K-rate and nitrification inhibitors on stover N content, total N removal and dry matter production on four corn hybrids. Waseca, MN 1988.

N-Rate	Hybrid	Inh.	K-Rate	Whole Plant 12 Leaf Stover			Whole Plant Tasseling Stover		
#/A			#/A	T/A	% N	#/A	T/A	% N	#/A
0	Pioneer 3732	---	---	1.08	1.96	42.1	2.91	1.04	60.6
0		---	100	1.21	2.02	48.8	2.86	1.04	56.6
80		---	---	1.04	2.23	46.4	3.28	1.29	83.8
80		NS	---	1.17	2.18	51.0	3.14	1.33	83.3
80		---	100	0.86	2.38	41.6	3.42	1.46	100.2
80		NS	100	1.10	2.34	51.4	3.54	1.29	91.0
160		---	---	1.17	2.31	53.9	3.60	1.46	105.2
160		NS	---	1.12	2.58	57.8	3.33	1.45	96.0
160		---	100	1.11	2.06	45.6	3.01	1.43	85.9
160		NS	100	1.06	2.26	47.5	3.68	1.44	105.8
0	Pioneer 3475	---	---	1.02	1.88	38.5	3.08	1.00	61.4
0		---	100	1.14	1.93	43.8	3.11	0.91	56.6
80		---	---	1.16	2.20	50.9	3.38	1.40	94.6
80		NS	---	1.02	2.08	42.2	3.12	1.27	79.2
80		---	100	1.02	2.17	44.3	2.99	1.39	83.3
80		NS	100	1.05	2.33	49.3	3.24	1.31	85.3
160		---	---	1.08	2.29	49.3	3.28	1.31	86.0
160		NS	---	1.01	2.27	46.0	3.27	1.39	90.5
160		---	100	1.00	2.26	45.2	3.26	1.56	101.5
160		NS	100	1.05	2.37	49.5	3.00	1.46	87.3
0	LH74 X LH51	---	---	0.91	1.92	34.8	2.89	1.13	65.2
0		---	100	0.88	1.85	32.6	3.10	1.13	70.2
80		---	---	0.85	2.33	39.2	3.09	1.33	82.6
80		NS	---	0.90	2.20	39.8	2.90	1.42	82.7
80		---	100	0.94	2.36	44.3	3.30	1.54	101.9
80		NS	100	0.82	2.40	39.5	3.00	1.51	90.6
160		---	---	0.97	2.49	48.2	3.04	1.50	91.2
160		NS	---	0.87	2.41	42.1	3.12	1.55	96.0
160		---	100	0.92	2.38	43.5	3.25	1.53	99.4
160		NS	100	0.89	2.36	41.6	3.10	1.53	94.9
0	A632 X LH38	---	---	0.80	2.15	34.2	2.50	1.04	51.6
0		---	100	0.74	2.32	34.1	2.49	1.28	64.4
80		---	---	0.93	2.46	45.6	3.28	1.54	100.5
80		NS	---	0.97	2.25	43.3	2.81	1.49	83.8
80		---	100	0.91	2.34	42.5	3.25	1.40	90.5
80		NS	100	0.96	2.53	48.1	2.55	1.51	76.5
160		---	---	1.09	2.34	51.2	3.15	1.48	93.1
160		NS	---	0.88	2.67	46.9	3.24	1.55	100.7
160		---	100	1.07	2.48	53.0	2.84	1.62	91.6
160		NS	100	0.87	2.28	39.6	2.72	1.56	84.5

Table 12. Influence of N-rate, K-rate and nitrification inhibitors on stover N content, total N removal and dry matter production on four corn hybrids at predent. Waseca, MN 1988.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
#/A			#/A	Bu/A	------------T/A-----------			
0	Pioneer 3732	---	---	67.5	1.60	2.39	0.43	4.41
0		---	100	65.3	1.55	2.90	0.44	4.89
80		---	---	73.6	1.74	2.66	0.45	4.85
80		NS	---	77.8	1.84	2.65	0.50	4.99
80		---	100	83.6	1.98	3.38	0.55	5.90
80		NS	100	84.2	1.99	3.19	0.59	5.78
160		---	---	89.0	2.11	2.92	0.57	5.60
160		NS	---	85.4	2.03	2.88	0.53	5.44
160		---	100	74.7	1.77	3.04	0.53	5.33
160		NS	100	81.1	1.92	3.12	0.54	5.58
0	Pioneer 3475	---	---	61.1	1.45	3.12	0.58	5.15
0		---	100	57.3	1.36	3.06	0.49	4.91
80		---	---	57.6	1.36	3.19	0.56	5.12
80		NS	---	65.5	1.55	3.14	0.62	5.31
80		---	100	67.3	1.59	3.09	0.68	5.36
80		NS	100	67.8	1.61	3.65	0.65	5.90
160		---	---	76.2	1.80	3.59	0.67	6.07
160		NS	---	69.8	1.65	3.06	0.58	5.29
160		---	100	60.3	1.43	3.43	0.61	5.46
160		NS	100	79.0	1.87	3.60	0.74	6.21
0	LH74 X LH51	---	---	41.9	0.99	3.13	0.41	4.53
0		---	100	32.2	0.76	3.05	0.31	4.17
80		---	---	48.8	1.16	3.75	0.47	5.38
80		NS	---	55.1	1.31	3.88	0.54	5.72
80		---	100	40.2	0.95	3.81	0.44	5.21
80		NS	100	49.2	1.17	3.80	0.54	5.50
160		---	---	59.7	1.41	3.82	0.56	5.79
160		NS	---	51.2	1.21	3.46	0.48	5.15
160		---	100	49.7	1.18	3.77	0.53	5.47
160		NS	100	47.1	1.11	3.44	0.54	5.10
0	A632 X LH38	---	---	46.5	1.10	2.27	0.35	3.72
0		---	100	47.5	1.12	2.69	0.43	4.24
80		---	---	70.6	1.67	3.10	0.53	5.30
80		NS	---	59.8	1.42	2.53	0.49	4.43
80		---	100	66.6	1.58	3.29	0.57	5.44
80		NS	100	52.8	1.25	2.75	0.46	4.46
160		---	---	61.6	1.46	2.73	0.48	4.66
160		NS	---	57.9	1.37	2.83	0.44	4.64
160		---	100	62.9	1.49	3.05	0.58	5.12
160		NS	100	59.1	1.40	2.90	0.53	4.83

Table 13. Influence of N-rate, K-rate and nitrification inhibitors on grain, stover and cob N content and total N removal on four corn hybrids at predent. Waseca, MN 1988.

N-Rate	Hybrid	Inh.	K-Rate	N-Concentration Stover	Grain	Cob	N-Removal Stover	Grain	Cob	Total
#/A			#/A	%			#/A			
0	Pioneer 3732	---	---	0.73	1.38	0.56	35.0	44.0	4.7	83.7
0		---	100	0.81	1.43	0.57	46.6	44.0	5.1	95.7
80		---	---	1.06	1.63	0.62	56.2	56.5	5.6	118.3
80		NS	---	0.97	1.56	0.49	51.6	57.2	5.0	113.7
80		---	100	1.14	1.67	0.63	76.0	65.7	6.8	148.4
80		NS	100	0.99	1.61	0.58	63.1	64.0	6.9	134.0
160		---	---	1.08	1.63	0.59	62.9	68.5	6.7	138.1
160		NS	---	1.04	1.62	0.59	59.6	65.7	6.2	131.5
160		---	100	1.13	1.56	0.64	68.4	55.1	6.7	130.2
160		NS	100	1.07	1.74	0.67	66.7	66.7	7.2	140.7
0	Pioneer 3475	---	---	0.71	1.51	0.60	44.1	43.6	6.9	94.6
0		---	100	0.76	1.54	0.66	46.2	41.5	6.4	94.1
80		---	---	0.99	1.78	0.71	63.1	48.6	7.9	119.6
80		NS	---	0.88	1.70	0.61	55.1	52.5	7.4	115.1
80		---	100	1.17	1.67	0.67	72.4	53.2	9.0	134.6
80		NS	100	0.95	1.68	0.70	68.9	53.7	9.1	131.7
160		---	---	1.04	1.61	0.70	74.9	58.0	9.4	142.3
160		NS	---	1.04	1.76	0.69	63.9	57.9	7.9	129.7
160		---	100	1.23	1.71	0.78	83.7	48.3	9.5	141.5
160		NS	100	1.06	1.58	0.61	76.1	58.5	8.9	143.5
0	LH74 X LH51	---	---	0.95	1.67	0.54	59.7	33.0	4.4	97.1
0		---	100	0.73	1.68	0.66	44.2	25.5	4.7	74.4
80		---	---	1.11	1.86	0.64	82.7	42.7	5.9	131.3
80		NS	---	1.12	1.79	0.61	87.2	46.3	6.6	140.1
80		---	100	1.01	1.95	0.74	77.2	36.9	6.5	120.6
80		NS	100	1.03	1.83	0.72	77.7	42.6	7.7	128.0
160		---	---	1.19	1.88	0.64	90.9	53.3	7.1	151.3
160		NS	---	1.02	1.85	0.67	70.3	45.1	6.5	121.9
160		---	100	1.18	1.83	0.66	88.2	42.9	6.8	137.9
160		NS	100	1.29	1.94	0.74	89.2	43.1	8.0	140.3
0	A632 X LH38	---	---	0.84	1.64	0.54	38.0	36.0	3.8	77.8
0		---	100	0.85	1.73	0.55	45.9	39.1	4.8	89.7
80		---	---	1.10	1.97	0.54	68.0	65.6	5.8	139.4
80		NS	---	1.04	2.08	0.58	52.3	58.7	5.6	116.7
80		---	100	0.98	1.83	0.60	64.7	57.4	6.8	128.9
80		NS	100	1.16	1.93	0.65	63.9	48.3	5.9	118.1
160		---	---	1.15	2.01	0.51	62.4	58.3	4.8	125.5
160		NS	---	1.11	2.02	0.58	62.9	55.4	5.0	123.3
160		---	100	1.32	2.17	0.61	79.9	64.5	7.1	151.5
160		NS	100	1.24	1.99	0.54	72.0	55.6	5.7	133.3

Table 14. Influence of N-rate, K-rate and nitrification inhibitors on stover N content, total N removal and dry matter production on four corn hybrids at physiological maturity. Waseca, MN 1988.

N-Rate	Hybrid	Inh.	K-Rate	Grain Yields	Dry Matter Production Grain	Stover	Total
#/A			#/A	Bu/A	---------T/A-----------		
0	Pioneer 3732	---	---	93.3	2.21	3.30	5.51
0		---	100	111.2	2.63	3.67	6.33
80		---	---	105.1	2.49	3.54	6.03
80		NS	---	113.0	2.67	3.69	6.36
80		---	100	121.6	2.88	4.08	6.96
80		NS	100	137.0	3.24	3.87	7.11
160		---	---	129.1	3.05	3.95	7.00
160		NS	---	116.1	2.75	3.79	6.53
160		---	100	126.4	2.99	3.85	6.84
160		NS	100	115.5	2.73	3.90	6.64
0	Pioneer 3475	---	---	128.9	3.05	3.87	6.92
0		---	100	115.8	2.74	3.98	6.72
80		---	---	113.2	2.68	4.15	6.83
80		NS	---	115.4	2.73	3.89	6.63
80		---	100	116.1	2.75	4.15	6.90
80		NS	100	113.9	2.69	4.14	6.83
160		---	---	140.8	3.33	4.32	7.66
160		NS	---	121.9	2.88	4.20	7.08
160		---	100	120.4	2.85	3.82	6.67
160		NS	100	136.2	3.22	4.44	7.66
0	LH74 X LH51	---	---	106.1	2.51	3.77	6.28
0		---	100	96.0	2.27	3.82	6.09
80		---	---	120.5	2.85	4.12	6.98
80		NS	---	142.9	3.38	4.22	7.60
80		---	100	130.3	3.08	4.31	7.40
80		NS	100	152.9	3.62	4.51	8.13
160		---	---	141.0	3.33	4.09	7.43
160		NS	---	131.9	3.12	4.05	7.17
160		---	100	124.8	2.95	3.98	6.93
160		NS	100	141.2	3.34	4.28	7.63
0	A632 X LH38	---	---	89.6	2.12	3.09	5.21
0		---	100	102.5	2.42	3.47	5.89
80		---	---	97.8	2.31	3.33	5.64
80		NS	---	120.4	2.85	3.66	6.51
80		---	100	111.9	2.65	3.54	6.19
80		NS	100	105.1	2.49	3.59	6.08
160		---	---	121.1	2.87	3.69	6.56
160		NS	---	101.7	2.41	3.20	5.61
160		---	100	130.8	3.09	4.03	7.12
160		NS	100	119.4	2.82	3.80	6.62

Table 15. Influence of N-rate, K-rate and nitrification inhibitors on grain and stover N content and total N removal on four corn hybrids at physiological maturity. Waseca, MN 1988.

N-Rate	Hybrid	Inh.	K-Rate	N-Concentration Stover	N-Concentration Grain	N-Removal Stover	N-Removal Grain	N-Removal Total
#/A			#/A	-------%-------		-----------#/A-----------		
0	Pioneer 3732	---	---	0.58	1.41	38.2	62.1	100.4
0		---	100	0.54	1.48	39.7	77.3	117.0
80		---	---	0.70	1.70	49.6	84.1	133.7
80		NS	---	0.62	1.65	45.4	88.2	133.6
80		---	100	0.69	1.55	56.6	88.9	145.5
80		NS	100	0.65	1.59	50.3	103.2	153.4
160		---	---	0.67	1.58	52.7	96.8	149.5
160		NS	---	0.66	1.76	49.5	96.9	146.3
160		---	100	0.71	1.66	54.5	98.9	153.3
160		NS	100	0.73	1.63	57.2	88.6	145.8
0	Pioneer 3475	---	---	0.53	1.27	41.2	77.3	118.4
0		---	100	0.54	1.44	42.7	78.5	121.1
80		---	---	0.69	1.65	56.8	88.4	145.2
80		NS	---	0.64	1.55	49.4	84.5	133.9
80		---	100	0.67	1.55	56.0	82.3	138.4
80		NS	100	0.64	1.51	52.3	81.7	134.0
160		---	---	0.69	1.49	59.1	99.1	158.2
160		NS	---	0.70	1.56	58.6	89.6	148.2
160		---	100	0.85	1.51	64.2	85.6	149.7
160		NS	100	0.70	1.50	62.1	95.9	158.1
0	LH74 X LH51	---	---	0.48	1.38	36.1	68.7	104.8
0		---	100	0.49	1.37	37.1	62.4	99.5
80		---	---	0.65	1.55	53.5	88.0	141.5
80		NS	---	0.66	1.60	54.9	107.4	162.3
80		---	100	0.72	1.60	61.8	98.7	160.5
80		NS	100	0.63	1.64	57.7	118.8	176.5
160		---	---	0.69	1.62	56.4	107.7	164.1
160		NS	---	0.73	1.63	59.1	101.9	161.0
160		---	100	0.78	1.65	61.1	97.3	158.4
160		NS	100	0.73	1.63	62.1	108.1	170.2
0	A632 X LH38	---	---	0.58	1.56	35.6	65.9	101.5
0		---	100	0.60	1.76	41.4	85.4	126.8
80		---	---	0.74	1.83	48.9	84.2	133.2
80		NS	---	0.72	1.91	52.2	108.1	160.3
80		---	100	0.68	1.84	47.8	97.0	144.8
80		NS	100	0.62	1.64	44.7	81.5	126.2
160		---	---	0.70	1.91	51.9	108.8	160.7
160		NS	---	0.83	1.94	53.0	93.3	146.3
160		---	100	0.83	1.99	66.6	123.2	189.7
160		NS	100	0.78	1.95	59.1	109.8	168.9

Waseca 1988

Table 16. Continued from table 1 and 2.	Whole Plant			Whole Plant		
0 # K-Rate only RCB (Hybrid X N-Rate)	12 Leaf Stover			Tasseling Stover		
Hybrids	T/A	% N	#/A	T/A	% N	#/A
Pioneer 3732	1.09	2.16	47.5	3.26	1.26	83.5
Pioneer 3475	1.08	2.12	46.2	3.24	1.23	80.7
LH74 X LH51	0.90	2.24	40.7	3.00	1.31	79.6
A632 X LH38	0.93	2.31	43.7	2.97	1.35	81.7
P-Value	99	99	99	97	98	23
BLSD (.05)	0.07	0.11	3.8	0.27	0.06	
N-Rate						
0	0.95	1.97	37.4	2.48	1.05	59.7
80	0.99	2.30	45.5	3.25	1.38	90.4
160	1.07	2.35	50.6	3.26	1.43	93.9
P-Value	99	99	99	99	99	99
BLSD (.05)	0.06	0.08	2.9	0.20	0.05	5.5
Hybrid X N-Rate	97	78	80	77	99	99

Predent	Grain	Dry Matter Production			
0 # K-Rate only RCB	Yields	Grain	Stover	Cob	Total
Hybrid	Bu/A	--------------T/A----------			
Pioneer 3732	76.7	1.81	2.65	0.48	4.95
Pioneer 3475	65.0	1.53	3.30	0.60	5.44
LH74 X LH51	50.1	1.18	3.56	0.47	5.23
A632 X LH38	59.6	1.41	2.69	0.45	4.56
P-Value	99	99	99	99	99
BLSD (.05)	5.7	0.13	0.02	0.04	0.34
N-Rate					
0	54.3	1.28	2.72	0.44	4.45
80	62.7	1.48	3.17	0.50	5.16
160	71.6	1.69	3.26	0.57	5.53
P-Value	99	99	99	99	99
BLSD (.05)	4.9	0.11	0.18	0.03	0.28
Hybrid X N-Rate	99	99	99	99	99
Physiological Maturity					
0 # K-Rate only RCB					
Hybrid					
Pioneer 3732	109.1	2.58	3.59	---	6.18
Pioneer 3475	127.6	3.02	4.11	---	7.13
LH74 X LH51	122.5	2.89	3.99	---	6.89
A632 X LH38	102.8	2.43	3.37	---	5.80
P-Value	99	99	99	---	99
BLSD (.05)	11.6	0.27	0.14		0.36
N-Rate					
0	104.4	2.47	3.51	---	5.98
80	109.1	2.58	3.78	---	6.37
160	132.9	3.14	4.01	---	7.16
P-Value	99	99	99		99
BLSD (.05)	9.4	0.22	0.13		0.31
Hybrid X N-Rate	61	61	63		42

Waseca 1988

Table 17. Continued from table 1 and 2.

100 # K-Rate only RCB (Hybrid X N-Rate)	Whole Plant 12 Leaf Stover			Whole Plant Tasseling Stover		
Hybrids	T/A	% N	#/A	T/A	% N	#/A
Pioneer 3732	1.05	2.15	45.3	3.09	1.30	81.9
Pioneer 3475	1.05	2.12	44.4	3.11	1.28	80.5
LH74 X LH51	0.91	2.19	40.1	3.21	1.39	90.5
A632 X LH38	0.90	2.37	43.2	2.86	1.43	82.2
P-Value	99	99	92	97	99	96
BLSD (.05)	0.06	0.10		0.27	0.06	8.2
N-Rate						
0	0.99	2.02	39.8	2.88	1.09	62.7
80	0.93	2.31	43.2	3.24	1.44	94.0
160	1.02	2.29	46.8	3.08	1.53	94.6
P-Value	99	99	99	99	99	99
BLSD (.05)	0.06	0.08	3.4	0.21	0.05	5.7
Hybrid X N-Rate	99	99	99	92	99	96

Predent 100 # K-Rate only RCB	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
Hybrid	Bu/A	-------------T/A-----------			
Pioneer 3732	74.5	1.76	3.10	0.50	5.37
Pioneer 3475	61.6	1.46	3.19	0.59	5.24
LH74 X LH51	40.7	0.96	3.54	0.44	4.94
A632 X LH38	59.0	1.39	3.00	0.52	4.93
P-Value	99	99	99	99	95
BLSD (.05)	5.6	0.13	0.24	0.05	0.42
N-Rate					
0	50.6	1.19	2.92	0.43	4.55
80	64.4	1.52	3.39	0.56	5.47
160	61.9	1.46	3.31	0.55	5.34
P-Value	99	99	99	99	99
BLSD (.05)	4.9	0.11	0.20	0.11	0.29
Hybrid X N-Rate	86	86	88	53	72
Physiological Maturity					
100 # K-Rate only RCB					
Hybrid					
Pioneer 3732	119.7	2.83	3.86	---	6.69
Pioneer 3475	117.4	2.78	3.98	---	6.76
LH74 X LH51	117.0	2.76	4.03	---	6.80
A632 X LH38	115.0	2.72	3.67	---	6.39
P-Value	20	20	97		95
BLSD (.05)			0.27		0.35
N-Rate					
0	106.3	2.51	3.73	---	6.24
80	120.0	2.83	4.02	---	6.86
160	125.5	2.97	3.91	---	6.89
P-Value	99	99	97		99
BLSD (.05)	7.9	0.18	0.22		0.25
Hybrid X N-Rate	93	93	93		99

Waseca 1988

Table 18. Continued from table 3 and 4.	N-Concentration			N-Removal			
0 # K-Rate only RCB (Hybrid X N-Rate)	Stover	Cob	Grain	Stover	Cob	Grain	Total
Hybrids Predent	-----------%--------			------------#/A-----------			
Pioneer 3732	0.95	0.58	1.54	51.3	5.6	56.3	113.3
Pioneer 3475	0.91	0.66	1.63	60.7	8.0	50.0	118.8
LH74 X LH51	1.08	0.60	1.80	77.7	5.7	42.9	126.5
A632 X LH38	1.03	0.53	1.86	56.1	4.7	53.3	114.2
P-Value	99	99	99	99	99	99	97
BLSD (.05)	0.09	0.07	0.05	6.3	0.6	4.6	10.8
N-Rate							
0	0.80	0.55	1.54	44.1	4.9	39.1	88.3
80	1.06	0.62	1.80	67.5	6.2	53.3	127.1
160	1.11	0.60	1.78	72.2	6.9	59.5	139.2
P-Value	99	92	99	99	99	99	99
Hybrid X N-Rate	15	29	98	46	82	99	97
0 # K-Rate only RCB Physiological Maturity							
Hybrid							
Pioneer 3732	0.64	---	1.56	46.8	---	80.9	127.8
Pioneer 3475	0.63	---	1.47	52.3	---	88.2	140.6
LH74 X LH51	0.60	---	1.51	48.6	---	88.1	136.7
A632 X LH38	0.67	---	1.76	45.4	---	86.3	131.7
P-Value	91		99	99		75	95
BLSD (.05)			0.05	4.6			10.9
N-Rate							
0	0.54	---	1.40	37.7	---	68.5	106.2
80	0.69	---	1.68	52.2	---	86.1	138.3
160	0.68	---	1.64	55.0	---	103.0	158.1
P-Value	99		99	99		99	99
Hybrid X N-Rate	37		99	9		56	37
100 # K-Rate only RCB Predent							
Hybrid							
Pioneer 3732	1.02	0.61	1.55	63.6	6.1	54.9	124.7
Pioneer 3475	1.04	0.70	1.63	67.4	8.3	47.6	123.3
LH74 X LH51	0.97	0.68	1.81	69.8	5.9	35.1	110.9
A632 X LH38	1.05	0.58	1.90	63.5	6.2	53.6	123.3
P-Value	73	99	99	84	99	99	99
BLSD (.05)		0.04	0.07		0.70	3.8	10.0
N-Rate							
0	0.78	0.61	1.59	45.7	5.2	37.5	88.4
80	1.07	0.65	1.78	72.5	7.2	53.3	133.1
160	1.21	0.67	1.81	80.0	7.5	52.6	140.2
P-Value	99	98	99	99	99	99	99
Hybrid X N-Rate	95	85	99	95	16	99	98
100 # K-Rate only RCB Physiological Maturity							
Hybrid							
Pioneer 3732	0.64	---	1.55	50.2	---	88.3	138.6
Pioneer 3475	0.68	---	1.48	54.3	---	82.1	136.4
LH74 X LH51	0.66	---	1.54	53.3	---	86.1	139.4
A632 X LH38	0.70	---	1.86	51.9	---	101.8	153.7
P-Value	75		99	50		99	99
BLSD (.05)			0.04			6.2	7.5
N-Rate							
0	0.54	---	1.51	40.2	---	75.9	116.1
80	0.68	---	1.62	55.5	---	91.7	147.3
160	0.78	---	1.70	61.5	---	101.2	162.8
P-Value	99		99	99		99	99
Hybrid X N-Rate	90		97	97		99	99

Table 19 Waseca 1988 Continued from table 1 and 2.

Split Plot without the 0 # N-Rate	Whole Plant 12 Leaf Stover			Whole Plant Tasseling Stover		
	T/A	% N	#/A	T/A	% N	#/A
K-Rate						
0	1.01	2.33	47.1	3.18	1.42	90.6
100	0.97	2.33	45.4	3.13	1.46	91.9
P-Value	52	2	59	86	86	43
Hybrid X N-Rate X Inhibitor						
Hybrid						
Pioneer 3732	1.08	2.29	49.4	3.37	1.39	93.9
Pioneer 3475	1.04	2.24	47.1	3.19	1.38	88.4
LH74 X LH51	0.89	2.36	42.3	3.10	1.48	92.4
A632 X LH39	0.96	2.41	46.3	2.97	1.51	90.1
P-Value	99	99	99	99	99	91
BLSD(.05)	0.04	0.07	2.6	0.13	0.03	
N-Rate						
80	0.96	2.29	45.0	3.14	1.40	88.1
160	1.01	2.36	47.5	3.18	1.48	94.3
P-Value	90	98	99	54	99	99
Inhibitor						
None	1.00	2.31	46.5	3.21	1.45	93.2
N-Serve	0.98	2.34	46.0	3.10	1.43	89.2
P-Value	78	68	44	96	51	99
Hybrid X N-Rate	73	36	24	2	11	17
Hybrid X Inhibitor	98	67	99	93	79	66
N-Rate X Inhibitor	99	92	93	97	66	99
Hybrid X N-Rate X Inhibitor	99	78	86	87	49	52
Hybrid X N-Rate X Inhibitor X K-Rate						
Hybrid X K-Rate	76	65	92	97	91	99
N-Rate X K-Rate	38	99	98	91	31	81
Hybird X N-Rate X K-Rate	26	86	37	46	99	94
Inhibitor X K-Rate	77	71	88	57	96	38
Hybrid X Inhibitor X K-Rate	79	69	91	97	52	80
N-Rate X Inhibitor X K-Rate	9	99	85	15	58	37
Hybrid X N-Rate X Inhibitor X K-Rate	74	98	92	85	99	99

Table 20 Predent Waseca 1988

Split Plot without the 0 # N-Rate	Grain Yields	Dry Matter Production Grain	Stover	Cob	Total
	Bu/A	------------T/A------------			
K-Rate					
0	66.2	1.56	3.13	0.52	5.23
100	64.1	1.51	3.33	0.56	5.41
P-Value	63	63	99	95	99
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3732	81.2	1.92	2.97	0.53	5.43
Pioneer 3475	67.9	1.60	3.34	0.63	5.59
LH74 X LH51	50.1	1.18	3.71	0.51	5.41
A632 X LH39	61.4	1.45	2.89	0.51	4.86
P-Value	99	99	99	99	99
BLSD(.05)	3.0	0.07	0.11	0.03	0.19
N-Rate					
80	63.8	1.51	3.24	0.53	5.29
160	66.6	1.57	3.22	0.55	5.36
P-Value	98	98	23	83	65
Inhibitor					
None	65.1	1.54	3.28	0.54	5.37
N-Serve	65.2	1.54	3.18	0.54	5.27
P-Value	6	6	98	3	84
Hybrid X N-Rate	92	92	92	31	84
Hybrid X Inhibitor	99	99	92	95	99
N-Rate X Inhibitor	29	29	37	84	49
Hybrid X N-Rate X Inhibitor	98	98	99	88	98
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	72	72	97	53	91
N-Rate X K-Rate	87	87	79	6	83
Hybird X N-Rate X K-Rate	95	95	68	92	91
Inhibitor X K-Rate	74	74	77	70	82
Hybrid X Inhibitor X K-Rate	29	29	98	54	86
N-Rate X Inhibitor X K-Rate	96	96	30	98	85
Hybrid X N-Rate X Inhibitor X K-Rate	66	66	23	69	40

Table 21 Predent Waseca 1988

Split Plot without the 0 # N-Rate	N-Concentration Stover	Cob	Grain	N-Removal Stover	Cob	Grain	Total
	----------%---------			-------------#/A-----------			
K-Rate							
0	1.05	0.60	1.79	66.5	6.4	55.6	128.6
100	1.12	0.65	1.79	74.2	7.4	53.5	135.2
P-Value	89	99	11	98	99	77	95
Hybrid X N-Rate X Inhibitor							
Hybrid							
Pioneer 3732	1.05	0.59	1.62	63.0	6.3	62.4	131.8
Pioneer 3475	1.04	0.68	1.68	69.7	8.6	53.8	132.2
LH74 X LH51	1.11	0.67	1.86	82.9	6.8	44.1	133.9
A632 X LH39	1.13	0.57	1.99	65.7	5.8	57.9	129.5
P-Value	99	99	99	99	99	99	38
BLSD(.05)	0.05	0.04	0.03	4.4	0.4	2.4	
N-Rate							
80	1.04	0.62	1.78	67.5	6.7	53.1	127.4
160	1.13	0.63	1.80	73.2	7.0	56.0	136.4
P-Value	99	42	89	99	92	99	99
Inhibitor							
None	1.11	0.64	1.79	73.2	7.0	54.7	134.9
N-Serve	1.06	0.62	1.79	67.5	6.8	54.4	128.8
P-Value	99	67	24	99	60	22	99
Hybrid X N-Rate	54	61	98	56	80	33	34
Hybrid X Inhibitor	90	83	31	12	92	99	67
N-Rate X Inhibitor	6	46	79	30	65	15	22
Hybrid X N-Rate X Inhibitor	73	86	99	79	36	93	93
Hybrid X N-Rate X Inhibitor X K-Rate							
Hybrid X K-Rate	56	62	91	94	8	77	95
N-Rate X K-Rate	95	68	75	75	55	75	12
Hybird X N-Rate X K-Rate	87	35	96	97	59	99	99
Inhibitor X K-Rate	31	3	32	69	67	76	81
Hybrid X Inhibitor X K-Rate	91	59	89	41	82	62	38
N-Rate X Inhibitor X K-Rate	3	98	46	35	28	93	77
Hybrid X N-Rate X Inhibitor X K-Rate	86	89	99	95	17	60	90

Table 22 Physiological Maturity Waseca 1988

Split Plot without the 0 # N-Rate	Grain Yields	Dry Matter Production Grain	Stover	Total
	Bu/A	----------T/A---------		
K-Rate				
0	120.7	2.85	3.86	6.72
100	125.2	2.96	4.01	6.98
P-Value	73	73	68	71
Hybrid X N-Rate X Inhibitor				
Hybrid				
Pioneer 3732	120.4	2.85	3.83	6.68
Pioneer 3475	122.2	2.89	4.13	7.03
LH74 X LH51	135.6	3.21	4.19	7.40
A632 X LH39	113.5	2.68	3.06	6.29
P-Value	99	99	99	99
BLSD(.05)	6.7	0.15	0.15	0.23
N-Rate				
80	119.8	2.83	3.92	6.75
160	126.1	2.98	3.96	6.94
P-Value	99	99	48	96
Inhibitor				
None	121.9	3.93	2.88	6.82
N-Serve	124.3	3.95	2.93	6.88
P-Value	59	59	22	52
Hybrid X N-Rate	90	90	84	96
Hybrid X Inhibitor	90	90	48	90
N-Rate X Inhibitor	99	99	34	99
Hybrid X N-Rate X Inhibitor	62	62	95	94
Hybrid X N-Rate X Inhibitor X K-Rate				
Hybrid X K-Rate	61	61	72	79
N-Rate X K-Rate	83	83	67	85
Hybird X N-Rate X K-Rate	96	96	95	99
Inhibitor X K-Rate	78	78	89	91
Hybrid X Inhibitor X K-Rate	92	92	81	90
N-Rate X Inhibitor X K-Rate	99	99	98	99
Hybrid X N-Rate X Inhibitor X K-Rate	72	72	7	32

Table 23 **Physiological Maturity Waseca 1988**

Split Plot without the 0 # N-Rate	N-Concentration Stover	Grain	N-Removal Stover	Grain	Total
	-------%---------		--------#/A----------		
K-Rate					
0	0.69	1.68	53.1	95.4	148.6
100	0.71	1.64	57.1	97.4	154.5
P-Value	72	76	84	55	76
Hybrid X N-Rate X Inhibitor					
Hybrid					
Pioneer 3732	0.67	1.63	51.9	93.1	145.1
Pioneer 3475	0.69	1.53	57.3	88.3	145.7
LH74 X LH51	0.69	1.61	58.3	103.4	161.8
A632 X LH39	0.73	1.87	53.0	100.7	153.7
P-Value	99	99	99	99	99
BLSD(.05)	0.03	0.03	3.3	5.4	6.3
N-Rate					
80	0.66	1.64	52.3	98.2	145.1
160	0.73	1.68	57.9	100.0	158.0
P-Value	99	99	99	99	99
Inhibitor					
None	0.71	1.66	56.0	95.5	151.6
N-Serve	0.68	1.66	54.2	97.3	151.5
P-Value	97	28	87	62	4
Hybrid X N-Rate	78	99	84	95	99
Hybrid X Inhibitor	56	79	28	96	96
N-Rate X Inhibitor	88	87	66	99	95
Hybrid X N-Rate X Inhibitor	50	75	39	77	81
Hybrid X N-Rate X Inhibitor X K-Rate					
Hybrid X K-Rate	66	90	17	82	84
N-Rate X K-Rate	99	99	88	19	58
Hybird X N-Rate X K-Rate	48	90	94	99	99
Inhibitor X K-Rate	98	95	61	9	35
Hybrid X Inhibitor X K-Rate	78	87	53	99	99
N-Rate X Inhibitor X K-Rate	85	81	18	97	95
Hybrid X N-Rate X Inhibitor X K-Rate	44	97	24	99	89

PRECISION FERTILIZER PLACEMENT FOR MOST PROFITABLE YIELD OF CORN GROWN IN A RIDGE-TILL MANAGEMENT SYSTEM

George Rehm, Andy Scobbie, and Greg Cremers[1/]

ABSTRACT: As ridge-till planting systems become more popular, several questions arise that pertain to fertilizer placement. This study was established to evaluate methods of placement of N, P_2O_5 and K_2O in ridges on corn production. The 1988 drought hindered the collection of much meaningful data. Nevertheless, the results from 1988 did show that substantial amounts of N as urea and K_2O could be applied in the fall without causing any damage to germination or early growth.

Background and Justification:

Several research studies conducted throughout the northern Corn Belt have shown that the ridge-till management system has several advantages for corn production. Use of this planting system reduces surface runoff thus diminishing soil erosion. Because of the recent concern for soil erosion and farm profitability, the farmer adoption of this planting system has accelerated rapidly in recent years. As adoption progresses, several unanswered questions surface each year. Many of these questions deal with fertilizer placement.

Users of conventional tillage systems can broadcast and incorporate fertilizer before planting, apply it in a band near the seed at planting (starter fertilizer), or use a combination of both placement methods. There are, however, no major tillage operations used in the ridge-till management system prior to the building of the ridge with a cultivator during the growing season. The lack of incorporation of broadcast immobile nutrients (P and K) leads to stratification where highest concentrations would persist near the soil surface. This stratification could be a major problem if soil is dry at planting time or if moisture is limited during the growing season.

Past research has also shown that rates of fertilizer P needed for maximum economic corn production can be reduced somewhat if banded rather than broadcast applications of phosphate fertilizer are used. The lower rate requirements with banded placement translate into reduced costs which, in turn, improves the potential for farm profitability. In addition to increasing the efficiency of P use, banded application of P fertilizers, when compared to broadcast usage, can reduce concerns for environmental quality which arise because of movement of surface applied P to lakes, rivers, and streams.

In conventional tillage systems, the placement of banded fertilizer is usually limited to some position near the seed at planting. With the ridge-till management system, however, there are several alternatives for banded application of fertilizer. It is also widely known that high amounts of N and/or K_2O can cause damage to germinating corn if applied too close to the seed. Yet, many growers are searching for a placement of fertilizer that will provide for maximum efficiency of fertilizer use while, at the same time, eliminating the potential for seedling damage.

By using equipment that is currently available, it is possible to place fertilizer, with precision, at several distances from the seed in a ridge-till system. If a grower using a ridge-till management system could apply all of the needed fertilizer in a band in the fall before planting, he would be able to take advantage of traditionally lower prices and eliminate some time involved with planting in the spring.

If a system for banded application of fertilizer is to be developed, there are several important questions that must be answered. The interactions between rate of N and/or K_2O and distance between seed and fertilizer must be comprehensively evaluated. We need to determine if all of the needed N and K_2O can be applied in a band in the fall before planting without causing germination problems in the following

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spring. Likewise, the effect of distance between seed and fertilizer on corn growth and development must be measured if high amounts of N and/or K_2O are to be applied in bands.

The effect of distance between the corn seed and the P in a fertilizer band on the optimum rate of phosphate fertilizer needed for corn production has not been addressed in any research program. The root growth model of Dr. Barber at Purdue University focuses on the effect of volume of soil fertilized on fertilizer use efficiency. Since root surface area and concentration of P and K near the root are important components of the model, one can speculate that the rate of phosphate fertilizer needed for most efficient production will vary with the distance between the seed and the phosphate fertilizer. This speculation needs to be verified in field research trials.

Objectives:

Based on the needs outlined in the previous paragraphs, the study described in the following sections is designed to meet 3 objectives. These are:

1. Measure the effect of distance between seed and fertilizer and phosphate applied on growth and yield of corn grown in a ridge-till management system.
2. Determine the effect of rate of urea-N applied in a band in the ridge in the fall on germination, early growth and yield of corn.
3. Determine the effect of rate of K_2O applied in the ridge in the fall on germination, early growth, and yield of corn.

Experimental Procedure:

Three separate studies were used to meet the stated objectives. Each study will be described separately.

Study #1: Rate Of Applied P_2O_5 And Distance From The Seed.

This study was conducted at the West-Central Experiment Station at Morris and the Southwest Experiment Station at Lamberton. At each site, 0-46-0 was used to supply 23,46, and 69 lb. P_2O_5/acre. Four methods of phosphate placement were compared. These were: 1) broadcast, 2) below and to the side of the seed at planting (starter), 3) a subsurface band in the center of the ridge in the fall at a depth of approximately 5 inches, and 4) a subsurface band 12 inches to the side of the row in the fall at a depth of approximately 3 inches. Four placement combinations were used (see Table 3) and all treatments were compared to a control which received no P_2O_5. Each treatment was replicated 4 times in a randomized complete block design.

Soil samples were collected at 1 foot intervals to a depth of 5 feet prior to fertilizer application. Results are summarized in Table 1. Ridges were constructed during the 1987 growing season. Except for the starter placement, all treatments were applied in the fall of 1987.

Corn was planted in late April at both sites. Management practices conducive to high yields were used at both sites.

Stand counts were taken at approximately 4 weeks after emergence and whole plant samples were collected at this time. These samples were dried, weighed, ground and analyzed for P. Plant uptake of P was calculated from these measurements. Grain yields were measured in the fall and corrected to the 15.5% moisture base.

Study #2: Nitrogen Rate And Placement For Corn Grown In A Ridge-Till System.

This study was conducted at the West-Central Experiment Station at Morris and the Southern Experiment

Station at Waseca. The soil property data listed in Table 1 are appropriate for this study at the Morris location. The soil property data for the Waseca site are summarized in Table 2.

Three rates of N (45, 90, 135 lb./acre) were used at the Morris site.. The N rates were 50, 100, and 150 lb./acre at the Waseca site. At Morris, urea (46-0-0) was applied: 1) in a band in the center of the ridge at a depth of 3 to 5 inches, 2) in a band at a depth of 3 to 5 inches 12 inches from the row, 3) broadcast in the fall and 4) broadcast in the spring. These various applications of 46-0-0 were also compared to a fall application of anhydrous ammonia (82-0-0).

Nitrogen placement was changed for the Waseca site. The urea was applied in the bands in the center of the ridge and at 12 inches from the ridge and a fall application of anhydrous ammonia was also a part of the study. An additional placement consisted of the application of N as 28-0-0 with a spoke injector at planting time. A control treatment (no N applied) was incorporated into the study at both locations. Recommended management inputs such as plant population and herbicide selection were used at both locations.

Stand counts were taken at 4 to 5 weeks after emergence. Whole plant samples were also taken at this time and were dried and weighed. Grain yields were measured in the fall and corrected to the 15.5% moisture base.

Table 1. Relevant soil properties for the experimental sites used in study #1.

Soil Property	Depth	Site: Morris	Site: Lamberton
pH	0- 6	8.1	6.4
	6-12	8.1	6.5
	12-24	8.2	7.3
	24-36	8.2	7.8
	36-48	8.4	8.1
	48-60	8.3	8.2
P*, ppm	0- 6	5.5	5.1
	6-12	6.9	4.1
	12-24	3.8	2.8
	24-36	.6	3.1
	36-48	.5	3.5
	48-60	.5	3.4
K, ppm	0- 6	111	188
	6-12	155	147
	12-24	118	103
	24-36	72	92
	36-48	67	90
	48-60	93	98
Zn, ppm	0- 6	2.2	1.0
Organic Matter, %	0- 6	4.7	4.3

*Bray and Kurtz #1 procedure used for soil samples from Lamberton; Olsen procedure used for soil samples from Morris.

Table 2. Relevant soil properties for the experimental sites at Waseca, 1988.

pH - - - - - - - - - -	7.9
P (Olsen), ppm - - - -	13.5
K, ppm - - - - - - - -	120

Study #3: Band Placement of K_2O In The Center Of The Ridge.

This study was conducted at the Southern Experiment Station at Waseca. Soil test properties listed in Table 2 are appropriate for this site.

Four rates of K_2O (20, 40, 80, 160 lb./acre) supplied as 0-0-60 were applied in the center of an existing ridge at a depth of 3 to 5 inches in the fall of 1987. A control (no K_2O) was also included. Recommended management practices such as selection of plant population and herbicide were used. The N (supplied as 82-0-0) was constant for all treatments.

Stand counts were taken at 4 to 5 weeks after emergence. Whole plant samples were also taken at this time. These samples were dried and weighed. Grain yields were measured in the fall and corrected to the 15.5% moisture base.

Results and Discussion:

Study #1

The effects of rate and placement of applied phosphate on grain yield, weight of young corn plant, phosphorus concentration in young corn plants, and phosphorus uptake by young corn plants are summarized in Tables 3, 4, 5, and 6. Whole plant samples were collected from the Lamberton location and weighed. However, they were discarded by mistake before analysis. Therefore, concentration and uptake data are not available from this location.

In 1988, grain yield as well as early growth and nutrient uptake by young plants was not influenced by either rate of P_2O_5 applied or the placement of the phosphate fertilizer. This lack of treatment response can be attributed to the drought throughout the growing season at both locations.

Grain yields were in the range of 50-60 bu./acre. Even though soil test levels for phosphorus were low, a response to phosphorus in a fertilizer program would not be expected. The dry weather during the early part of the growing season also limited growth and root development of young plants. Consequently, the treatments used had no significant effect on early plant growth and nutrient absorption by these young plants.

Table 3. The effect of rate of applied phosphate and placement of phosphate fertilizer on corn yield. 1988

		P_2O_5 rate (lb./acre)		
Placement		23	46	69
		- - - - - - - - - - bu./acre - - - - - - - -		
Morris:				
control	51.4			
center of ridge		48.4	51.9	51.8
starter		54.2	43.6	57.1
12 in. from ridge center		56.7	47.2	48.2
broadcast		58.1	45.7	52.1
	Ave:	54.4	47.1	52.3
Lamberton:				
control	56.3			
center of ridge		47.5	60.4	64.3
starter		54.0	69.7	58.0
12 in. from ridge center		60.2	51.6	60.3
broadcast		60.0	62.2	48.4
	Ave:	55.4	61.0	57.8

Table 4. The effect of rate and placement of applied phosphate on the weight of young corn plants. 1988.

Placement		P_2O_5 rate (lb./acre) 23	46	69
		gm/6 plants		
Morris:				
control	32.3			
center of ridge		39.0	32.3	33.0
starter		29.3	33.0	29.8
12 in. from ridge center		33.3	37.0	39.0
broadcast		33.0	36.8	36.5
	Ave:	33.7	34.8	34.6
Lamberton:				
control	36.0			
center of ridge		46.5	45.0	55.8
starter		43.0	44.0	49.3
12 in. from ridge center		38.8	40.5	47.3
broadcast		46.8	35.5	43.3
	Ave:	43.8	41.3	48.9

Table 5. Effect of rate and placement of applied phosphate on the phosphorus content of young corn plants. Morris. 1988.

Placement		P_2O_5 rate (lb./acre) 23	46	69
		% P		
control	.374			
center of ridge		.375	.375	.368
starter		.371	.373	.390
12 in. from ridge center		.412	.363	.379
broadcast		.358	.360	.380
	Ave:	.379	.368	.379

Table 6. The effect of rate and placement of applied phosphate on phosphorus uptake by young corn plants. Morris. 1988.

Placement		P_2O_5 rate (lb./acre) 23	46	69
		g P/6 plants		
control	.121			
center of ridge		.146	.121	.122
starter		.110	.124	.115
12 in. from ridge center		.138	.135	.148
broadcast		.118	.131	.138
	Ave:	.128	.128	.131

Study #2

The primary purpose of this study was to evaluate the effect of placement of 46-0-0, applied at 3 rates, on corn emergence, early growth of corn, and corn yield. At Morris, these placements were compared to the standard fall application of 82-0-0. At Waseca, these placements were compared with the fall application of 82-0-0 as well as the application of 28-0-0 with a spoke injector into the ridge at planting time.

The effect of the placement of 46-0-0 at a depth of 5 inches in the center of the ridge was of special interest. If this placement had no harmful effect on production, it would be possible for farmers to apply all of the fertilizer needs in the ridge in the fall thereby saving time during the busy planting season.

At Morris, neither N rate nor placement had a significant effect on grain yield, weight of young corn plants, and emergence (Tables 7, 8, 9). Yields were reduced by the dry weather. Therefore, no response to fertilizer N was expected. With a corn/soybean rotation, this soil is capable of supplying the N requirements for 50-60 bu./acre corn.

The fall application of high rates of 46-0-0 in the center of the ridge did not reduce the weight of young corn plants or hinder emergence (Tables 8, 9). If negative effects were not recorded in a dry year with a calcareous soil, it is doubtful if the use of 46-0-0 in this way would be harmful to early corn growth in other years.

Table 7. The effect of nitrogen rate and management on corn yield in 1988 at Morris.

N Management		N rate (lb./acre) 45	90	135
		- - - - - bu./acre	- - - - - - -	
control	56.6			
46-0-0, center of ridge		56.2	60.2	50.9
46-0-0, 12 in. from ridge center		56.4	48.2	47.7
46-0-0, fall broadcast		50.8	65.2	52.0
82-0-0, fall applied		58.7	52.6	53.3
46-0-0, spring broadcast		66.3	58.7	55.3

Table 8. The effect of nitrogen rate and management on the weight of young corn plants at Morris.

N Management		N rate (lb./acre) 45	90	135
		- - - - - - gm/6 plants	- - - - - -	
control	38.6			
46-0-0, center of ridge		42.0	33.8	33.0
46-0-0, 12 in. from ridge center		36.3	39.5	41.3
46-0-0, fall broadcast		36.5	31.8	35.3
82-0-0, fall applied		34.8	41.3	41.0
46-0-0, spring broadcast		41.5	44.3	44.8

Table 9. The effect of nitrogen rate and management on the emergence of corn at 5 weeks after planting at Morris.

N Management		N rate (lb./acre) 45	90	135
		- - - - plants/20 ft. of row	- - - -	
control	29			
46-0-0, center of ridge		28	26	28
46-0-0, 12 in. from ridge center		29	28	28
46-0-0, fall broadcast		27	26	27
82-0-0, fall applied		29	29	28
46-0-0, spring broadcast		27	27	29

Data from the Waseca site are summarized in Tables 10, 11, and 12. Grain yield was not significantly affected by the placement of the nitrogen fertilizer (Table 10). When averaged over all rates of applied N, the 46-0-0 and the 28-0-0 applied in the ridge were as effective as the band of 46-0-0 to the side of the ridge and the fall applied 82-0-0.

Grain yields did increase with the rate of N used. These increases, however, were small. The major increase occurred when the control is compared to the 50 lb./acre N rate. Yield increases from applied N were expected to be small because of the low yields.

Nitrogen placement had no significant effect on the weight of young corn plants (Table 11). However, early growth increased with rate of applied N. Again, increases were small.

Neither N placement nor rate of N used had a significant effect on emergence (Table 12). This is encouraging for those growers who would like to place all of the fertilizer in the ridge in the fall. The potential damaging effect of urea applied at high rates in a band directly below the seed should be most obvious in a dry year.

Study #3

This study was conducted to evaluate the effects of rate of K_2O fall applied at a depth of 5 inches in the center of the ridge on corn emergence, early growth, and subsequent grain yields. Results are summarized in Table 13. The rate of applied K_2O had no significant effect on any of the variables measured.

The soil test value for K was in the very high range. Therefore, a yield response to rate of applied K_2O would not be expected.

High rates of K_2O applied near the seed at planting have been known to reduce corn emergence and reduce early growth. These reductions were not noted in this study. Apparently, the K_2O applied in the fall dissolves in soil moisture in late fall and early spring and has no damaging impact on corn emergence.

Table 10. The effect of nitrogen rate and management on corn yield in 1988 at Waseca.

N Management		N rate (lb./acre) 50	100	150
		- - - - - - - bu./acre	- - - - - - -	
control	77.4			
46-0-0, center of ridge		86.9	90.3	93.8
28-0-0, spoke injector		86.3	85.7	89.6
46-0-0, 12 in. from ridge center		89.3	81.4	88.3
82-0-0, fall applied		81.7	83.0	88.0

Table 11. The effect of nitrogen rate and management on the weight of young corn plants at Waseca in 1988.

N Management		N rate (lb./acre) 50	100	150
		- - - - - - gm/6 plants	- - - - - -	
control	26.4			
46-0-0, center of ridge		32.8	32.8	31.5
28-0-0, spoke injector		28.0	30.3	28.0
46-0-0, 12 in. from ridge center		28.9	30.8	31.3
82-0-0, fall applied		27.5	27.8	34.3

Table 12. The influence of nitrogen rate and management on the emergence of corn measured 5 weeks after planting at Waseca in 1988.

N Management		N rate (lb./acre) 50	100	150
		- - - - - - plants/20 ft - - - - - -		
control	34			
46-0-0, center of ridge		34	33	34
28-0-0, spoke injector		33	34	32
46-0-0, 12 in. from ridge center		32	33	34
82-0-0, fall applied		33	34	34

Table 13. The effect of rate of K_2O applied in the center of the ridge at a depth of 5 inches on corn yield, early growth and emergence at Waseca, 1988.

K_2O Applied	Yield	Growth	Emergence
lb./acre	bu./acre	gm/6 plants	plants/20 ft.
0	84.4	29	33
20	81.7	31	33
40	78.4	29	33
80	86.3	35	34
160	83.6	31	34

SULFUR FOR CORN PRODUCTION IN SWIFT COUNTY

Pat Maher and George Rehm[1/]

ABSTRACT: This study was conducted to demonstrate the importance of soil texture in determining a need for fertilizer S. One rate of S (25 lb./acre) was broadcast and incorporated before planting for corn grown on an irrigated sand and corn grown on a non-irrigated fine textured soil. Sulfur increased grain yield by about 11 bu./acre on the sandy soil only. There was no response to S on the fine textured soil.

Past research in Minnesota has shown that the addition of sulfur (S) to a fertilizer program will increase the yield of corn grown on sandy soils. Responses to S fertilization have not been measured for fine textured soils with an organic matter content in excess of 1.8%. Yet, we continue to get questions about the need for sulfur. So, this trial was conducted in Swift County to demonstrate the importance of soil texture in determining the need for S in a fertilizer program for corn.

EXPERIMENTAL PROCEDURE:

Two sites were selected. Irrigated corn was grown on a sandy soil at one site while a non-irrigated fine-textured soil was chosen for the second site. Selected soil properties are summarized in Table 1.

Granular gypsum was used to supply S at a rate of 25 lb./acre at each site. This gypsum was broadcast and incorporated before planting. One variety was used at the sandy site while two were planted at the fine-textured site. Appropriate management practices for profitable corn production were used at each site. Grain yields were measured in mid-October and corrected to 15.5% moisture.

Table 1. Relevant soil properties for the soils used in this trial.

Site	Soil Property						
		P					
Description	pH	Bray	Olsen	K	S	Zn	O.M.
		- - lb./acre - - -			- - ppm - -		%
Irrigated	6.8	53	-	310	1	.9	1.9
Dryland	8.2	3	10	259	19	.5	6.5

RESULTS AND DISCUSSION:

Grain yields are summarized in Table 2. As expected, there was a yield increase when S was applied to the sandy soil. The low organic matter content (1.9%) and low soil test for S (1 ppm) are soil properties where responses to fertilizer S Can be expected.

Use of fertilizer S did not increase the yield of either variety at the dryland site. This was to be expected because of the high organic matter content (6.5%) and high soil test for S (19 ppm). The results obtained in this trial are consistent with other trials involving the application of S for corn production in Minnesota.

Table 2. The effect of S application on the yield of corn in Swift County.

Site	Hybrid	Without S	With S
		- - - - - - bu./acre	- - - - - -
Irrigated	Pioneer 3737	168	177
Dryland	Pioneer 3737	138	127
Dryland	Northrup King EX99	125	129

1/ County Extension Agent, Swift County and Extension Specialist, respectively.

THE IMPACT OF LASSO COMBINED WITH UAN ON EARLY SEASON WEED CONTROL AND YIELD OF CORN

Jeff Gonsulus, Doug Miller, Greg Cremers, Andy Scobbie, and George Rehm[1/]

ABSTRACT: The practice of combining some herbicides with liquid nitrogen fertilizer (UAN) instead of water has been widely promoted in the absence of verification of supposed benefits through research. This study was conducted at 3 locations in 1988 to measure the impact of Lasso-liquid N combinations on weed control and corn yield. The use of split applications of N was also evaluated. Weed control was not improved when Lasso was combined with UAN instead of water and this herbicide-N combination had no positive effect on yield. Split applications of N also had no positive effect on yield.

In recent years, there has been widespread promotion via testimonials of the practice of applying some herbicide with liquid N (UAN) instead of water. The practice has not been adequately evaluated in research trials. Consideration of the basic principles of weed control and soil fertility would indicate that there should be no positive effects noted from these combinations. Therefore, this study was conducted to: 1) evaluate the impact of the Lasso-UAN combination on foxtail control and corn yield, 2) measure the effect of split applications of N as UAN on corn yield, and 3) determine if the use of UAN as a carrier would allow for the use of reduced rates of Lasso.

EXPERIMENTAL PROCEDURE:

This study was conducted at 3 sites (Benton, Renville, Winona Counties) in 1988. Corn was grown on an irrigated sand in Benton County. In Renville County, the soil was a silty clay loam with a calcareous pH. A silt loam soil with an acid pH was selected in Winona County. Relevant soil properties are listed in Table 1.

Three rates of Lasso, plus a control, were combined with 4 nitrogen management plans in a complete factorial with 4 replications. A randomized complete block design was used at each site.

Corn was planted with accepted management practices by the cooperating farmer at each location. Treatments were applied within one week of planting. Lasso rates were .83, 1.66, and 2.50 lb. a.i./acre at the Benton County site. In Renville County, the rates were 1.17, 2.33, and 3.50 lb. a.i./acre. For Winona County, the selected rates were 1.00, 2.00, and 3.00 lb. a.i./acre.

The nitrogen rates selected for sites in Benton and Winona Counties were based on yield goal, cropping history, and the soil organic matter content. In Renville County, the selected nitrogen rate was based on yield goal in combination with the results of the soil nitrate test. The selected rates were 220, 170, and 170 lb./acre for Benton, Renville, and Winona County respectively.

All rates of Lasso were applied preemergence with either 10 gallons of water or 10 gallons of 28-0-0 (UAN) per acre. When Lasso was applied with the UAN, the remainder of the N needed to attain the desired rate was applied as a sidedress treatment.

In the second nitrogen management strategy, all of the N was applied as a sidedress treatment and Lasso was applied with water. In a third management strategy, Lasso was applied with water, UAN was applied in a separate operation at the same time and the remainder of the needed N was applied as a sidedress treatment.

Plots were visually evaluated for weed control in early June and cultivated after evaluation. The UAN was sprayed on the soil surface for the sidedress treatment and incorporated with cultivation.

Grain yields were measured in October and corrected to 15.5% moisture.

1/ Extension specialist, junior scientist, assistant scientist, junior scientist and extension specialist, respectively.

Table 1. Relevant soil properties for the 1988 experimental sites.

Soil Property	County Location Benton	Renville	Winona
pH	5.3	7.8	-
P, lb./acre	110	48	81
K, lb./acre	268	382	193
O.M., %	3.9	6.8	2.4
NO_3-N, lb./acre	-	61	36
Texture	sandy loam	silty clay loam	silt loam

RESULTS AND DISCUSSION:

Control of giant foxtail at all locations was affected by rate of Lasso applied. The full rate of Lasso was needed for the best control at the Benton and Renville County sites (Tables 2 and 3). In Winona County, the 2 lb. rate of Lasso was adequate for optimum control (Table 4). A heavy snow immediately after herbicide application probably improved the control of the giant foxtail.

The effectiveness of Lasso was not improved by mixing with 28-0-0 instead of water and there was no significant interaction between the rate of Lasso used and the N management system. There was also no indication that the rate of Lasso needed for optimum control could be reduced if it was mixed with 28-0-0 instead of water.

Table 2. Effect of N management system and Lasso rate on control of giant foxtail - Benton County.

N Management Preemerge	Sidedress	Lasso Carrier	Lasso Rate (lb. a.i./acre) .83	1.66	2.50	Ave.
lb./acre			- - - - - - % control - - - - - -			
-	-	water	72.0	89.5	93.8	85.1
-	220	water	76.2	90.5	96.5	87.8
30	190	water	74.5	94.8	95.2	88.2
30	190	28-0-0	78.0	87.0	95.0	86.7
		Ave.	75.2	90.4	95.1	

LSD for Lasso Rate = 4.3; LSD for N Management - NS

Table 3. Effect of N management system and Lasso rate on control of giant foxtail. Renville County.

N Management Preemerge	Sidedress	Lasso Carrier	Lasso Rate (lb. a.i./acre) 1.17	2.33	3.50	Ave.
lb./acre			- - - - - % control - - - - -			
-	-	water	58.8	77.8	89.2	75.2
-	170	water	52.5	77.8	89.5	73.2
30	140	water	51.2	77.0	89.2	72.5
30	140	28-0-0	52.5	73.8	85.5	70.6
		Ave.	53.8	76.6	88.4	

LSD for Lasso Rate -=6.5; LSD for N Management = NS

Table 4. Effect of N management system and Lasso rate on control of giant foxtail, Winona County.

N Management		Lasso	Lasso Rate (lb. a.i./acre)			
Preemerge	Sidedress	Carrier	1.0	2.0	3.0	Ave.
- - - - lb./acre - - -			- - - - - - % control - - - - -			
-	-	water	92.2	95.5	99.5	95.8
0	170	water	93.2	96.2	99.0	96.2
30	140	water	92.0	97.0	100.0	96.3
30	140	28-0-0	90.8	99.0	98.5	96.1
		Ave.	92.1	96.9	99.2	

LSD for Lasso Rate = 2.6; LSD for N Management = NS

Grain yield was affected by both Lasso rate and N management systems. In Benton County, there was no yield response from the application of fertilizer N (Table 5). However, yields did increase with the rate of Lasso applied. The application of .83 lb. a.i. per acre was adequate for optimum yield.

The lack of a response to N at this sandy site was surprising. Traditionally, sandy soils have relatively low levels of NO_3-N in the root zone at the beginning of the growing season. This site had received heavy applications of manure in the past. Apparently, ample N was released from the manure and the soil organic matter.

The yield goal for this site was 190 bu./acre. The drought, however, had a negative impact on yield. There was also a large amount of variability in yields which is attributable to the dry weather.

Table 5. Effect of N management system and Lasso rate on corn yield, Benton County.

N Management		Lasso	Lasso Rate (lb. a.i./acre)				
Preemerge	Sidedress	Carrier	0	.83	1.66	2.50	Ave.
- - - - lb./acre - - - -			- - - - - - - - - bu/acre - - - - - - - - -				
-	-	water	116.5	163.6	159.0	148.6	146.9
-	220	water	96.9	145.2	161.2	175.7	144.7
30	190	water	109.0	161.3	168.5	166.8	151.4
30	190	28-0-0	110.1	165.7	156.4	157.2	147.3
		Ave.	108.1	158.9	161.3	162.1	

LSD for Lasso Rate = 16.5; LSD for N Management = NS

The N management system as well as the rate of Lasso used had a significant effect on yield at the Renville County site (Table 6). There was, however, no significant interaction between these two factors.

The highest yield was associated with the highest rate of Lasso used (3.5 lb. a.i./acre). Therefore, the highest yield was associated with the lowest weed pressure. Since weeds compete with corn for moisture, this observation would be expected in a dry year.

Yields were also substantially improved by the use of fertilizer N. The use of split applications of N, however, had no effect on yield. When averaged over all rates of Lasso, the yield was 81.6 bu./acre when all of the N was applied as a sidedress treatment. With water as a carrier and a split application of N, the yield was 85.1 bu./acre when averaged over all rates of Lasso applied. Again, the dry weather caused a large amount of variability in measured yields.

Table 6. Effect of N management system and Lasso rate on corn yield, Renville County.

N Management		Lasso	Lasso Rate (lb. a.i./acre)				
Preemerge	Sidedress	Carrier	0	1.17	2.33	3.50	Ave.
- - - - lb./acre - - - -			- - - - - - - - - bu./acre - - - - - - - -				
-	-	water	18.8	60.4	72.0	76.5	56.9
-	170	water	30.4	84.7	77.5	113.8	81.6
30	140	water	29.5	87.1	106.8	116.8	85.1
30	140	28-0-0	26.5	84.8	91.7	99.4	75.6
		Ave.	26.3	79.3	92.0	101.6	

LSD for Lasso Rate = 8.6; LSD for N Management = 8.6

Grain yields at the Winona County site were affected by both the N management system and the rate of Lasso used (Table 7). The application of fertilizer N increased yields, but method of application had no significant effect. The split application was not superior to a single application of N.

The use of Lasso at 2 lb. a.i. per acre produced the optimum yield of corn. Yield was not affected by the carrier used for the Lasso herbicide.

Table 7. Effect of N management system and Lasso rate on corn yield, Winona County.

N Management		Lasso	Lasso Rate (lb. a.i./acre)				
Preemerge	Sidedress	Carrier	0	1.0	2.0	3.0	Ave.
- - - - lb./acre - - - -			- - - - - - - - - bu./acre - - - - - - - -				
-	-	water	61.9	102.0	102.4	108.7	93.7
-	170	water	61.8	106.3	121.5	130.8	105.1
30	140	water	72.9	110.5	128.2	129.3	110.2
30	140	28-0-0	86.2	116.0	129.5	132.2	116.0
		Ave.	70.7	108.7	120.4	125.2	

SUMMARY AND CONCLUSIONS:

This study has been conducted at several locations over a period of 2 years (1987, 1988). Based on the information collected at this time, it is possible to draw the following conclusions:

1. Lasso applied with 28-0-0 instead of water does not improve the control of giant foxtail.

2. The mixture of Lasso and 28-0-0 does not allow for a reduction in the rate of Lasso that is recommended.

3. Split applications of N did not increase grain yield when compared to a single sidedress treatment.

4. There's a reason for using recommended rates of herbicide and nitrogen -- it's called profit.

SURVEY OF EMERGENCY CORN FORAGE FOR NITRATE CONTENT, FEED VALUE, AND YIELD

Mike Schmitt, Neal Martin, and George Rehm[1/]

ABSTRACT: The drought experienced by many livestock producers in 1988 created situations where emergency forages were needed in the middle of the summer. One possible source of emergency forage was corn. In many cases, the corn was looking very stressed and the thought that the crop would not produce any significant grain stimulated the idea to chop the forage for feed during July and August. The nitrate levels in the plants and the expected yields were of primary concern to producers.

PROCEDURE:

In the middle of August, samples were collected from Goodhue and Rice Counties and two areas of Stearns County. At each field site, six plants were measured for height and weight, and a sample of the plant material was collected for moisture, nitrates and NIRS analyses. A general observation of the field was made for overall color of the plants and notes were taken as to the development of ears.

RESULTS AND DISCUSSION:

Data from all of the fields that were sampled are listed in Table 1. Independent variables that a producer might use to evaluate the crop would include the plant height, color of the foliage, and the presence of ears. The dependent variables--those items a producer would want to predict from an independent variable--include the nitrate contents, feed quality, and yields. Data is sorted by plant height at the bottom portion of Table 1.

Yield

Yields from these fields ranged from 1.2 to 4.6 tons of dry matter per acre. Plants that were less than three feet tall had the lowest yields; however, there was no correlation between plant height and forage yield for plants taller than three feet. Numerous publications make a generalized statement that drought-stressed corn will yield approximately one ton of dry matter for each foot of height. This approximation was made for corn that grew somewhat normally until stress during the reproductive period caused little or no ear formation. This generalization does not apply to the 1988 case because stress occurred early in the season as well as during the reproductive stages.

Nitrates

Nitrate analyses were run on a portion of the sampled fields and the quantities ranged from 690 to 3383 parts per million nitrate nitrogen. The higher quantities were in the range that feeding restrictions should apply. Nitrate concentrations were not correlated to plant height. Although there were only 13 samples run for nitrates, there was a slight pattern of the nitrates being high when no ears were developing on shorter stature plants that were turning brown. This would be expected since these plants do not have an active sink for the nitrogen to be translocated to.

Forage Quality

As might be expected, crude protein amounts were inversely correlated to the height of the plants--as the height increased, the protein concentrations decreased. This effect is mainly a dilution function since the dry weights did increase somewhat as the height increased. The acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents had great variation within each height interval and did not have any general trends.

1/ Extension Specialist, Soil Fertility; Extension Specialist, Forage Crops; Extension Specialist, Soil Fertility, respectively.

Summary

The severity, longevity, and timing of high temperature and low moisture stress greatly affects corn quality, quantity, and potential toxicity. In 1988, there were no general guidelines to predict some of these parameters and the best advice for all livestock/crop producers was to test their corn forage for nitrates, moisture, quality, etc.

Table 1. Data of several characteristics from corn plants sampled in Minnesota, 1988.

Sample I.D.[1]	Ear Present	Plant Color[2]	Plant Height	Dry Matter	Yield (D.M.)	Nitrate-N	Crude Protein	ADF	NDF
			in.	%	T/A	ppm	%	%	%
A1	Y	G	68	20	4.4	3241	9.3	30.8	39.6
A2	N	GB	38	58	4	3383	11.0	36.7	48.0
A3	N	G	43	28	2.3	1949	9.9	33.3	44.3
A4	Y	G	41	30	3.4		10.0	29.9	43.2
A5	Y	G	41	30	3.4	1559	10.9	28.1	40.5
A6	N	G	21	21	1.2		12.1	35.1	43.9
A7	Y	G	46	35	3.7		9.2	36.3	41.6
A8	Y	G	41	33	4.6		7.9	32.4	49.1
A9	Y	G	34	32	2.2		8.5	35.0	49.7
B1	Y	G	26	26	1.7	1004	11.3	32.4	44.1
B2	Y	G	52	32	3.5		8.2	34.4	49.3
B3	Y	G	36	29	1.9		9.2	28.5	40.0
B4	Y	G	32	29	2.6		10.4	31.5	44.4
B5	Y	G	31	22	1.6		11.4	34.7	45.3
B6	Y	GB	39	38	3.2		8.5	30.7	45.8
B7	Y	G	27	30	2.3		9.7	36.5	49.9
B8	Y	G	35	25	1.9	690	10.5	32.7	44.0
B9	Y	GB	53	43	4.2	338	6.2	37.8	56.9
B10	Y	G	45	32	2.8		7.3	34.8	54.2
B11	Y	G	48	29	4		9.8	35.4	49.4
B12	Y	G	34	29	2.2		9.4	34.4	48.0
B13	Y	G	39	32	2.1		8.5	33.3	48.2
C1	N	B	56	29	2.8	1539	9.5	40.0	55.1
C2	Y	G	65	27	3.2		8.6	31.2	42.4
C3	Y	G	66	37	3.7	1360	8.4	35.9	51.1
C4	Y	G	63	33	2.5		8.4	31.8	43.8
C5	Y	GB	58	30	4	1802	9.6	30.1	39.9
C6	Y	B	60	42	3.4	1181	10.1	30.8	45.5
C7	Y	GB	57	34	4.5		8.6	30.7	43.6
C8	Y	B	50	43	3.2		9.4	32.4	48.6
C9	Y	GB	64	36	3.3		8.5	33.1	46.8
C10	Y	GB	48	44	3.2	791	7.4	38.3	54.5
C11	N	B	36	35	1.6	2438	10.4	41.2	57.9
Mean Heights									
1-3 feet			31	27.8	1.9	1377	10.3	34.2	46.7
3-4 feet			43	35.4	3.4	1921	9.1	33.6	47.1
4-5 feet			55	36.1	3.7	1373	8.8	33.7	48.4
5-6 feet			65	30.6	3.4	2301	8.6	32.6	44.7
ALL			45	32.5	3.0	1685	9.3	33.6	46.9

[1] Samples designated A were from Stearns County taken on Aug. 12, 1988, B samples were from Stearns County taken Aug. 23, 1988 and C samples were from Goodhue and Rice Counties taken Aug. 16, 1988.

[2] Color was abbreviated G for green, B for brown, and GB for plants that were turning brown.

INFLUENCE OF EXPERIMENTAL DESIGNS ON ON-FARM TRIAL INTERPRETATIONS

M.A. Schmitt and S.J. Openshaw[1]

ABSTRACT: Experimental designs used in on-farm research trials are largely responsible for the precision of the research results. Three experimental designs (unreplicated strip, unreplicated strip with "tester", and randomized complete block (RCB)) were compared from modeled uniformity trial data from four uniformity trial experiments in the Upper Midwest and from seven field trials conducted in Minnesota (Schmitt and Openshaw, 1988). True error variances were 20-45% less for the RCB (3 reps) compared to the strip design. The strip with "tester" design's true error was highest. Treatment mean differentiation based on either a set confidence interval or least significant differences (LSD) was directly correlated to the relative size of the error terms. Field results from 1988 indicate that the RCB (2 reps) estimated error was 25-50% less than the strip design. There were no differences between the strip and strip with "tester" design errors in the field trials conducted at University of Minnesota Agricultural Experiment Stations at Waseca and Lamberton and five on-farm trials.

INTRODUCTION

On-farm research trials provide information used to make decisions affecting the productivity and profitability of a farming operation. Virtually all practices and products warrant on-farm trials because their effects depend heavily on the management and environment of each farm. Because these two components are unique to each farm, research results conducted by neighbors, local farm groups, private companies, and university research are not always directly transferable.

As the trend develops to place increasing emphasis on on-farm trials, the validity of these trial results must be emphasized. The role of experimental design and statistics in determining trial validity is often neglected, yet without validity, interpretation of results have little impact. In conducting on-farm large-plot research trials, the experimental design is often determined by logistical convenience rather than by statistical desirability.

On-farm trials cannot be expected to involve intricate experimental designs that researchers may use under controlled station plots. Those designs are impractical and probably unnecessary in order to provide useful, interpretive results. Although many basic designs have been suggested for on-farm trials, no data has compared designs with respect to their error terms or final interpretations.

The objectives of this project are two-fold. First, we want to compare the precision of three experimental designs used in large-plot research. Second, we want to investigate how experimental design might affect interpretation of the results.

MATERIALS AND METHODS

Two sources of data were used. One set of data is from four uniformity trials previously conducted by other researchers at land grant universities in the Upper Midwest. The second pool of data--which will be reported here--was collected from a series of field trials established for the purpose of this project.

Three basic experimental designs commonly used in large plot, on-farm trials were compared. These three designs are: 1) a nonreplicated strip (strip), in which the number of plots equals the number of treatments, 2) a nonreplicated strip that has a common treatment placed in every second or third plot (strip with "tester"), in which the number of plots equals the number of treatments times (2 or 1.5) plus 1, and 3) a randomized complete block (RCB), in which the number of plots equals the number of treatments times the number of replications.

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The experimental design used in the field trials (Figure 1) incorporated each of the three experimental designs investigated in this study. Five of the locations in Minnesota were on farmers' fields, with each plot having a width of 30 feet and a length from 330 to 1320 feet. Two sites were at University of Minnesota experiment stations, the width was 10-15 feet and the length between 100 and 200 feet. All of the sites were selected based on visual uniformity of the soil.

Management practices were followed at each site that were parallel to that practiced by top corn producers. There were five treatments at each location, consisting of different hybrids: Pioneer brands 3737, 3751, 3732, 3585, and XC272. Pioneer brand 3737 was used as the "tester" in the strip with "tester" design. Grain yields were measured after physiological maturity using a combine and weigh wagons, and grain yields were adjusted to 15.5% moisture.

Approximate errors associated with the three experimental designs were estimated. One main assumption of the analysis is that the size and number of plots do not change depending on the experimental design used. So for the design in Figure 2, assume there are 18 plots (rather than 19 for mathematical logistics), providing the space for 18 treatments in a strip design, 12 treatments in a strip with "tester" design using a "tester" in every third plot, and 9 treatments in an RCB with the minimum of 2 replications.

The error variance for a strip design having as many treatments as there are strips can be approximated by calculating the residual mean square from a completely random design (CRD) analysis (Eq. 1) that used the unadjusted yields of the nontester plots. By using a CRD, only the treatment effects are partitioned from the trial variance--not any block effects.

Eq. 1: $$S^2 = \sum_{1}^{n} \sum_{1}^{r} (X_{ij} - \overline{X}_{i.})^2 / n(r-1)$$

The strip with "tester" design's error variance is approximated in a similar manner as the strip design's error. First, however, the yields are adjusted according to Eq. 2. The adjusted yields for the nontester hybrids are then used in a CRD analysis, partitioning out the treatment effect, resulting in the error variance associated with the total plot area as if a strip with "tester" design were used (Eq. 3).

Eq. 2: $X^{l} = X - ((.667)t_{left} + (.333)t_{right}) + t_{..}$, when the tester to the left is adjacent to the treatment

$X - ((.333)t_{left} + (.667)t_{right}) + t_{..}$, when the tester to the right is adjacent to the treatment

Eq. 3: $$S^2 = \sum_{1}^{n} \sum_{1}^{r} (X^{l}_{ij} - X^{l}_{i.})^2 / n(r-1)$$

The estimated experimental error for a RCB design can only be given as a range based on the assumption that there can be 2 replicates of 9 treatments in the given plot area. The error variance associated with the 1 block of 9 plots is the experimental error of a treatment mean for those 9 plots. By analyzing the unadjusted treatment means as an RCB (with 3 blocks, as the design is laid out), the residual mean square is actually the error associated with 6 plots of a strip design. The estimated error variance for 9 plots will lie between the estimates for 6 and 18 plots. With 2 replicates, the error variances are divided by 2 to obtain the error associated with a treatment mean.

RESULTS AND DISCUSSION

The measurement that is used to evaluate the precision of the different experimental designs is the error variance. The relative size of the error variance is inversely related to the degree of precision of the design. The larger the error variance, the less precision the experiment possesses. The precision of an experiment is directly related to the confidence one can give to the data.

For example, a large relative error variance results in larger differences between treatment means in order for the treatments to be significantly different. A 10 bushel per acre difference in two corn treatment means might be significantly different if relatively low error variance was measured, but would not necessarily be different if a relatively high error variance was measured.

Calculated error variances from the 7 field locations are reported in Table 1. When the analysis was made without adjustmeant for the "testers", simulating a strip design, the range of the unreplicated error variance of a treatment mean was 18.6-91.3. If the treatment means were adjusted for the "tester", the error variance of a treatment mean ranged from 3.2-110.8. The mean of the error variances were almost identical (51.2, 51.0) when combined over locations. There was a wide range of error variances between locations while the relative relationship between the two analyses was similar. The severe drought throughout Minnesota created large variations in yields among locations.

Table 1. Treatment mean error variances as affected by experimental design, 1988.

Location	Strip	Strip w/"Tester"	R.C.B.
			--range--
Woodlake	18.7	3.2	3.3- 9.3
Litchfield	22.0	64.9	11.0-12.2
Utica	30.6	35.9	14.0-15.3
Hector	59.4	51.5	15.0-29.7
Sleepy Eye	59.5	11.4	4.8-29.7
Waseca-AES	91.3	110.8	8.0-45.6
Lamberton-AES	76.9	79.2	30.4-38.4

The error variance of a treatment mean for an RCB design with 2 replicates were estimated to average between 12.5 and 25.6 (Table 2). This represents a reduction in the error variance of 50-75% as compared to the strip design. While the treatment mean error variance is greatly reduced in the RCB design compared to the two strip designs, the compromising factor is that for the given amount of plots, fewer treatments can be evaluated.

Table 2. Mean and range of treatment mean error variances from 7 Minnesota locations as affected by experimental design, 1988.

Design	Plots	Trt	Mean Error Variance
Strip	18	18	51.2
Strip w/"Tester"	18	12	51.0
R.C.B.	18	9	25.6>E>12.5

SUMMARY

Results from the field data provide similar conclusions as those from previous uniformity trial data. In terms of precision, error variances were consistently smaller for the RCB design than for the strip or strip with "tester" designs. The strip with "tester" design did not provide any more precision than the strip design. This means that greater confidence or better interpretation of treatment mean differences are not achieved by using a "tester" design in 1988.

The results of this study favor the practice of replication. The precision of error and the resulting interpretations are all enhanced using a replicated design. Although the logistical argument of increased plotwork is generally presented, the confidence in the results should provide the incentive. The amount of time and effort necessary to lay out an on-farm trial using an RCB or strip with "tester" design are not very different, yet the use of the strip with "tester" (or control) design is greater than for the replicated design.

Note: This is the first year data of a multi-year study.

References:

Schmitt, M.A. and S. J. Openshaw. 1988. Influence of experimental designs on on-farm trial interpretations. Paper presented at 1988 American Society of Agronomy meetings, Anaheim, CA.

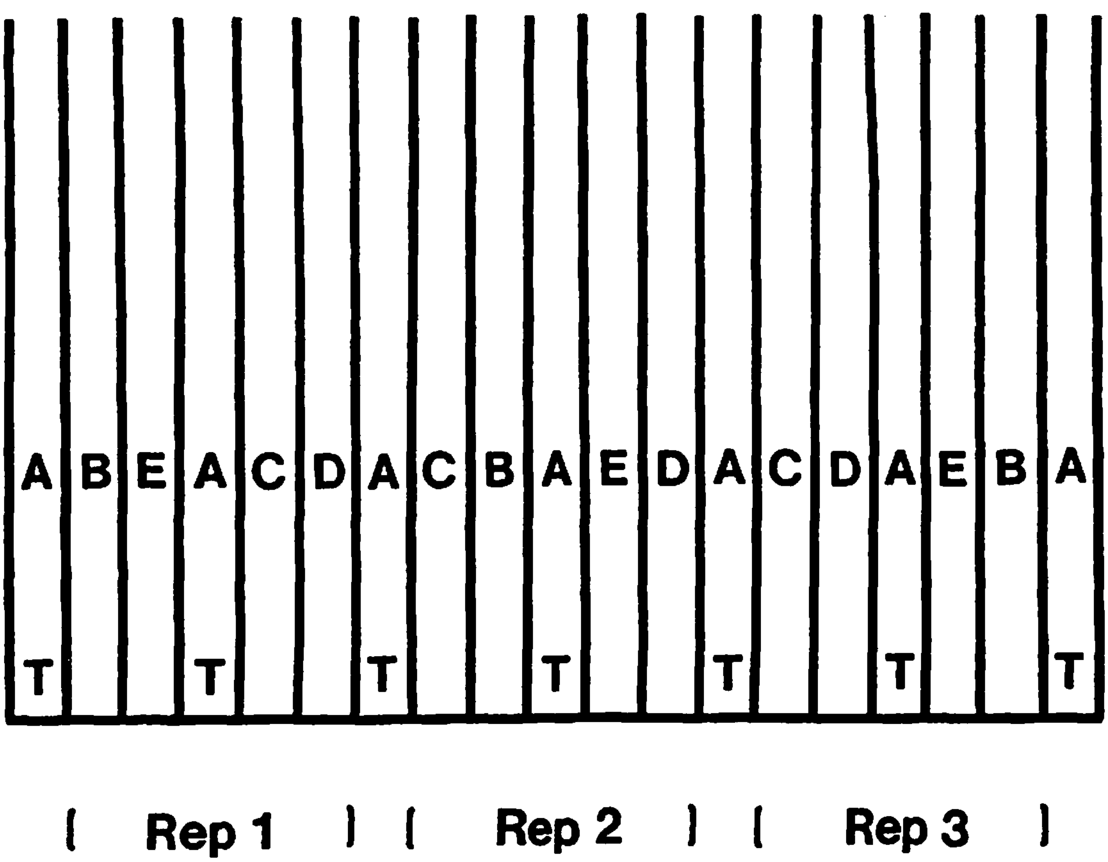

Figure 1. Experimental design used in field trials.

EVALUATION OF COMBINATIONS OF POTASSIUM FERTILIZER, VARIETY, AND FUNGICIDE USE ON PRODUCTION OF HIGH YIELDING SOYBEANS IN MINNESOTA

Ward Stienstra, Greg Cremers, Andy Scobbie, and George Rehm[1/]

ABSTRACT: Potassium fertilization has frequently been associated with the ability of crops to tolerate pressure from some disease organisms. This study was conducted to evaluate the effect of potassium fertilization and the fungicide, Ridomil, on soybean production where phytophthora root rot was known to be a problem. Three sites were selected in Dodge and Mower Counties. Use of K had no effect on yield (soil test K values were in excess of 200 lb./acre). The use of Ridomil produced substantial increases in yield with the greatest increase associated with the most susceptible variety. This study will be conducted in 1989 with special emphasis on location of sites having low soil test values for K.

Background and Scope:

The corn-soybean rotation is a dominant crop production system in Minnesota. The management of crop inputs in this rotation system has been dominated by the corn crop. Fertilizer management practices for many growers include extra phosphate and/or potash when fertilizing the corn crop with the expectation that the soybean crop will use the carryover. This practice may be questioned in view of: 1) documented fixation reactions of P and K in the soil, 2) environmental concerns caused by use of extra inputs, and 3) emphasis on efficient use of inputs to achieve high yields and increased profitability.

Researchers throughout the United States have demonstrated that soybeans respond to applications of phosphate fertilizer when soil test levels for P are low. In Minnesota, this response to P was first reported by Ham and co-workers. The response of soybeans in Minnesota to fertilizer K has been conflicting. No response was measured when soybeans were grown on a sandy soil with a low K test. Yet, there has been some indication of a positive response to K when soil test levels were in the medium to high range. Clearly, more information is needed to improve K fertilizer recommendations for soybean production in Minnesota.

Phytophthora root rot (PRR) is a serious and growing problem in Minnesota. The application of a fungicide in the furrow at planting is available and will reduce the damage caused by this disease. Soil moisture is a critical factor affecting the severity of PRR. The disease is usually not a problem in well drained soils unless the soil becomes saturated in the area of seedling development. A perched water table, heavy rainfall during the week after planting, or drought stress may allow expression of this disease in areas not expected to be prime sites for PRR. The disease is not limited to heavy soils with poor internal drainage. It can and does occur in soils that require irrigation.

The influence of fertilizer management and use on the incidence and severity of PRR is not clear. There are reports that the amount of PRR in Harsoy soybeans increased as the level of soil fertility increased. There was no attempt to identify the specific nutrient responsible for this increase. Another report has stated that chloride salts increased the severity of damage caused by PRR. Since KCl (0-0-60) is the dominant source of fertilizer K in Minnesota, this use may enhance the damage and yield reduction caused by PRR. Therefore, this study was conducted to evaluate the effects of: 1) rate of fertilizer K, 2) soybean variety, and 3) fungicide use on production of soybeans in a high yield environment in Minnesota.

Experimental Procedure:

This study was conducted at 3 locations in southeast Minnesota in 1988. All sites had a known history of soybean damage caused by PRR. It was also hoped that the sites would have a wide range of soil test K values representative of the soils in the region.

[1/] Extension Plant Pathologist, Assistant Scientist, Junior Scientist and Extension Specialist, respectively.

Three factors (K rate, variety, fungicide use) were combined into a complete factorial with a split, split plot design. Four replications of each treatment were used. Rates of applied K (0, 40, 80, 160 lb./acre) were the main plots. Soybean varieties (54-254, BSR-101, Corsoy 79) were the sub plots. Fungicide use (with and without) were the sub-sub plots.

Soil samples from 0-6, 6-12, 12-24, 24-36, 36-48, and 48-60 inches were collected at the initiation of the study. The results of the analyses of these samples are summarized in Table 1. As would be expected, soil test values for K decreased substantially with depth at all locations. The soil test value for K (0-6 in.) at the Ruhter site is considered to be in the medium range. The soil test K values at the Meyer and Hortop locations are considered to be in the high or very high range.

Table 1. Relevant soil test values for the experimental sites used in the study.

Property	Depth	Site: Ruhter	Site: Meyer	Site: Hortop
	in			
pH	0- 6	5.9	7.9	6.6
P (Bray & Kurtz), lb./acre	0- 6	39	75	88
K (1 N $NH_4C_2H_3O_2$), lb./acre	0- 6	214	320	250
	6-12	133	219	188
	12-24	78	180	195
	24-36	80	72	91
	36-48	139	202	92
	48-60	169	203	90
Organic Matter, %	0- 6	2.1	6.6	6.3

The fertilizer K was broadcast and incorporated before planting. The fungicide treatment consisted of the application of Ridomil in the seed furrow at planting at a rate of approximately 6 lb./acre. Seeding rate was approximately 10 seeds per foot of row. Row spacing was 30 inches at all sites. Appropriate herbicides were used for weed control.

During the growing season, plant stands were determined by counting the number of plants in 5 feet of row. Plant height was also measured. The most recently matured leaflet was collected at early bloom, dried, ground, and analyzed for K. Grain yields were measured in early October.

The effect of fertilizer K applied in a starter was also measured at the Ruhter and Meyer locations. For this study, K (supplied as 0-0-60) was applied at planting at rates of 0, 20, 40, and 80 lb./acre. The Corsoy 79 variety was used and Ridomil was also applied. Soybean management practices were consistent with those used in the other phase of the study.

Results and Discussion:

Yield

The broadcast applications of K had no significant effect on yield throughout the study (Table 2). There was also no significant interaction between K rate and variety or K rate and fungicide use. Values reported, therefore, are averaged over variety and fungicide use.

Table 2. The influence of rate of broadcast K on soybean yield. Mower and Dodge Counties. 1988.

K Applied	Site Ruhter	Meyer	Hortop
lb./acre	- - - - - - - -	bu./acre	- - - - - - -
0	31.2	42.8	46.2
40	29.6	44.5	46.9
80	29.8	44.0	43.8
160	28.4	44.5	41.6

The use of K in a starter fertilizer had no effect on soybean yield at the Ruhter and Meyer locations (Table 3).

Table 3. The effect of rate of K applied in a starter fertilizer on soybean yield. Mower and Dodge Counties. 1988.

K Applied	Site Ruhter	Meyer
lb./acre	- - - - - bu./acre	- - - -
0	33.7	50.5
20	35.7	52.3
40	33.4	50.9
80	31.1	51.6

Because of the high soil test values for K at the Meyer and Hortop locations, the lack of response to both broadcast and starter applied K would be expected. The soil test K value at the Ruhter location is considered to be in the medium range. Apparently the soil at this site was capable of supplying the K needed for the soybean crop.

Soybean yield at all locations was affected by both variety and fungicide use. There was also an interaction between these two inputs (Table 4). Values reported are averaged over all K rates used.

Table 4. Soybean yield as affected by variety and fungicide use. Mower and Dodge Counties. 1988.

Site	Fungicide Used	Variety 54-254	BSR-101	Corsoy 79
		- - - - - - - - -	bu./acre	- - - - - - - -
Ruhter	no	8.9	34.9	33.0
	yes	24.4	41.1	36.3
Meyer	no	15.7	51.4	50.1
	yes	42.0	52.4	52.1
Hortop	no	33.7	51.4	44.3
	yes	40.8	51.9	45.6

Use of Ridomil increased the yield of the 54-254 variety at all sites. The disease pressure from PRR was considered to be high at the Ruhter site, intermediate at the Meyer site, and low at the Hortop site. The 54-254 variety is susceptible to PRR.

The BSR-101 variety is resistant to most races of PRR. Use of Ridomil increased the yield of this variety where disease pressure was high (Ruhter location) but not at the other two sites. There was also a small increase in the yield of the Corsoy 79 variety when Ridomil was used at the Ruhter site. The Corsoy 79 variety was considered to be most resistant to PRR.

Considering variety, yields were generally lower with the 54-254 soybeans with the yield from the BSR-101 and Corsoy-79 varieties being nearly equal (Table 4).

K Concentration in Plant Tissue

The most recently matured trifoliate leaves were sampled at early to mid-bloom to provide an indication of K uptake by the soybean crop. The effect of K rate, variety and fungicide on the K concentration in the soybean tissue varied with location. The K concentration increased with rate of applied K at the Ruhter, but not at the Meyer and Hortop locations (Table 5). Values listed are averaged over variety and fungicide treatment.

Table 5. Effect of rate of broadcast K on the K concentration in soybean leaves at early to mid-bloom. Mower and Dodge Counties, 1988.

K Applied	Site: Ruhter	Site: Meyer	Site: Hortop
lb./acre		% K	
0	1.76	1.92	1.96
40	1.90	2.00	1.99
80	1.96	2.03	1.99
160	2.03	2.07	1.99

Use of 80 lb. K/acre was needed to increase the K concentration of the soybean tissue to near the 2.00% value which is generally considered to be the critical concentration for K in soybean leaves. This is probably a reflection of the overall damage to the root system caused by the PRR when disease pressure is high.

Use of K in a starter fertilizer had no significant effect on the K concentration in soybean tissue of the Corsoy 79 variety at both the Ruhter and the Meyer locations (Table 6). This is further evidence that the soils at these sites were able to supply the K needed for soybean production.

Table 6. Effect of rate of K applied in a starter fertilizer on the K concentration in soybean tissue. Mower and Dodge Counties, 1988.

K Applied	Site: Ruhter	Site: Meyer
lb./acre	% K	
0	1.93	1.93
20	2.00	1.98
40	2.10	1.95
80	2.02	2.03

The K concentration in the soybean tissue was affected by both variety and use of the Ridomil (Table 7).

Table 7. The influence of variety and fungicide use on the K concentration in soybean leaf tissue. Mower and Dodge Counties, 1988.

Site	Fungicide Used	54-254	Variety BSR-101	Corsoy-79
		- - - - - - - - -	% K	- - - - - - - - -
Ruhter	no	1.65	2.02	1.98
	yes	1.75	2.07	2.01
Meyer	no	1.87	2.16	1.97
	yes	1.89	2.16	1.99
Hortop	no	1.86	2.09	1.98
	yes	1.91	2.09	1.98

The K concentration was lowest in the 54-254 variety at all sites. Highest concentrations were recorded with the BSR-101 variety.

The use of Ridomil produced a significant increase in the K concentration of all varieties at the Ruhter site. The impact of the heavy disease pressure on the root system was apparently limiting K uptake at this site. There was no significant fungicide treatment x variety interaction. The fungicide application had no effect on the K concentration at the Meyer and Hortop sites.

Soybean Stand

For soybeans, final yield is not necessarily related to stand. Therefore, stand counts were used to provide an additional evaluation of the variables used in this study. The rate of K broadcast and incorporated before planting had no significant effect on the number of plants counted in a 5 foot section of row at all sites (Table 8).

Table 8. The influence of rate of broadcast K on the stand of soybeans. Mower and Dodge Counties. 1988.

K Applied	Ruhter	Site Meyer	Hortop
lb./acre	- - - - - - - - -	plants/5 ft.	- - - - - - - - -
0	34	30	33
40	34	33	33
80	36	32	32
160	36	33	33

Both variety and fungicide use had a significant effect on stand at all locations. There was also a highly significant variety x fungicide interaction at each site (Table 9). Since PRR has a major impact on the health and persistence of the soybean plant, this type of observation can be expected.

Table 9. The effect of variety and fungicide use on soybean stand. Mower and Dodge Counties. 1988.

Site	Fungicide used	54-254	Variety BSR-101	Corsoy 79
		plants/5 ft.		
Ruhter	no	30	29	33
	yes	47	34	38
Meyer	no	24	30	35
	yes	36	34	35
Hortop	no	33	31	32
	yes	33	31	37

Use of Ridomil improved the stand of all varieties at the Ruhter site. The largest improvement was noted with the 54-254 variety. The same observations were recorded at the Meyer site.

Plant Height

The height of the soybean plants was measured in mid-June at the Ruhter and Meyer sites. Plant height at both locations was not affected by the rate of K broadcast and incorporated before planting (Table 10). These results are consistent with yield, K concentration, and stand density measurements.

Table 10. The effect of rate of broadcast K on plant height of soybeans. Mower and Dodge Counties. 1988.

K Applied	Site Ruhter	Meyer
lb./acre	in.	
0	26.5	26.7
40	26.6	25.6
80	25.8	26.0
160	26.2	26.9

The height of the soybean plants was significantly affected by both variety and fungicide use at both locations. There was also a significant variety x fungicide interaction at the Meyer location (Table 11.)

Table 11. The influence of variety and fungicide use on the height of soybean plants. Mower and Dodge Counties. 1988.

Site	Fungicide used	54-254	Variety BSR-101	Corsoy 79
		in		
Ruhter	no	21.5	23.5	28.8
	yes	25.2	26.4	32.2
Meyer	no	21.0	25.6	28.6
	yes	25.4	27.1	30.0

These observations are consistent with the other measurements taken in the study.

Soil Test K

Soil samples (0-6 in.) were collected at the end of the growing season to measure the effect of broadcast K on changes in the soil test K values. Results are summarized in Table 12. As would be expected, soil test K values increased as rate of broadcast K increased. The increase was linear at all locations. It's also important to note that there were no major decreases in soil test values when no fertilizer K was applied even though a respectable yield of soybeans was produced in 1988.

Table 12. The effect of rate of broadcast K on soil test K values at the end of the growing season. Mower and Dodge Counties. 1988.

K Applied	Site		
	Ruhter	Meyer	Hortop
lb./acre	- - - - - - - - - -	lb. k/acre	- - - - - - - - -
0	204	316	262
40	240	326	290
80	234	350	290
160	264	368	306

Summary and Conclusions:

It is not practical to make broad and sweeping conclusions from data collected from only one year. Nevertheless, there are some summary statements that can be made. These are:

1) Use of fertilizer K had no effect on soybean yield at sites with medium to high soil test levels for K. This indicates that the soils chosen were able to supply adequate K for soybean production.

2) Soybean yield was affected by variety. The 54-254 variety produced the lowest yield. Yields from the BSR-101 and Corsoy 79 varieties were nearly equal at all sites.

3) The use of the fungicide, Ridomil, had a positive effect on soybean yield. Substantial increases were observed with the 54-254 variety at all locations. This treatment also increased the yield of the BSR-101 variety at 2 locations.

4) The results of measurements of stand persistence and plant height parallel the observations made for yield.

5) Soil test values for K measured at the end of the growing season increased linearly with rate of K broadcast and incorporated before planting.

NITRATE AND AMMONIUM MONITORING IN IRRIGATED SOILS USED FOR POTATO PRODUCTION[1]

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ABSTRACT: Soil samples from six irrigated commercial potato fields were collected to a depth of three feet during the 1988 growing season. Nitrate and ammonium-N were extracted from each sample using 2 N KCl. Concentrations of nitrate-N and ammonium-N in rows were nearly double those between rows. In general, levels of nitrate-N at the end of the growing season were related to N fertilizer application rates. Only background levels of ammonium-N were detected at the end of the season. Highest N fertilizer rates were not associated with highest yields. The results of this study in a dry season show that if nitrogen is managed carefully leaching losses can be kept to a minimum.

The irrigated soils of Sherburne and Pope counties have been identified as soils susceptible to nitrate leaching. Excessive applications of nitrogen could potentially contaminate the ground water. Few studies could be found which actually monitored how nitrates might be moving in these soils used for potato production. This monitoring is essential to determine the extent of the problem and to improve upon nitrogen management practices for potato production on irrigated soils. The objective of this study, therefore, was to monitor nitrate and ammonium through the growing season under various potato grower production practices.

Procedures

Five potato fields (fields A - E) in Sherburne county and one field (field F) in Pope county were selected for monitoring. All soils in Sherburne county were characterized as Hubbard loamy sands and the soil in Pope county was characterized as an Esterville sandy loam. The cultivar grown was 'Russet Burbank' except in Field E which was in 'Norchip'. The previous crop in all cases was corn. All fields were sampled to a depth of 3 feet at one foot increments. Samples were collected from 4 locations in each field and each sample depth was made up of 3 cores. The first sampling date was in April prior to planting. Fields were sampled again in the same approximate locations in July during tuber enlargement. At this time samples were collected both between rows and within rows. A final sampling date was in September prior to or within one week after harvest. Samples were again collected between and within rows.

Fertilizer rate, timing, and method of application were recorded, but actual practices were left up to each grower. Approximate yields were recorded by harvesting two, 20 ft rows. All soil samples were placed in plastic bags and 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 was calculated on a dry weight basis. All results are expressed as pounds of nitrate-N or ammonium-N per acre using the convention ppm X 2 = lb/A for a 6" acre 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, total nitrate-N and ammonium-N in the 3 foot profile were calculated by assuming that half the field was 'within row' and the remainder was 'between row'.

Results and Discussion

During the season little rainfall occurred until August. Although these conditions are not that normal, interpretation of the results is made easier. Since the July samples were collected before any leaching events took place, it is assumed that this mode of N loss was minimal. Yields varied from approximately

[1] Support for this project was provided by the Minnesota Agricultural Experiment Station and Minnesota Extension Service.

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200 cwt/A to 450 cwt/A and N fertilizer rates varied from 160 - 380 lb N/A. There was little relationship, however, between total N applied and yield.

Nitrate-N levels through the growing season are presented in Tables 1a - 6a and a summary providing means and ranges over all fields is presented in Table 7. The practice of hilling and placing fertilizer N in the row greatly affects N distribution in the field. Concentrations of nitrate-N and ammonium-N in rows were nearly double those between rows. In general, higher N fertilizer rates were associated with higher residual nitrates in September than lower N fertilizer rates. An exception to this observation was field B where highest rates of fertilizer N were used, but levels of nitrate-N in July and September were near the average. Ammonium-N levels are presented in Tables 1b - 6b and a summary providing means and ranges over all fields is presented in Table 8. In general, ammonium-N levels were greatest in July and lowest in September. Nitrification obviously played a major role in the conversion of ammonium-N to nitrate-N.

Residual nitrate-N in the top three feet ranged from 20 lb/A to 102 lb N/A with an average of 61 lb/A. With sufficient rainfall during the fall and winter, substantial leaching of the high residual nitrate might occur. This study will be continued to determine nitrate status in the spring of 1989. A good example of how nitrogen can be managed with minimal nitrate residual or leaching can be found in field C. In this field, 166 lb N/A was applied and a yield of 456 cwt/A was obtained. Residual nitrate-N in September was 20 lbs/A in the top three feet; only three lbs more than what was found in April before planting. Of course had heavy rains occurred during the season additional N would probably have been necessary; however the results do show that if nitrogen is managed carefully leaching losses can be kept to a minimum.

Field A

Initial Soil pH 0-12" - 5.4
N Fertilizer Management: 60 lbs N/A. starter
190 lbs N/A. irrigation
Total 250 lb. N/A
Estimated Yield - 210 cwt/A

Table 1a. Nitrate-N levels in sandy soils used for potato production (means of 4 samples per field).

	Sampling Date[z]				
	April	July		September	
		in row	betn. row	in row	betn. row
Depth	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.
ft.	lb NO_3-N/A				
0-1	9.6 ± 1.6	10.0 ± 4.0	7.0 ± 3.0	11.6 ± 4.1	3.2 ± 0.2
1-2	8.4 ± 2.4	14.2 ± 9.0	4.0 ± 1.2	21.6 ± 13.8	3.0 ± 1.6
2-3	14.0 ± 3.2	9.8 ± 5.4	3.4 ± 1.6	15.4 ± 5.6	7.0 ± 2.4
Total	32.0 ± 5.0	34.0 ± 18.0	14.4 ± 5.5	48.6 ± 21.4	13.2 ± 4.0
Total in row + between row		48.4 ± 22.4		61.8 ± 22.3	

Table 1b. Ammonium-N levels in sandy soils used for potato production (means of 4 samples per field).

	Sampling Date[z]				
	April	July		September	
		in row	betn. row	in row	betn. row
Depth	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.
ft.	lb NH_4-N/A				
0-1	3.1 ± 1.6	9.1 ± 4.6	8.1 ± 3.4	14.8 ± 11.0	1.8 ± 0.2
1-2	4.0 ± 1.2	4.6 ± 2.0	2.6 ± 1.4	1.8 ± 0.4	1.2 ± 0.4
2-3	3.6 ± 1.2	3.2 ± 1.8	1.4 ± 0.6	2.1 ± 1.6	0.8 ± 0.1
Total	10.7 ± 1.8	16.9 ± 6.1	12.1 ± 4.6	18.7 ± 12.7	3.8 ± 0.5
Total in row + between row		29.0 ± 10.0		22.5 ± 12.6	

[z] April - prior to planting and fertilizer application
July - during tuber enlargement
Sept. - 10 days prior to vine kill

Field B

Initial Soil pH 0-12" - 5.6

N Fertilizer Management:

	70 lbs. N/A starter
	160 lbs. N/A as 82-0-0 pre emergence
	150 lbs. N/A at hilling
Total	380 lbs. N/A

Estimated Yield - 309 cwt/A

Table 2a. Nitrate-N levels in sandy soils used for potato production (means of 4 samples per field).

	Sampling Date[z]				
	April	July		September	
		in row	betn. row	in row	betn. row
Depth	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.
ft.	lb NO_3-N/A				
0-1	2.5 ± 0.4	38.8 ± 12.2	5.0 ± 2.8	10.4 ± 1.2	12.0 ± 7.8
1-2	2.4 ± 0.4	44.4 ± 22.6	7.6 ± 7.0	9.0 ± 2.2	6.8 ± 3.8
2-3	6.7 ± 1.6	10.4 ± 4.4	7.2 ± 4.4	7.2 ± 2.0	4.1 ± 3.4
Total	11.6 ± 1.1	93.6 ± 27.8	19.8 ± 11.8	26.6 ± 2.2	23.0 ± 14.0
Total in row + between row		113.4 ± 35.4		49.6 ± 14.7	

Table 2b. Ammonium-N levels in sandy soils used for potato production (means of 4 samples per field).

	Sampling Date[z]				
	April	July		September	
		in row	betn. row	in row	betn. row
Depth	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.
ft.	lb NH_4-N/A				
0-1	10.6 ± 2.3	13.5 ± 20.5	3.7 ± 2.2	1.5 ± 0.6	1.1 ± 0.2
1-2	10.9 ± 5.5	5.9 ± 5.6	1.7 ± 0.6	1.6 ± 1.2	1.1 ± 0.2
2-3	7.9 ± 3.4	1.7 ± 0.7	1.4 ± 0.3	2.0 ± 1.8	0.8 ± 0.4
Total	29.4 ± 10.6	21.1 ± 19.8	6.8 ± 3.0	5.1 ± 3.6	3.0 ± 0.6
Total in row + between row		28.0 ± 18.9		8.1 ± 4.2	

[z] April = prior to planting and fertilizer application.
July = during tuber enlargement.
Sept. = after vines were killed but before harvest.

Field C

Initial Soil pH 0-12" - 5.3
N Fertilizer Management: 70 lbs. N/A starter
30 lbs. N/A.irrigation
66 lbs. N/A hilling
Total 166 lbs. N/A
Estimated Yield - 456 cwt/A

Table 3a. Nitrate-N levels in sandy soils used for potato production (means of 4 samples per field).

	Sampling Date[z]				
	April	July		September	
		in row	betn. row	in row	betn. row
Depth	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.
ft.	lb NO_3-N/A				
0-1	9.6 ± 1.2	8.4 ± 6.0	6.2 ± 4.2	5.4 ± 1.2	5.0 ± 1.0
1-2	4.8 ± 1.2	3.2 ± 1.0	2.8 ± 1.4	3.0 ± 0.6	2.2 ± 0.4
2-3	3.2 ± 0.8	1.2 ± 0.4	1.4 ± 1.6	2.4 ± 0.4	2.4 ± 2.4
Total	17.6 ± 2.8	12.8 ± 7.3	10.4 ± 4.8	10.8 ± 1.8	9.6 ± 1.9
Total in row + between row		23.2 ± 10.6		20.4 ± 3.2	

Table 3b. Ammonium-N levels in sandy soils used for potato production (means of 4 samples per field).

	Sampling Date[z]				
	April	July		September	
		in row	betn. row	in row	betn. row
Depth	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.
ft.	lb NH_4-N/A				
0-1	5.1 ± 2.6	5.5 ± 3.2	3.3 ± 1.4	1.2 ± 0.3	1.2 ± 0.3
1-2	6.5 ± 1.2	2.2 ± 1.2	1.6 ± 0.2	1.2 ± 0.4	1.4 ± 0.2
2-3	4.4 ± 1.1	1.9 ± 0.7	1.4 ± 0.1	1.1 ± 0.2	1.2 ± 0.2
Total	16.0 ± 4.1	9.6 ± 3.8	6.3 ± 1.2	5.1 ± 3.6	3.0 ± 0.6
Total in row + between row		15.9 ± 4.8		7.3 ± 1.2	

[z] April = prior to planting and fertilizer application.
July = during tuber enlargement.
Sept. - after vines were killed but before harvest.

Field D

Initial Soil pH 0-12" - 5.4
N Fertilizer Management: 45 lbs. N/A starter
120 lbs. N/A emergence
120 lbs. N/A hilling
Total 285 lbs. N/A
Estimated Yield - 446 cwt/A

Table 4a. Nitrate-N levels in sandy soils used for potato production (means of 4 samples per field).

	Sampling Date[z]				
	April	July		September	
		in row	betn. row	in row	betn. row
Depth	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.
ft.	lb NO_3-N/A				
0-1	32.8 ± 30.4	73.8 ± 20.4	12.4 ± 7.4	31.2 ± 6.0	16.4 ± 1.8
1-2	30.0 ± 18.0	18.6 ± 6.4	13.6 ± 7.8	29.8 ± 9.8	7.4 ± 2.2
2-3	16.8 ± 7.2	8.0 ± 4.6	8.0 ± 5.4	13.2 ± 3.8	4.0 ± 0.4
Total	79.6 ± 54.0	100.4 ± 28.4	34.0 ± 13.5	74.2 ± 16.6	27.8 ± 3.4
Total in row + between row		134.4 ± 22.2		102.0 ± 3.4	

Table 4b. Ammonium-N levels in sandy soils used for potato production (means of 4 samples per field).

	Sampling Date[z]				
	April	July		September	
		in row	betn. row	in row	betn. row
Depth	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.
ft.	lb NH_4-N/A				
0-1	5.1 ± 2.6	41.4 ± 9.4	1.1 ± 1.1	1.8 ± 0.1	1.0 ± 0.1
1-2	4.4 ± 1.5	4.2 ± 4.4	0.6 ± 0.8	1.2 ± 0.2	0.8 ± 0.1
2-3	4.4 ± 4.1	2.6 ± 1.4	0.9 ± 0.9	0.9 ± 0.1	0.8 ± 0.1
Total	13.9 ± 4.9	48.2 ± 13.6	2.6 ± 2.8	3.9 ± 0.5	2.6 ± 0.1
Total in row + between row		50.8 ± 15.2		6.5 ± 0.4	

[z] April = prior to planting and fertilizer application.
July = during tuber enlargement.
Sept. = after vines were killed but before harvest.

Field E

Initial Soil pH 0-12" - 5.4
N Fertilizer Management: 75 lbs. N/A starter
100 lbs. N/A broadcast late May
Total 175 lbs. N/A
Estimated Yield - 440 cwt/A

Table 5a. Nitrate-N levels in sandy soils used for potato production (means of 4 samples per field).

	Sampling Date[z]				
	April	July		September	
		in row	betn. row	in row	betn. row
Depth	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.
ft.	lb NO_3-N/A				
0-1	4.8 ± 0.8	11.6 ± 7.2	8.2 ± 2.6	22.0 ± 9.8	16.8 ± 2.4
1-2	12.0 ± 13.6	3.2 ± 2.4	0.8 ± 0.4	7.6 ± 0.8	3.6 ± 1.4
2-3	7.2 ± 6.4	1.4 ± 1.4	0.8 ± 0.8	3.2 ± 0.4	4.6 ± 4.0
Total	24.0 ± 18.8	16.2 ± 9.6	9.8 ± 2.2	32.8 ± 9.9	25.0 ± 3.8
Total in row + between row		26.0 ± 9.8		57.8 ± 13.2	

Table 5b. Ammonium-N levels in sandy soils used for potato production (means of 4 samples per field).

	Sampling Date[z]				
	April	July		September	
		in row	betn. row	in row	betn. row
Depth	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.
ft.	lb NH_4-N/A				
0-1	1.5 ± 0.4	42.0 ± 44.0	7.0 ± 3.8	1.8 ± 1.1	1.0 ± 0.2
1-2	3.3 ± 1.2	3.9 ± 2.8	1.6 ± 0.4	1.0 ± 0.1	0.8 ± 0.1
2-3	1.3 ± 1.0	1.7 ± 0.1	2.6 ± 0.8	0.8 ± 0.1	1.0 ± 0.1
Total	6.1 ± 1.1	47.6 ± 45.0	11.2 ± 3.4	3.6 ± 1.1	2.8 ± 0.3
Total in row + between row		58.8 ± 46.2		6.4 ± 1.0	

[z] April = prior to planting and fertilizer application
July = during tuber enlargement
Sept. = after harvest; in row and between row are therefore approximate

Field F

Initial Soil pH 0-12" - 5.8
N Fertilizer Management: 15 lbs. N/A broadcast
50 lbs. N/A starter
200 lbs. N/A hilling
Total 265 lbs. N/A
Estimated yield - 243 cwt/A

Table 6a. Nitrate-N levels in sandy soils used for potato production (means of 4 samples per field).

	Sampling Date[z]				
	April	July		September	
		in row	betn. row	in row	betn. row
Depth	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.
ft.	lb NO_3-N/A				
0-1	36.0 ± 11.6	161.4 ± 67.6	80.4 ± 42.4	18.0 ± 9.8	14.2 ± 2.0
1-2	9.6 ± 4.8	17.4 ± 6.8	10.6 ± 5.6	16.8 ± 12.6	8.8 ± 5.6
2-3	6.0 ± 1.5	6.2 ± 1.6	3.0 ± 0.5	9.6 ± 6.6	7.0 ± 4.4
Total	51.6 ± 15.2	185.0 ± 63.0	94.0 ± 45.0	44.4 ± 27.4	30.0 ± 8.0
Total in row + between row		279.0 ± 49.1		74.0 ± 23.2	

Table 6b. Ammonium-N levels in sandy soils used for potato production (means of 4 samples per field).

	Sampling Date[z]				
	April	July		September	
		in row	betn. row	in row	betn. row
Depth	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.	mean ± s.d.
ft.	lb NH_4-N/A				
0-1	4.4 ± 1.8	39.8 ± 27.0	56.4 ± 82.0	0.8 ± 0.1	3.0 ± 3.9
1-2	1.9 ± 1.7	6.2 ± 4.4	7.4 ± 7.6	1.0 ± 0.2	2.0 ± 2.6
2-3	1.2 ± 1.0	2.5 ± 0.7	2.2 ± 0.1	1.0 ± 0.4	1.0 ± 0.3
Total	7.5 ± 3.0	48.5 ± 24.3	66.0 ± 90.0	2.8 ± 0.8	6.0 ± 6.7
Total in row + between row		114.5 ± 88.2		8.8 ± 6.6	

[z] April = prior to planting and fertilizer application
July = during tuber enlargement
Sept. = after vines were killed but before harvest

Table 7. Summary of soil nitrate-N levels in irrigated potato fields over the growing season. Means and ranges of six commercial potato fields.

Ranges in total N fertilizer applied: 166 - 380 lb N/A
Ranges in total yield: 210 - 456 cwt/A

April 1988

Depth (ft)	Mean	Range
	lb NO_3-N/A	
0 - 1	15.8	2.4 - 36.0
1 - 2	11.2	2.4 - 30.0
2 - 3	9.6	3.2 - 16.8
Total	36.1	11.6 - 79.6

July 1988

	Within Row		Between Row	
Depth (ft)	Mean	Range	Mean	Range
	lb NO_3-N/A			
0 - 1	50.4	8.4 - 161.4	19.9	5.0 - 80.4
1 - 2	16.8	3.2 - 44.4	6.6	0.8 - 13.6
2 - 3	6.1	1.2 - 10.4	4.0	0.8 - 8.0
Total	73.7	12.8 - 186.2	30.4	9.8 - 94.0
Total in row + between row			104.1	23.2 - 279.0

September 1988

	Within Row		Between Row	
Depth (ft)	Mean	Range	Mean	Range
	lb NO_3-N/A			
0 - 1	16.5	5.4 - 31.2	11.3	3.2 - 16.8
1 - 2	14.6	3.0 - 29.8	5.3	3.0 - 8.8
2 - 3	8.5	2.4 - 15.4	4.9	2.4 - 7.0
Total	39.6	10.8 - 74.2	21.4	9.6 - 30.0
Total in row + between row			61.0	20.4 - 102.0

Table 8. Summary of soil ammonium-N levels in irrigated potato fields over the growing season. Means and ranges of six commercial potato fields.

April 1988

Depth (ft)	Mean	Range
	lb NH_4-N/A	
0 - 1	4.9	1.5 - 10.6
1 - 2	5.2	1.9 - 10.9
2 - 3	3.8	1.2 - 7.9
Total	13.9	6.1 - 29.4

July 1988

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
		lb NH_4-N/A		
0 - 1	23.0	5.5 - 42.0	13.2	1.1 - 56.4
1 - 2	4.5	2.2 - 6.2	2.5	0.6 - 7.4
2 - 3	2.3	1.7 - 3.2	1.7	0.9 - 2.6
Total	29.8	9.6 - 48.5	17.4	2.6 - 66.0
Total in row + between row			47.2	15.9 - 114.0

September 1988

Depth (ft)	Within Row Mean	Within Row Range	Between Row Mean	Between Row Range
		lb NH_4-N/A		
0 - 1	3.7	0.8 - 14.8	1.5	1.0 - 3.0
1 - 2	1.3	1.0 - 1.8	1.2	0.8 - 2.0
2 - 3	1.3	0.8 - 2.1	0.9	0.8 - 1.2
Total	6.3	2.6 - 6.7	3.6	2.8 - 18.7
Total in row + between row			9.9	6.4 - 22.5

EFFECT OF RATE AND PLACEMENT OF POTASSIUM ON EARLY GROWTH AND YIELD OF CORN.

George Rehm, Greg Cremers, and Andy Scobbie[1/]

ABSTRACT: Recent concerns for farm profitability have stimulated interest in placement of potash fertilizer for corn production. This study was initiated to evaluate broadcast and starter application of potash on the yield of 2 corn hybrids grown on a soil having a low to medium soil test for K. Early growth, K uptake, and grain yield were hindered by the 1988 drought. There was no significant response to applied K. When averaged over all rates of applied K and both placements, yield from Pioneer 3737 was significantly higher than the yield from the Pioneer 3732 variety.

Background and Justification:

The recent crisis in farm profitability and current attention to lower inputs in agriculture has stimulated a considerable amount of interest in fertilizer placement. There is considerable research to show that lower rates of fertilizer P are needed if phosphate is applied in a band close to the seed rather than broadcast and incorporated before planting. This practice reduces fertilizer cost thereby improving profitability. Since K, like P, is relatively immobile in soils, we can anticipate that the same principle will apply with this nutrient. Studies which focus on the effect of placement of fertilizer K on crop growth are very limited.

Soils in southeast Minnesota typically have low to medium levels of soil test K. These soils also usually have the ability to fix or "tie up" some of the fertilizer K needed for crop production in the region. In addition, substantial amounts of K are removed from the soil system when corn silage (a common use of corn) is harvested as part of the dominant dairy enterprise in the region.

From farmer experience, there is also some indication that corn hybrids may differ in their response to the use of fertilizer K. There has been no research information to support these observations.

The effect of placement of fertilizer K on corn production had not been studied extensively in Minnesota. Therefore, the study described in this report was designed to measure the effect of rate and placement of fertilizer K on early growth and yield of two corn hybrids in southeast Minnesota.

Experimental Procedures:

This study was conducted in Olmsted County in 1988. Soil samples were collected prior to fertilizer application.

Table 1. Relevant soil properties for the experimental site.

pH - - - - - - - - - - - - - - - - - - -	5.8
P (Bray & Kurtz #1), lb./acre - - - - -	34
K (1 N $NH_4C_2H_3O_2$), lb./acre - - - - - -	123
organic matter, % - - - - - - - - - - -	2.6

Four rates of K (0, 40, 80, 160, 320) supplied as 0-0-60 were broadcast in mid-April. Urea was also applied at this time to supply 189 lb. N/acre. These fertilizers were incorporated with the disk soon after application.

Corn was planted on May 16. The 0-0-60 was used to supply 0, 20, 40, 80, and 160 lb. K/acre in a starter fertilizer at planting. In addition to the various rates of K, the starter supplied 23 lb. N and 23 lb. P_2O_5 per acre. All broadcast and starter treatments were applied to two hybrids (Pioneer 3732, Pioneer

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3737). The planted population was 27,000 plants per acre. The recommended rate of the Lasso-Bladex combination was applied preemergence for weed control.

Whole plant samples were collected at 4 to 5 weeks after emergence. These samples were dried, weighed, ground, and analyzed for K. Potassium uptake was calculated from the plant weight and K concentration values. Grain yields were measured in mid-October.

Results and Discussion:

Grain Yield

The 1988 grain yields were depressed by the dry weather. Consequently, rate and placement of fertilizer K had no significant effect on yield. Yields resulting from broadcast applications are summarized in Table 2 while yields resulting from the starter placement are listed in Table 3.

Table 2. The effect of broadcast applications of K on the yield of two corn varieties. Olmsted County, 1988.

K Rate	Variety: Pioneer 3732	Variety: Pioneer 3737
lb./acre	bu./acre	bu./acre
0	102.0	107.5
40	100.6	115.6
80	97.9	117.9
160	91.8	104.1
320	87.1	104.3
Ave:	95.9	109.9

Table 3. Effect of rate of K applied in a starter fertilizer on the yield of two corn varieties. Olmsted County, 1988.

K Rate	Variety: Pioneer 3732	Variety: Pioneer 3737
lb./acre	bu./acre	bu./acre
0	97.0	101.8
20	100.8	128.8
40	97.6	110.0
80	93.3	102.5
160	96.8	112.4
Ave:	97.1	110.1

The lack of a response to fertilizer K indicates that this soil was capable of supplying the K needed to support a corn crop of approximately 100 bu./acre. If drought had not limited yields, a response to fertilizer K could have been expected.

Grain yield was significantly affected by the variety used. With both broadcast and starter placement of K, the yield from the Pioneer 3737 variety was significantly higher than the yield from the Pioneer 3732 variety. The yield difference was approximately 13 bu./acre for both placement situations.

Early Growth

Six whole plants were taken from each plot at 4 to 5 weeks after emergence to get a measure of the effect of treatment used on early growth. When K was broadcast, early growth was not affected by the rate of K applied (Table 4). The rate of K applied in the starter, however, produced significant differences in the weight of young corn plants (Table 5). This trend was toward a linear decrease over the range of K rates used. There is no ready explanation for the reduction in early growth with increasing rate of applied K.

Table 4. The influence of rate of broadcast K on the early growth of two corn varieties. Olmsted County, 1988.

K Rate		Variety Pioneer 3732	Pioneer 3737
lb./acre		- - - - weight of 6 plants, gm.	- - - -
0		42.3	41.5
40		45.8	38.3
80		44.3	32.3
160		35.8	35.5
320		45.5	42.8
	Ave:	42.7	38.1

Table 5. The effect of rate of K applied in a starter on the early growth of two corn varieties. Olmsted County, 1988.

K Rate		Variety Pioneer 3732	Pioneer 3737
lb./acre		- - - - weight of 6 plants, gm	- - - -
0		42.5	32.0
20		60.0	46.8
40		41.8	38.5
80		37.5	31.3
160		28.0	31.8
	Ave:	42.0	36.1

The variety used had no significant effect on early growth. This was consistent for both methods of K placement.

K Concentration

The effect of placement and variety on the concentration of K in young corn plants is summarized in Tables 6 and 7.

Table 6. The effect of rate of broadcast K on the K concentration in young corn plants. Olmsted County, 1988.

K Rate	Variety Pioneer 3732	Pioneer 3737
lb./acre	- - - - - - - - - % - - - - - - - - - -	
0	1.92	2.03
40	2.14	2.82
80	2.13	2.61
160	2.28	2.61
320	2.85	2.53
Ave:	2.26	2.72

Table 7. The influence of rate of K applied in a starter fertilizer on the K concentration in young corn plants. Olmsted County, 1988.

K Rate	Variety Pioneer 3732	Pioneer 3737
lb./acre	- - - - - - - - - % - - - - - - - - - -	
0	2.05	1.89
20	3.12	3.59
40	3.09	3.39
80	4.09	3.98
160	4.34	4.34
Ave:	3.34	3.44

As would be expected, the K concentration in the young corn plants increased as rate of applied K increased. The increase was linear for both broadcast and starter placement. Except for the control treatment, K concentration was higher when fertilizer K was applied near the seed at planting (starter placement). The use of 20 lb. K/acre in a starter produced a higher concentration than the broadcast application of 320 lb. K/acre. These data indicate that the K applied in a band near the seed at planting is used very effectively by the young corn plants. The root systems of the young plants were not able to effectively absorb the K that was broadcast and incorporated before planting.

K Uptake

Potassium uptake by the young plants was determined by multiplying dry weight by concentration values. Uptake values from broadcast and starter applications are summarized in Table 8 and 9 respectively.

Table 8. The effect of rate of K broadcast and incorporated before planting on the amount of K taken up by young corn plants. Olmsted County, 1988.

K Rate	Variety Pioneer 3732	Pioneer 3737
lb./acre	- - - - - - gm in 6 plants - - - - - - -	
0	.81	.84
40	1.05	1.06
80	.97	.85
160	.93	.90
320	1.31	1.51
Ave:	.99	1.03

Table 9. The influence of rate of K applied in a starter fertilizer on the amount of K taken up by young corn plants. Olmsted County, 1988.

K Rate	Variety Pioneer 3732	Pioneer 3737
lb./acre	- - - - - - gm in 6 plants - - - - - - -	
0	.86	.61
20	1.87	1.75
40	1.27	1.27
80	1.53	1.25
160	1.21	1.38
Ave:	1.35	1.25

The variety had no effect on K uptake. This was true for both placements.

Potassium uptake did increase with rate of K applied. This increase was linear for both the broadcast and the starter placement. Consistent with concentration values, K uptake was greater when the fertilizer K was applied in a starter. Potassium uptake during the latter part of the growing season was probably curtailed by the dry weather. Therefore, uptake values for early in the season were not related to yield.

Summary

There is very little to summarize from this study because yields were severely reduced by the very dry weather. Rate and placement of fertilizer K had no significant effect on grain yield of two varieties. The data collected from the analysis of young corn plants indicate that fertilizer K applied in bands close to the seed (starter fertilizer) is more readily absorbed than fertilizer K broadcast and incorporated before planting. This difference in uptake between the starter and broadcast applications was probably magnified by the dry year.

EVALUATION OF THE EFFICIENCY OF BAND PLACEMENT OF P FERTILIZER FOR CORN, SOYBEAN, AND WHEAT[1]

J.A. Lamb, G.W. Rehm, G.W. Randall, and W.W. Nelson[2]

ABSTRACT: The third year of a four-year study was completed looking at the effects of broadcast, knife, and starter placement of phosphorus on corn, soybean, and spring wheat in Minnesota. Preliminary conclusions are that broadcast application for soybean performed as well or better than the knife and starter placements. The starter placement for soybean did not perform well. In dry conditions, the knife placement may be superior because of the better soil moisture conditions at that placement point. Phosphorus application method in corn is not as crucial as originally thought. No one application method consistently performed superior under normal soil moisture conditions.

OBJECTIVE: Efficient P fertilizer use is continuing to be an important area of production management in finding the least cost method of production. Little information is available in the Northern Corn Belt about which methods application is best. Winter wheat growing areas (Kansas, Nebraska and Colorado), have found that a starter or row application of P can be many times more efficient than a broadcast application. This report is concerned with the results of the third year of a study conducted in Minnesota with the overall objective to evaluate the efficiency of band placement methods (starter, and knife) over the northern corn belt. Under this broad objective the two following specific objectives will be addressed.

1) Determine the efficiency of band applications of P as compared to broadcast on a spring wheat - soybean rotation in northwestern Minnesota and corn-soybean rotation at two locations in southern Minnesota.

2) Determine residual effects of band and broadcast placements of fertilizer P on P uptake and crop yield.

MATERIALS AND METHODS: The third of three years of this study was conducted in 1988 at Waseca, Lamberton, and Crookston, MN. Corn and soybeans were grown at Waseca and Lamberton and spring wheat and soybean grown at Crookston. Table 1 presents the soil test information for each location. The following variables were measured on corn at Waseca and Lamberton; grain yield, forage yield, forage P concentration and uptake, ear leaf P concentration at silking, and grain moisture content. Soybean variables measured at all locations were; grain yield, forage yield, forage P concentration and uptake, leaf P concentration at mid-flower, and grain moisture. At Crookston the parameters measured on the wheat were grain yield, grain protein content, bushel weight, grain moisture content, forage yield, and whole plant P concentration and uptake at anthesis. The grain moisture has been incorporated into the grain yield data. The corn, soybean, and wheat grain yields have been corrected to 15.5, 13.5, and 13.5% moistures, respectively. The wheat protein values are reported on a dry weight basis.

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Table 1. Soil test values for P-efficiency study, 1987.

	Crookston*		Waseca**		Lamberton**	
	Soybean	Wheat	Soybean	Corn	Soybean	Corn
pH	8.0	8.0	5.9	5.9	6.1	6.2
OM%	2.9	2.9	3.5	3.5	3.9	3.8
Salts mmho	0.3	0.3	-	-	-	-
NO_3^--N 0-24"	54	59	-	-	-	-
P lb A^{-1}	9	10	10	10	7	3
K lb A^{-1}	370	320	320	331	290	259

* $NaHCO_3$-P
** Bray-P

Table 2 lists the treatments that were established on all six sites. Four replications of a complete factorial arrangement of three methods of phosphorus placement and five phosphorus rates were established. The broadcast method was incorporated at all locations. The knife method at Waseca (corn

Table 2. Treatment description for project MN-1L.

Treatment Number	Factor: Placement	Factor: P Rate lb P/A
1	Broadcast	0**
2	Broadcast	10
3	Broadcast	20
4	Broadcast	30
5	Broadcast	40
6	Knife *	0
7	Knife *	10
8	Knife *	20
9	Knife *	30
10	Knife *	40
11	Starter +	0
12	Starter +	10
13	Starter +	20
14	Starter +	30
15	Starter +	40
16	Broadcast + Knife	20 + 20***
17	Broadcast + Starter	20 + 20***
18	Knife + Starter	20 + 20***

* 15-inch width at wheat-soybean location.
\+ 5-7 inches from row in soybean and corn - applied with seed in spring wheat.
** P rates are 0, 5, 10, 15, and 20 pounds P per acre at Crookston in 1987 and 1988.
*** At Crookston the P rate was 5 + 5.

and soybean) and Lamberton (corn and soybean), placed a preplant band of fertilizer at a 6-inch depth between the 30 inch width rows. At the Crookston (spring wheat) site the knife method placed preplant fertilizer 6 inches deep with a shank spacing of 15 inches. The knife method for Crookston soybean was two 15-inch width preplant bands between the 30-inch rows applied at a 6-inch depth. The starter method at Waseca (corn and soybean), Lamberton (corn and soybean), and Crookston (soybean) involved a band of fertilizer applied at planting 5 to 7 inches from the row and 2.5 to 3 inches deep. The Crookston (spring wheat) site starter treatment involved placement of fertilizer directly with the seed. At Waseca and Lamberton the phosphorus rates were 0, 10, 20, 30 and 40 lb P A^{-1}. At Crookston, the rates were 0, 5, 10, 15 and 20 lb P A^{-1}. Ammonium polyphosphate, 10-34-0, was the P source at all locations. Three extra treatments were added to the factorial to test effect of combined application methods. These were 20 + 20 lb P/A (5 + 5 lb P A^{-1} at Crookston) broadcast + knife, broadcast + row, and row + knife (Table 2). They were analyzed statistically as a method comparison with the broadcast, knife, and row treatment at the 40 lb P A^{-1} levels (10 lb P A^{-1} at Crookston).

RESULTS AND DISCUSSION:

Crookston - Spring Wheat - 1988: In 1988, grain yield and whole plant uptake were increased by the addition of phosphorus. The grain yield was maximized at the 5 pound P per acre (Table 3). The increase was five bushels per acre. No method effect occurred. The plant P uptake was affected similarily with a 1.8 pound per acre increase with 5 pounds P per acre rate maximizing uptake.

Crookston - Soybean - 1988: Grain yield was increased 6 bushels per acre by P fertilization (P=0.10, Table 3). The maximum yield occurred at 15 pounds P per acre. Again, method of application did not effect grain yield.

Lamberton - Corn - 1988: In 1988, the corn grain yield, young plant P concentration and young plant P uptake at Lamberton were significantly increased by P fertilization and method of application (Table 4). Both grain yield and young plant P uptake were increased linearly from 0 to 40 pounds P/acre treatment. The knife treatment increased grain yield and young plant P uptake greater than the broadcast applications. The starter application grain yield and young plant P uptake was intermediate. There was a significant method by P rate interaction for young plant P concentration. Phosphorus applied as starter or knife significantly increased the young plant P concentration. Broadcast applications of P did not effect the P concentrations. The knife application caused greater P concentrations than starter.

Lamberton - Soybean - 1988: Grain yield, forage yield, trifoliate leaf P concentration, whole plant P concentration, and P uptake were significantly increased by P application (Table 4). Knife P application caused the greatest grain yield. Broadcast P application increased the grain yield the least. The starter treatment was intermediate. Forage yield, whole plant P concentration, and P uptake were increased the most by knife application of P. Broadcast and starter application methods performed significantly poorer than knife P applications. Trifoliate leaf P concentrations were effected by a P rate by method of application interaction. Trifoliate leaf P concentrations were not effected by broadcast P application. The knife and starter methods increased the P concentration of the trifoliate leaf with increased application of P fertilizer. Knife P application increased leaf P greater than the starter method.

Waseca - Corn - 1988: Grain yield, young plant P concentration, young plant P uptake, and ear leaf P concentration were significantly increased with P applications (Table 5). These increases were linear increasing with increased rates of P.

Waseca - Soybean - 1988: Phosphorus application increased grain yield, forage yield, trifoliate leaf P concentration, whole plant P concentration, and P uptake of soybeans at Waseca (Table 5). Whole plant P concentration and P uptake responses were not effected by application methods. Grain yield, forage yield, and trifoliate leaf P concentration were greater when P was knife applied. The starter application caused the smallest increases with broadcast application only doing slightly better.

Table 3. Means and statistical analyses for Crookston spring wheat, 1988.

Method	P Rate lb/A	Spring Wheat: Yield Bu/A	Spring Wheat: Forage lb/A	Spring Wheat: Plant P ppm	Spring Wheat: P Uptake lb/A	Spring Wheat: Plant Population Plant/A	Spring Wheat: Bushel wt. lb/Bu	Soybean: Yield Bu/A	Soybean: Forage lb/A	Soybean: Trifoliate P ppm	Soybean: Plant P ppm	Soybean: P Uptake lb/A
Broadcast	0	45.1	3521	2873	9.9	798019	60.1	26.2	2169	3860	4018	8.8
	5	53.1	3525	2848	9.9	818928	60.2	26.0	2559	4157	3876	9.8
	10	52.3	3448	2864	10.0	893851	60.5	23.9	2294	3840	3541	8.3
	15	52.9	4144	2824	11.8	931313	60.4	30.3	2465	4256	3878	9.6
	20	49.6	3584	3054	10.9	889495	60.7	24.5	2300	4079	3649	8.3
Knife	0	49.0	3501	2449	8.5	824155	60.4	18.7	2085	3925	2980	6.3
	5	50.2	3760	3135	11.8	811958	60.5	28.0	2245	4245	3352	7.7
	10	50.8	3668	3155	11.6	865102	59.7	22.1	2110	3677	3372	7.2
	15	54.0	3516	3260	11.5	865973	60.1	25.9	2367	3979	3274	7.8
	20	49.6	3638	2881	10.4	811958	60.7	23.4	2582	4104	3899	10.0
Starter	0	48.3	3362	3017	10.2	883397	59.8	19.0	2093	3787	3665	7.7
	5	55.1	3868	3079	11.8	838966	60.6	24.2	2394	4070	3834	9.6
	10	54.1	3782	2892	11.0	865973	60.1	25.6	2447	4100	4089	10.0
	15	52.1	3868	2749	10.8	897336	60.3	25.7	2428	4323	4073	9.6
	20	60.0	4162	2903	12.2	797148	60.6	25.2	2297	4035	4452	10.2
P Rate	0	47.5	3461	2779	9.5	835190	60.1	21.3	2116	3358	3554	7.6
	5	52.8	3718	3021	11.2	823284	60.4	26.0	2399	4157	3687	9.0
	10	52.4	3632	2970	10.9	874975	60.1	23.9	2284	3872	3667	8.5
	15	53.0	3843	2944	11.3	898207	60.2	27.3	2420	4186	3742	9.0
	20	53.1	3794	2946	11.2	832867	60.7	24.3	2393	4072	4000	9.5
Method												
Broadcast		52.0	3675	2897	10.6	883397	60.4	26.2	2405	4083	3736	9.0
Knife		51.1	3645	3108	11.3	838748	60.2	24.8	2326	4001	3474	8.2
Starter		55.3	3920	2906	11.5	849856	60.4	25.2	2391	4132	4112	9.8
Method		+	NS	+	NS	NS	NS	NS	NS	NS	++	NS
P Rate		+	NS	NS	NS	++	NS	++	NS	++	NS	NS
Linear		++	+	NS	++	NS	+	+	+	+	NS	++
Quadratic		+	NS	NS	NS	++	NS	++	NS	NS	NS	NS
Method x P Rate		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.		12.3	14.7	11.2	20.4	8.6	1.2	21.4	18.7	8.3	22.5	28.3

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

Table 4. Means and statistical analyses for Lamberton corn and soybean, 1988.

		Corn			Soybean				
			Young Plant	Young Plant P			Trifoliate	Plant	P
Method	P Rate	Yield	P	Uptake	Yield	Forage	P	P	Uptake
	lb P/A	Bu/A	ppm	mg/plant	Bu/A	lb/A	ppm	ppm	lb/A
Broadcast	0	53.7	3053	30.0	20.5	2879	3185	1594	4.6
	10	55.8	3183	31.6	19.3	2700	3031	1584	4.3
	20	55.1	3148	31.4	21.0	3119	3236	1887	5.9
	30	58.2	3630	36.5	20.6	2791	3295	1774	5.0
	40	58.2	3186	37.7	22.1	3062	3184	1751	5.4
Knife	0	50.9	2993	26.9	19.0	2805	3210	1471	4.1
	10	58.6	3354	36.9	22.4	3396	3629	1820	6.1
	20	63.7	3642	45.4	23.0	3600	3847	1848	6.6
	30	65.2	3756	44.3	23.5	3419	3976	1879	6.4
	40	72.6	4125	48.0	25.0	3648	4145	2095	7.6
Row	0	61.0	3097	29.7	18.4	2807	2860	1552	4.4
	10	62.3	3109	31.6	20.8	2869	3401	1758	5.1
	20	53.7	3227	33.1	21.9	3202	3535	1771	5.7
	30	59.4	3482	34.7	21.2	2966	3159	1691	5.0
	40	60.9	3538	36.3	22.9	3075	3176	1867	5.7
P Rate	0	55.2	3047	28.9	19.3	2830	3085	1539	4.4
	10	58.9	3215	33.0	20.8	2988	3354	1721	5.1
	20	57.5	3339	36.5	22.0	3307	3539	1835	6.1
	30	60.9	3623	38.6	21.7	3058	3477	1781	5.5
	40	63.9	3616	40.6	23.4	3261	3501	1904	6.2
Method									
Broadcast		56.8	3287	34.3	20.7	2918	3186	1749	5.1
Knife		65.0	3719	43.7	23.5	3515	3899	1911	6.7
Starter		59.1	3339	33.7	21.7	3028	3318	1772	5.4
Method		++	**	**	**	**	**	*	**
P Rate		+	**	**	**	**	**	**	**
Linear		*	**	**	**	**	**	**	**
Quadratic		NS	NS	NS	NS	NS	*	+	++
Method x P Rate		NS	*	NS	NS	NS	*	NS	NS
C.V.		15.2	7.4	22.6	4.6	11.2	7.8	10.5	14.3

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

Table 5. Means and statistical analyses for Waseca corn and soybean, 1988.

		Corn				Soybean				
Method	P Rate lb P/A	Yield Bu/A	Young Plant P ppm	Young Plant P Uptake mg/plant	Ear P ppm	Yield Bu/A	Forage lb/A	Trifol-iate P ppm	Plant P ppm	P Uptake lb/A
Broadcast	0	62.8	2873	14.6	1321	20.6	3082	2707	1434	4.5
	10	78.2	3162	19.4	1483	23.8	3111	2988	1584	4.9
	20	86.9	3207	23.0	1827	26.0	3310	3124	1766	5.9
	30	101.9	3138	18.1	1863	24.7	3242	3453	2199	7.1
	40	96.0	3542	27.2	2241	24.5	3548	3501	2189	7.7
Knife	0					20.9	3181	2851	1592	5.0
	10					26.3	3327	3404	1699	5.6
	20					26.3	3755	3753	1731	6.5
	30					27.3	3883	3981	1999	7.8
	40					28.9	3625	3988	1839	6.5
Row	0					19.5	2946	2790	1358	4.0
	10					16.8	3007	3056	1659	5.0
	20					23.8	3455	3203	1925	6.6
	30					24.7	3434	3139	1773	6.3
	40					28.5	3005	3479	2204	6.6
P Rate	0					20.3	3069	2782	1461	4.5
	10					22.3	3148	3149	1647	5.2
	20					25.4	3506	3360	1807	6.3
	30					25.6	3520	3524	1990	7.1
	40					27.3	3393	3656	2077	7.0
Broadcast						24.7	3303	3266	1934	6.4
Knife						27.2	3647	3782	1817	6.6
Starter						23.4	3225	3219	1890	6.1
Method						*	*	**	NS	NS
P Rate		+	+	++	*	**	*	**	**	**
Linear		*	*	*	**	**	*	**	**	**
Quadratic		NS	NS	NS	NS	NS	++	*	NS	++
Method x P Rate						+	NS	NS	NS	NS
C.V.		18.8	6.2	17.6	11.9	16.5	12.6	6.2	15.7	18.2

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

Split Application Study - 1988: At Crookston, there was no response to the split application treatments in spring wheat or soybean (Table 6). At Lamberton, the knife treatment was superior to broadcast or starter and the split treatments performed well for corn yield, young plant P concentration, and young plant P uptake (Table 7). The knife alone was superior to the split applications for all measured Lamberton soybean parameters. At Waseca, the corn grain yield was not effected by P application method (Table 8). The knife alone and knife + broadcast treatments had the greatest amount of P in the plant as measured by young plant P concentration, young plant P uptake, and ear leaf P. Soybean grain yield was the greatest with the knife, starter, broadcast + knife, and broadcast + starter treatments. The unusual result was the lack of response with the knife + starter treatment. Knife and broadcast + knife treatments provided the great-est forage yields. No consistent increase from application method occurred for trifoliate leaf P concentration, plant P concentration, and plant P uptake. In summary, the split applications did not increase the effectiveness of P fertilization over a single application.

Summary - 1988: In 1988, Minnesota experienced a drought. This has influenced the effect of P application methods on the various measured parameters at Lamberton and Waseca. The knife application consistantly performed better than the other application methods. This probably occurred because the fertilizer was placed in the soil where there was moisture. The plant roots could be able to utilize that P fertilizer over broadcast and starter placed P because these other methods placed the P in dry soil where the roots could not grow to intersect the fertilizer. At Crookston, application method has not been a factor in P responses.

Overall summary for grain yield in P placement study 1986-1988:

Crookston: A grain yield response to P fertilizer occurred in all three years of the study for spring wheat and only in 1988 for soybeans (Fig. 1). The method of application did not effect yield for either crop at this location. This result was surprising for spring wheat. It was thought that knife or seed placement would have been superior. Results for this and other P studies indicate that some other factor is involved with the P nutrition of plants grown in this area. Possible processes include organic P mineralization and a failure of the sodium bicarbonate soil test to accurately predict plant available P.

Waseca: In 1986, 1987, and 1988 soybean grain yields were increased by P fertilization (Fig. 2). The method of application was only significant in 1988. The knife and broadcast placements performed better than starter placement at the lower P rates. At the 40 lb P/A rate, the starter treatment was similar to knife and the broadcast performed the worst. The knife treatment performed the best because the roots were better able to utilize the fertilizer P because of better soil moisture at this placement position than the others in 1988.

Corn yield consistently responded to P fertilizer throughout the whole study (Fig. 2). Grain yield was maximized in all years at 30 lb P/A. No application method effects occurred.

Lamberton: Corn grain yields responded to the P application in all three study years (Fig. 3). In 1986 there was no application effect. The broadcast application of phosphorus was superior to starter and knife in 1987. At the 10 and 20 lb P/A rate, starter and knife application performed similarly. At 40 lb P/A the knife treatment grain yields were greater than grain yield from starter application. In 1988, the knife treatment grain yields were superior to the broadcast and starter application yields. At P rate of 20 lb P/A and greater, the grain yields for broadcast and starter applications were similar. Again the dry conditions of 1988 caused the knife placement to be the best, mainly because of better soil moisture conditions at the point.

Table 6. Means and statistical analyses for Crookston wheat and soybean, 1988.

		Spring Wheat						Soybean				
Method	P Rate lb/A	Yield Bu/A	Forage lb/A	Plant P ppm	P Uptake lb/A	Plant Population Plant/A	Bushel wt. lb/Bu	Yield Bu/A	Forage lb/A	Trifoliate P ppm	Plant P ppm	P Uptake lb/A
B + K	5+5	42.2	3257	3031	10.0	876427	59.8	24.9	2628	4177	4336	11.1
B + S	5+5	56.0	3722	2986	11.3	897336	60.3	22.7	2248	4101	4097	9.2
K + S	5+5	56.7	3907	2781	10.7	862488	60.1	27.1	2656	4231	3574	9.7
B	10	52.3	3448	2864	10.0	893851	60.5	23.9	2294	3840	3541	8.3
K	10	50.8	3668	3155	11.6	865101	59.7	22.1	2110	3677	3372	7.2
S	10	54.1	3782	2892	11.0	865973	60.1	25.6	2447	4100	4089	10.0
Check	0	47.5	3461	2779	9.5	835190	60.1	21.3	2116	3858	3554	7.6
Trt		*	NS	NS	NS	NS	NS	NS	+	++	NS	NS
LSD 0.05		9.4	781	610	3.5	54109	0.4	7.3	572	434	1258	3.7
C.V.		12.8	15.0	14.5	23.1	7.8	1.3	21.5	17.1	7.5	23.1	29.2

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

Table 7. Means and statistical analyses for Lamberton corn and soybean, 1988.

		Corn			Soybean				
Method	P Rate lb P/A	Yield Bu/A	Young Plant P ppm	Young Plant P Uptake mg/plant	Yield Bu/A	Forage lb/A	Trifoliate P ppm	Plant P ppm	P Uptake lb/A
B + K	20+20	69.0	3899	52.1	23.1	3306	3674	1880	6.2
B + S	20+20	60.3	3312	37.7	22.4	2936	3541	1882	5.5
K + S	20+20	67.5	3706	52.4	23.7	3383	3693	2044	6.9
B	40	58.2	3186	37.7	22.1	3062	3184	1751	5.4
K	40	72.6	4125	48.0	25.0	3648	4145	2095	7.6
S	40	60.9	3538	36.3	22.9	3075	3176	1867	5.7
Check	0	55.2	3047	28.9	19.3	2830	3085	1539	4.4
Trt		*	**	**	**	**	**	**	**
LSD 0.05		14.0	331	3.7	1.9	482	401	309	1.4
C.V.		15.6	6.6	23.6	5.9	10.7	8.1	11.9	16.6

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

Table 8. Means and statistical analyses for Waseca corn and soybean, 1988.

Method	P Rate lb P/A	Corn Yield Bu/A	Corn Young Plant P ppm	Corn Young Plant P Uptake mg/plant	Corn Ear Leaf P ppm	Soybean Yield Bu/A	Soybean Forage lb/A	Soybean Trifoliate P ppm	Soybean Plant P ppm	Soybean P Uptake lb/A
B + K	20+20	102.8	3963	32.9	2465	27.1	3812	4008	2061	7.8
B + S	20+20	93.9	3630	28.1	2192	29.5	3561	3494	2077	7.4
K + S	20+20	99.5	3723	23.1	2350	21.8	3164	3917	2311	7.3
B	40	96.0	3542	27.2	2241	24.5	3548	3501	2189	7.7
K	40	95.0	4187	30.3	2538	28.9	3625	3988	1839	6.5
S	40	100.9	3505	27.4	2195	28.5	3005	3479	2204	6.6
Check	0	64.6	2813	14.0	1305	20.3	3069	2782	1461	4.5
Trt		**	**	**	**	**	*	**	**	**
LSD 0.05		18.5	305	5.9	210	4.2	621	289	350	1.5
C.V.		13.5	5.7	15.8	6.6	11.8	12.9	5.8	12.7	16.3

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

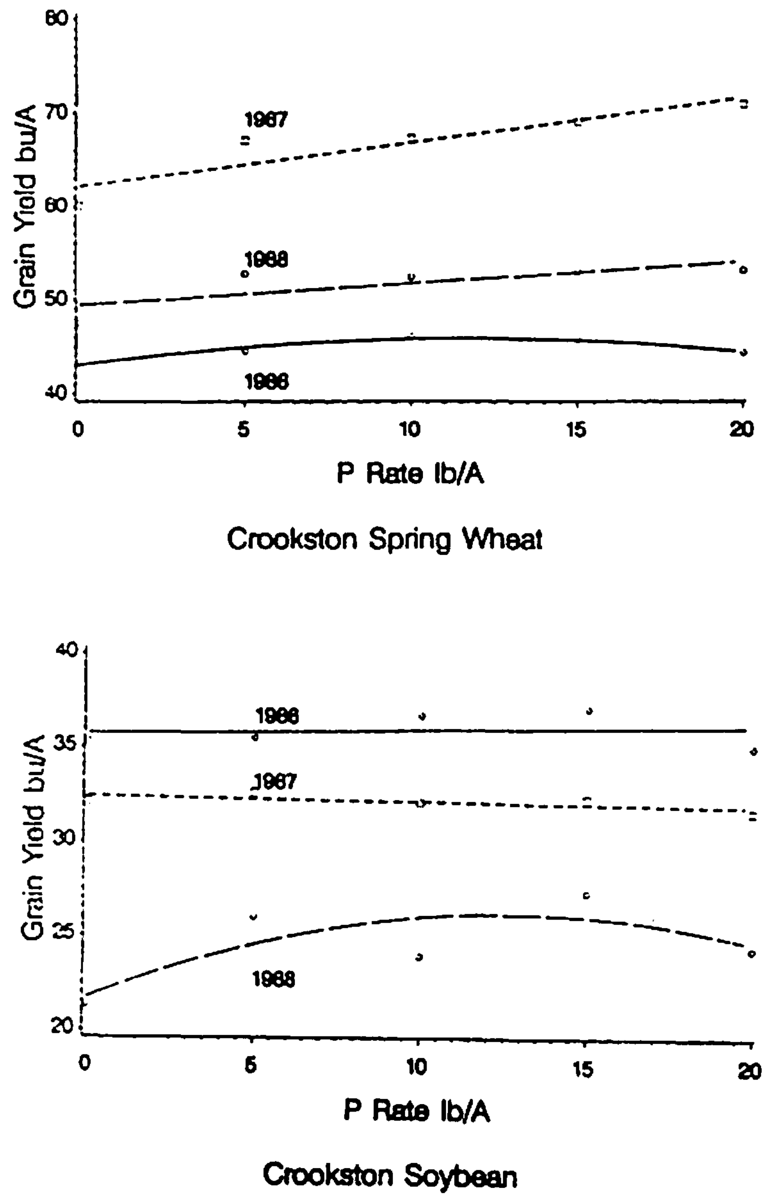


Figure 1. Phosphorus rate response curves for spring wheat and soybean grain yields for 1986 through 1988 at Crookston, MN.

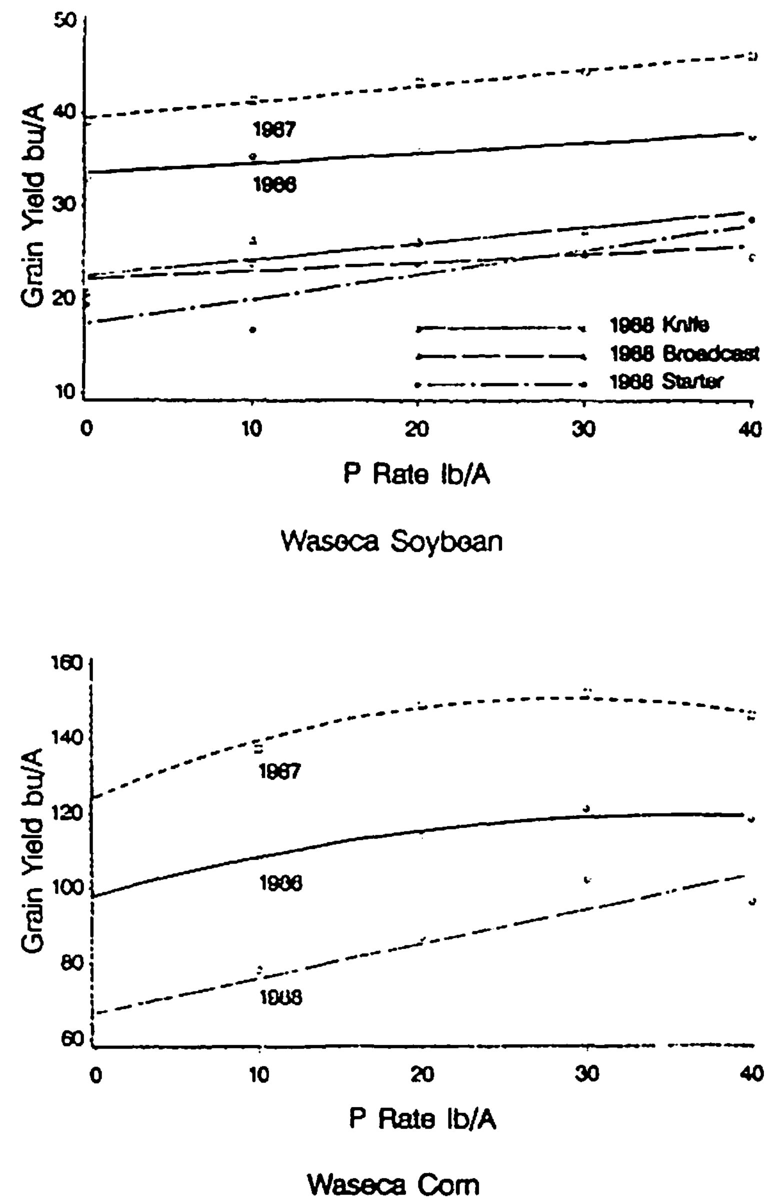
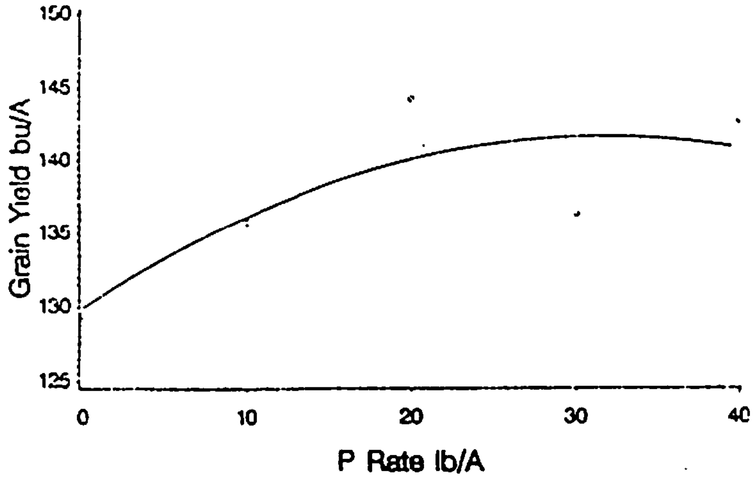


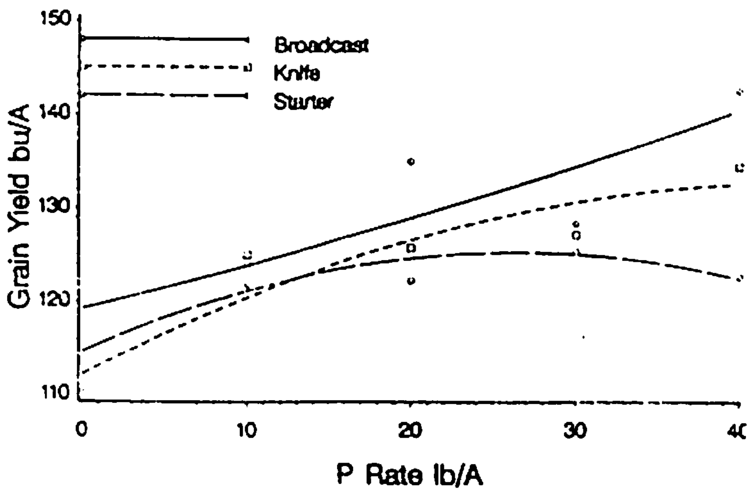
Figure 2. Soybean and corn grain yield responses for P fertilization at Waseca, MN, 1986 to 1988.

Soybean grain yields responded to P application and the method to which the fertilizer was applied (Fig. 4). In 1986 and 1987, the broadcast application method performed the best. In 1986 starter and knife caused similar grain yield responses while 1987 the knife application treatment had grain yields similar to broadcast at the 10 and 20 lb P/A rates. At the greater P rates, the knife behaved similar to the starter treatment. In 1988 the knife application was superior to both broadcast and starter applications of P fertilizer. Starter and broadcast had grain yields similar to each other. Again, the dry conditions caused the knife treatment to perform better.

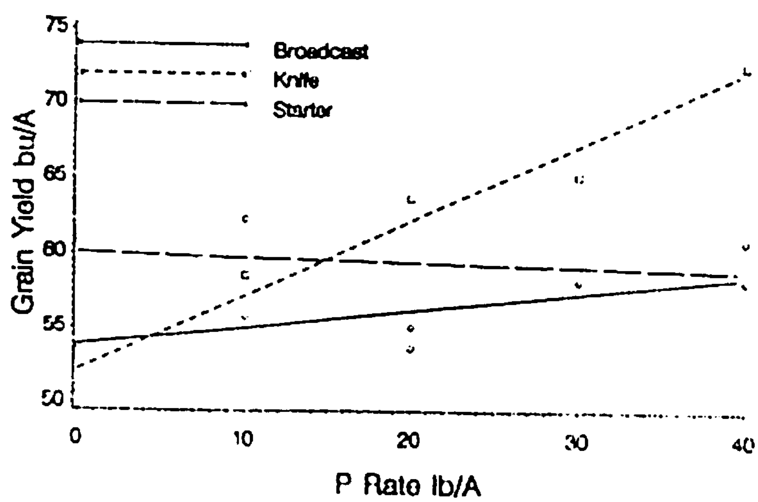
The following general conclusions can be drawn from this study. With soybeans, the broadcast application performs as well or better than any other application method of P. In an abnormally dry season, knife placement may be superior in soybeans and corn. This is because of the better soil moisture conditions that occur in the soil at that placement point. The starter treatment consistently performed poorer than the other application methods for soybean production. Phosphorus application method in corn is not as crucial as originally thought. No one application method consistently performed superior.



Lamberton Corn 1986

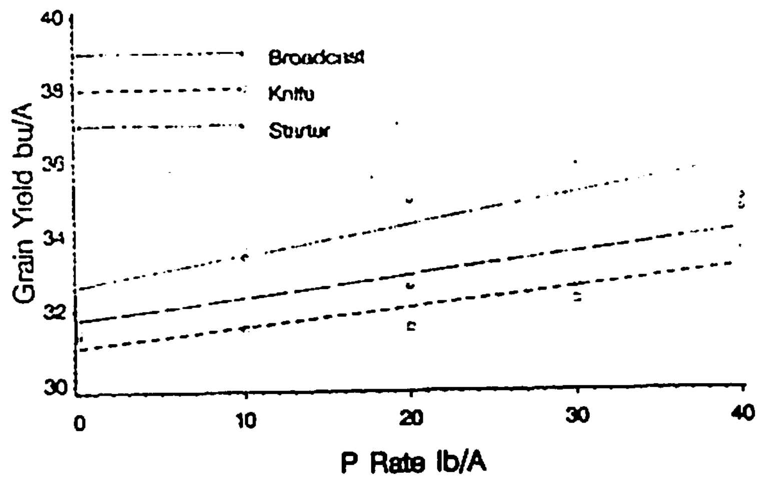


Lamberton Corn 1987

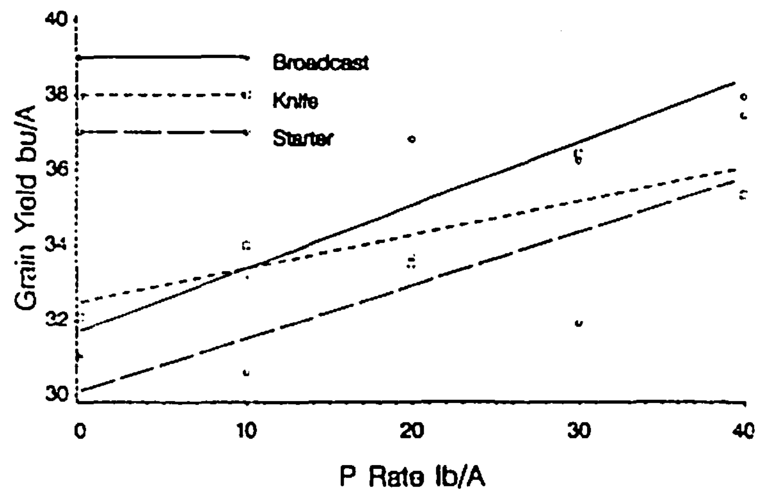


Lamberton Corn 1988

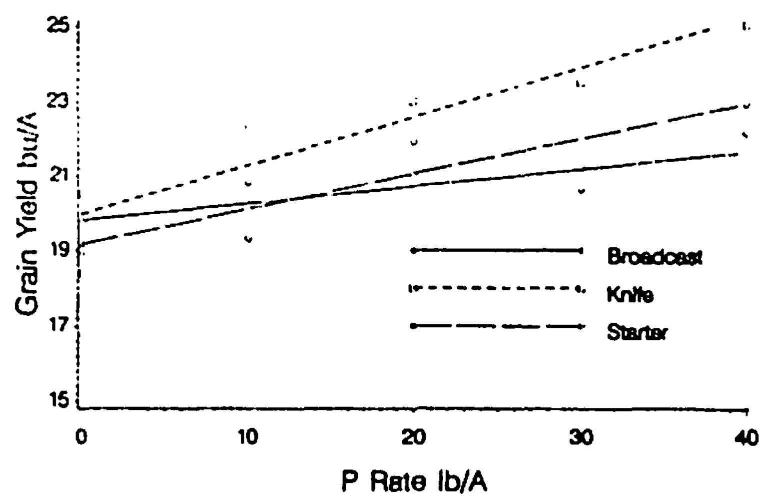
Figure 3. Corn grain yield responses to P application and method of application at Lamberton, MN, 1986 to 1988.



Lamberton Soybean 1986



Lamberton Soybean 1987



Lamberton Soybean 1988

Figure 4. Soybean grain yield responses to P application and method of application at Lamberton, MN, 1986 to 1988.

Precipitation Summary for Tillage Research on Farmer-Cooperator Farms, 1988

J.J. Kuznia, G.J. Spoden, and J.F. Moncrief[1]

The table presented below is a summary of the growing season precipitation for tillage demonstrations and research on farmer cooperator farms throughout Minnesota. The results from these demonstrations are published in this publication under the tillage section. Precipitation values are averaged weekly. Data is from the actual site when possible. When not available data was obtained from the high density weather observer network data base maintained by the Department of Natural Resources, State Climatologist Office. The nearest weather observer to the demonstration site ranged from 1 to less than 10 miles.

Table 1. Weekly precipitation for the 1988 growing season for tillage demonstrations on farmer cooperator farms.

	LOCATION																		
Date	Becker[3]	Dodge[2]	Douglas[3]	Fillmore[2]	Goodhue[3] Nord	Goodhue[3] Flueger	Isanti[3]	Lamberton[2]	Meeker[3]	Morris[3]	Norman[3]	Pine[2]	Stearns[3]	Steele[2]	Wabasha[3]	Wadena[3]	Waseca[2]	Winona[3]	Wright[3]
4/1-9	0.00	0.35	0.03	1.04	0.31	0.26	0.51	1.06	0.64	0.44	0.00	0.25	0.35	0.05	0.72	0.37	0.78	0.91	0.04
4/10-16	0.00	0.00	0.00	0.28	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.00
4/17-23	0.00	0.61	0.00	0.00	0.56	0.64	0.09	0.80	0.23	0.00	0.00	0.05	0.25	0.52	0.00	0.00	0.77	0.41	0.02
4/24-30	0.00	1.50	0.00	0.17	0.81	0.54	0.08	0.78	0.32	0.13	0.00	0.16	0.40	0.80	1.63	0.01	0.88	1.10	0.38
Total	**0.00**	**2.46**	**0.03**	**2.49**	**1.69**	**1.46**	**0.68**	**2.64**	**1.19**	**0.57**	**0.00**	**0.46**	**1.00**	**1.37**	**2.35**	**0.40**	**2.43**	**2.44**	**0.44**
5/1-7	0.02	1.00	0.00	0.61	0.00	0.00	0.40	0.07	0.00	0.06	0.23	0.06	0.10	1.00	0.00	0.05	0.76	0.00	0.00
5/8-14	1.12	0.25	1.23	0.07	2.16	1.78	1.90	0.36	1.25	0.71	0.27	1.28	1.50	0.47	1.60	0.60	0.86	1.05	1.29
5/15-21	0.70	0.35	0.28	0.00	0.26	0.15	0.00	0.20	0.04	0.48	0.74	0.05	0.25	0.00	0.00	0.32	0.10	0.02	0.62
5/22-28	0.62	0.25	0.77	0.44	0.24	0.25	0.15	0.85	0.35	0.46	0.16	0.59	0.50	0.45	0.00	0.59	0.27	0.24	0.28
5/29-6/4	0.00	0.00	0.00	0.00	0.02	0.07	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**2.46**	**1.95**	**2.28**	**1.12**	**2.68**	**2.25**	**2.50**	**1.50**	**1.64**	**1.71**	**1.40**	**1.98**	**2.35**	**1.92**	**1.60**	**1.56**	**1.99**	**1.31**	**2.19**
6/5-11	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/12-18	1.27	0.15	0.65	0.00	0.12	0.07	0.00	0.39	0.24	0.41	1.25	0.45	0.00	0.20	0.00	0.39	0.35	0.00	0.17
6/19-25	0.75	1.22	0.32	1.01	0.69	0.52	0.10	0.20	0.00	0.08	0.90	0.10	0.10	0.88	1.20	1.21	0.55	0.97	0.00
6/26-7/2	0.02	0.00	0.00	0.03	0.00	0.02	0.15	0.18	0.00	0.03	0.00	0.10	0.00	0.09	0.38	0.00	0.45	0.34	0.00
Total	**2.04**	**1.37**	**0.97**	**1.04**	**0.81**	**0.61**	**0.30**	**0.77**	**0.24**	**0.52**	**2.15**	**0.71**	**0.10**	**1.17**	**1.58**	**1.60**	**1.35**	**1.31**	**0.17**
7/3-9	1.04	1.75	0.22	0.53	0.35	0.48	1.75	0.62	0.09	0.36	0.55	0.03	0.01	0.50	0.80	0.02	0.23	0.00	0.26
7/10-16	0.50	3.70	1.55	0.45	0.70	0.51	1.35	0.17	0.76	1.07	0.60	1.24	0.20	1.25	0.45	1.26	0.05	0.72	0.26
7/17-23	0.00	0.43	0.37	0.41	0.29	0.39	0.70	0.05	0.86	0.31	0.04	0.41	0.20	0.34	0.48	0.24	0.33	0.30	0.56
7/24-30	0.65	0.00	0.11	0.41	0.00	0.00	1.50	0.00	0.05	0.06	0.00	0.97	0.00	0.00	0.00	0.52	0.00	0.00	0.00
7/31-8/6	2.25	0.86	1.43	0.54	1.16	1.22	1.25	1.46	0.66	2.55	2.17	1.98	0.43	0.93	1.12	2.99	1.85	0.97	0.64
Total	**4.44**	**6.74**	**3.68**	**2.34**	**2.50**	**2.60**	**6.55**	**2.30**	**2.42**	**4.35**	**3.36**	**4.63**	**0.84**	**3.02**	**2.85**	**5.03**	**2.46**	**1.99**	**1.72**
8/7-13	1.70	0.65	1.78	1.72	0.75	1.17	2.40	0.98	0.55	1.72	3.21	1.53	1.65	0.95	1.50	2.65	1.18	1.54	1.76
8/14-20	0.15	0.25	1.72	0.37	0.11	0.25	0.00	0.63	0.70	0.00	0.04	1.06	0.00	0.05	0.25	0.00	0.05	0.72	0.00
8/21-27	0.39	0.65	0.57	1.41	0.97	0.89	0.40	1.36	0.71	0.36	0.08	0.05	1.15	0.83	1.37	0.68	0.61	1.39	0.68
8/28-9/3	0.17	0.25	0.30	0.04	0.72	0.64	0.30	0.05	0.39	1.05	0.00	0.36	0.25	0.15	0.30	0.73	0.97	0.08	0.26
Total	**2.41**	**1.80**	**4.37**	**3.54**	**2.55**	**2.95**	**3.10**	**3.02**	**2.35**	**3.13**	**3.33**	**3.00**	**3.05**	**1.98**	**3.42**	**4.06**	**2.81**	**3.73**	**2.70**
9/4-10	0.00	0.15	0.00	0.26	0.37	0.17	0.00	0.03	0.00	0.00	0.00	0.07	0.00	0.00	0.10	0.00	0.00	0.23	1.39
9/11-17	0.77	0.00	0.94	0.06	0.36	0.36	0.60	1.96	0.72	1.59	0.91	0.80	1.33	0.25	0.00	1.10	0.36	0.27	0.94
9/18-24	2.06	3.82	0.37	2.01	3.32	1.96	2.00	0.08	0.57	0.48	2.21	1.91	0.70	3.14	3.39	0.87	3.06	3.88	0.85
9/25-10/1	0.31	0.43	0.97	0.12	0.55	0.56	1.00	0.96	0.80	1.46	0.27	0.55	0.85	0.50	0.35	0.93	0.95	0.35	0.76
Total	**3.14**	**4.40**	**2.38**	**2.45**	**4.60**	**3.05**	**3.60**	**3.03**	**2.09**	**3.53**	**3.39**	**3.33**	**2.88**	**3.89**	**3.84**	**2.90**	**4.37**	**4.73**	**3.94**

1. Joe J. Kuznia and John F. Moncrief are Assistant Scientist and Associate Professor respectively in the Soil Scientist Department, University of Minnesota, St. Paul, MN. 55108. Greg J. Spoden is the Assistant State Climatologist, Department of Natural Resources, St. Paul, MN. 55108.
2. Precipitation values were obtained at the site.
3. Precipitation values were obtained from the nearest weather observer for the State Climatology office high density observer network.

Tillage Effects on Corn Production in Eastcentral Minnesota[1]

J.F. Moncrief, W.W. Schoper, T.I. Siira, and J.J. Kuznia[2]

Abstract: Tillage was evaluated for continuous corn production at two sites in northeastern Minnesota (Moldboard and chisel plowing, spring discing, and no tillage). Tillage affected early corn growth at two sites in 1987 and 1988. Early growth in 1988 was double that of 1987 at both sites. Grain yields were affected at both sites in 1987 and one site in 1988. Average yields were higher with chisel plowing at one site and lower with a no till treatment at the other site.

This is the second year of a study in Isanti and Pine counties in northeastern Minnesota to evaluate the effect of tillage system on continuous corn production. Tillage ranges from Moldboard plowing with secondary tillage to a no till approach. The planters at both sites are conventional planters with 2" fluted coulters mounted ahead of the planter units. There has been tillage effects at both sites. Following is a two year summary.

Pine County

The Pine county site is on a Cushing loam soil on a dairy farm in northeastern Minnesota. This is the third year of corn. The soil test P and K are in the high range. The average "in row" cover by corn residue after planting has been consistent between the two years (table 3). The disc and chisel plow systems resulted in about 35% cover in the row and about twice that with a no tillage approach. The 2" fluted coulter reduced the "in row" cover 3, 5, 9, and 18 per cent for the moldboard, chisel, disc, and no till treatments respectively.

The effect of in row cover by corn residue on early corn growth is shown in table 4. The growth at a given point in time in 1988 was about double of that in 1987. This reflects the early spring and warm conditions in 1988. There was a tillage affect on early growth in both years however. Early growth is closely correlated with in "row cover".

Tillage affected plant stand in 1987 but not in 1988 at this site (table 5). Chisel and Moldboard plowing had higher stands than the disc and no till treatments in 1987. This is probably due to the 1.26 inches of rainfall that occurred in 1988 during the week after planting (see weather data from tillage studies this publication).

In 1987 systems that eliminated primary tillage reduced the density of annual weeds on May 28 (table 6). Volunteer corn was the only weed affected by tillage on June 17, 1987. In 1988 there did appear to be an affect of tillage on the relative ranking of weed species but not on the total cover by weeds (tables 9 and 8 respectively). There were very few discernable trends of tillage on weeds at harvest in 1988 (table 10). Weeds were grouped into two categories based on assumptions as to their competitiveness. The results are shown in table 11. Less tillage increased weeds with a low growth habit (weak competitors). There was no significant affect of tillage on the strong competitors although the range was great.

Grain yields at this site were affected by tillage both years (table 12). In 1987 the no till grown corn resulted in a yield 14 bushels per acre less than discing or moldboard plowing. The chisel plowing system resulted in yields about 10 bushels per acre higher than these two systems. In 1988 less tillage and increased levels of residue resulted in higher yields. This site had about 7 inches of rainfall in July and early August that appeared to have resulted in a residue advantage in reducing runoff and increasing the amount of available water. Conservation tillage options at this site resulted in the highest two year average yields. Even though extremes in tillage options resulted in a .7 and .4 difference in early growth for 1987 and 1988 respectively,

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1 This project is supported in part by the Soil Conservation Service. Their support is greatly appreciated. Konval H. Bergum and Michael J. Muzzy, the District Conservationist in Pine and Isanti Counties respectively, helped collect much of the data presented. This study could not have been possible without their assistance.

2 John F. Moncrief and Joe J. Kuznia are associate professor and assistant scientist respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN. 55108. Wayne W. Schoper and Tom I. Siira are county agricultural agents in Isanti and Pine Counties, Minnesota respectively.

grain moisture showed little influence.

In summary, tillage affected soil cover, early corn growth, and weed species both years at this site. Grain yields were higher with conservation tillage options.

PINE COUNTY

Table 1. Cultural practices at Pine County, MN. 1988.

Tillage
- No Till
- Fall Disc
- Fall Chisel Plow
- Fall Moldboard Plow-light disc spring

Cropping History
- 1986-Corn
- 1987-Corn Land O Lakes 1093

1988 Crop
- Land O Lakes 1093 Single cross hybrid (95 day)

Planting Information for 1987 & 1988 Crop Years

A four row 36 inch John Deere Max-Emerge planter with 2 inch fluted coulters was used.

Crop	Date	Rate	Harvested
Corn	May 4, 1987	26,700 plants/A	Oct. 6, 1987

Crop	Date	Rate	Harvested
Corn	May 6, 1988	25,700 plants/A	Oct. 14, 1988

Fertilizer 1987

Crop	Material Analysis (rate)	N	P_2O_5	K_2O	Date Applied
		—	lbs/A	—	
Corn	46-0-0 (250 lbs/A)	115	0	0	May 2, 1987
	10-15-35[1] (280 lbs/A)	28	42	98	May 4, 1987

1. Planter applied 2" beside and 2" below seed.

Fertilizer 1988

Crop	Material Analysis (rate)	N	P_2O_5	K_2O	Date Applied
		—	lbs/A	—	
Corn	46-0-0 (200 lbs/A)	92	0	0	April 25, 1988
	9-23-30[1] (200 lbs/A)	18	46	60	May 6, 1988

1. Planter applied 2" beside and 2" below seed.

Soil

The soil at this site is a Cushing (Glossic Eutroboralfs, fine-loamy, mixed) loam, soil is well drained.

Weed Control

2.5 qt/A (3.75 lbs/A) Bicep 6L (1.69 lbs/A Atrazine & 2.06 lbs/A Dual) surface applied preemergence.

Table 2. Soil test on April 7, 1987.

Nutrient	Sig. of Tillage	No Till	Disc	Chisel	Moldboard
		—	—	lb/A	—
P	(.193)	124	107	61	84
K	(.711)	471	411	464	422

Table 3. The effect of tillage on soil cover by corn residue on May 28, 1987 and May 13, 1988.

Location	Year	No Till	Disc	Chisel	Moldboard
		—	—	%	—
In Row	1987	56	42	26	1
	1988	69	32	37	7
Average		63	37	32	4
Between Row	1987	78	59	35	4
	1988	84	33	39	9
Average		81	46	37	7

Table 4. The effect of tillage on early corn growth.

Year	Date	No Till	Disc	Chisel	Moldboard	Sig.	n
		Tillage					
		------ leaves/plant			--------		
1987	5/24	1.7	1.9	2.0	2.3	.007	40
	6/17	5.3	5.5	6.1	6.3	.000	40
Average		3.5	3.7	4.1	4.3		
1988	5/27	3.6	3.5	3.5	3.7	.027	80
	6/24	9.5	10.2	10.2	10.3	.190	8
Average		6.6	6.9	6.9	7.0		

Table 5. The effect of tillage on corn stand, n=16.

Year	Date	No Till	Disc	Chisel	Moldboard	Sig.
		Tillage				
		----- 1000's	plants/A		-------	
1987	5/24	23.2	22.1	26.5	27.2	.000
1987	6/17	23.4	22.0	25.6	27.3	.000
Average		23.3	22.1	26.1	27.3	
1988	5/27	22.3	23.1	22.6	23.1	.746

Table 6. The effect of tillage on the presence of weed species and density on May 28, 1987, n=32.

Weed	NoTill	Disc	Chisel	Mlbd	Sig.
	Tillage				
	---- plants/A x 10^{-3}			-----	
Pigweed	0.6	1.3	5.5	5.0	.059
Foxtail	0.0	0.7	3.8	8.0	.059
Crabgrass	5.9	8.5	0.0	0.0	
Nutsedge	72.9	24.7	63.9	39.7	.552
Ragweed	1.2	2.9	6.9	11.1	.288
Lambsquarter	0.0	2.4	7.7	3.8	.099
Smartweed	0.0	2.4	0.0	0.0	
Vol Corn	0.0	5.5	4.2	0.9	.330
Quackgrass	0.0	0.9	0.0	0.0	

Table 7. The effect of tillage on the presence of weed species and density on June 17, 1987, n=32.

Weed	NoTill	Disc	Chisel	Mlbd	Sig.
	Tillage				
	---- plants/A x 10^{-3}			-----	
Crabgrass	1.8	0.0	12.1	0.0	.400
Nutsedge	117.1	37.9	35.8	47.2	.320
Ragweed	0.3	1.2	4.9	0.3	.287
Lambsquarter	0.0	0.0	2.8	2.7	
Smartweed	0.0	0.0	2.0	0.3	
Vol Crn	0.1	15.9	11.8	5.2	.011
Quackgrass	2.8	2.1	5.8	3.9	.373

Table 8. The effect of tillage on percent soil cover by weeds in 1988.

Date	No Till	Disc	Chisel	Moldboard	Sig.
	Tillage				
	-----------	%		-------------	
5/27/88	14	28	19	10	.159
6/24/88	58	50	50	38	.730

Table 9. The effect of tillage on weed ranking[1].

Weeds	N-T	Disc	Chl	Mld	N-T	Disc	Chl	Mld
	Sampling Date							
	May 27, 1988				June 24, 1988			
	Tillage							
	-------- Numerical Rating --------							
Nutsedge	3	1	1	1	2	1	1	1
Foxtail	-	2	2	2	6	2	2	3
Quackgrass	1	3	2	-	1	-	4	-
Pigweed	-	-	-	3	-	5	3	4
Ragweed	-	-	-	4	-	4	5	2
Lambquarters	-	-	-	5	-	-	3	2
Dandelion	2	-	-	-	3	-	-	-
Vol. Corn	-	-	2	-	-	3	-	-
Milkweed	5	-	-	-	5	-	-	-
Horse Thistle	-	-	2	-	-	-	-	5
Alfalfa	4	-	-	-	-	6	-	-
Canada Thistle	5	-	-	-	-	-	-	-
White Cockle	-	-	-	-	4	-	-	-
Sow Thistle	-	-	-	-	5	-	4	-
Mushrooms	-	-	-	-	7	-	-	-

1. Weed species were ranked by visually estimating the most dominant species, based on percent soil cover, with 1 being the most dominant.

Table 10. Effect of tillage on cover by weeds in corn at Pine Co. Sept. 23, 1988, n=4.

	Tillage				
	No Till	Disc	Chisel	Moldboard	
Weed	% cover				Sig.
Yelnutedge	23.3	18.0	14.5	3.5	.184
Pensmartweed	0.0	0.3	0.1	0.8	
Foxtail	21.3	48.3	25.5	47.3	.334
W.Buckwheat	0.0	0.0	0.0	0.0	
Quackgrass	1.8	1.8	0.8	0.3	.598
RrtPigweed	1.8	8.3	22.5	14.0	.196
GtRagweed	1.8	1.0	3.0	10.3	.372
Lambquarter	1.0	0.5	4.3	8.8	.058
Dandelion	6.8	4.0	1.3	0.3	.153
Vol.Corn	0.7	3.0	2.8	0.0	
Milkweed	0.3	0.0	0.0	0.3	
Crabgrass	9.5	19.5	10.0	2.0	.509
Elmtree	0.1	0.0	0.0	0.0	
Alfalfa	2.3	6.5	0.3	0.5	.430
Canada This	1.8	0.0	0.0	0.0	
White Cockle	0.8	0.3	0.0	0.0	
Mushroom	0.0	0.3	0.5	0.8	
W.Prosomillt	18.8	1.3	5.0	1.0	.478
Barnydgrass	0.0	0.3	0.0	0.3	
Sowthistle	0.0	0.0	0.0	0.3	

Table 11. Effect of tillage on weed competitiveness in corn at Pine Co. Sept. 23, 1988, n=4.

	Tillage				
	No Till	Disc	Chisel	Moldboard	
Competitiveness	% cover				Sig.
Weak[1]	39.5	41.5	25.8	5.9	.084
Strong[2]	41.2	72.8	62.5	77.8	.738

1. Weak competitors are yellow nutsedge, dandelions, and crabgrass.
2. Strong competitors are foxtail, redroot pigweed, lambsquarters, giant ragweed, and volunteer corn.

Table 12. The effect of tillage on grain yield and moisture on Oct. 6, 1987 and Oct. 14, 1988 n=4.

	Tillage				
	No Till	Disc	Chisel	Moldboard	
Year	bu/A				Sig.
1987	141	158	166	155	.026
1988	73	53	65	45	.046
Average	107	106	116	100	
	% moisture				
1987	26.7	25.7	25.5	24.2	.329
1988	25.1	24.9	24.9	26.1	.000
Average	25.9	25.3	25.2	25.2	

Isanti County

The soil at this site is an Alstad fine sandy loam with somewhat poor internal drainage. Corn followed soybeans in 1987 and corn in 1988. There are very few weeds at this site.

Tillage affected early growth of corn by a full leaf only with the no till system on May 27, 1988 (table 16). This is the result of 35% vs 75% "in row" cover for the chisel and disc systems vs the no till system (table 14). The planter (conventional planter equipped with 2" fluted coulters) reduced in "row cover" 14% with no other tillage.

The plant population was reduced with no tillage by four thousand plants per acre in 1987 (table 15). This resulted in a 10 bushel per acre reduction in grain yield with this system (table 17). In 1988 plant stands were reduced with the no till and chisel plowing systems but were at a higher level than in 1987. These differences in stand did not affect grain yields. Tillage did affect grain moisture in both years however. Higher in row cover increased grain moisture.

In summary, corn early growth and plant stands were affected by tillage at this site. In 1987 no till grown corn resulted in 10 bushels per acre less grain yield than other systems. The yield reduction with the no till system in this year was strongly correlated to the stand loss. In 1988 there were stand losses associated with several tillage systems but this did not affect yields. The two year average yield was about 4 bushels per acre less with the no till system. It is important to note that if crop residue was cleared out of the row area at planting this small yield difference probably would not have happened.

ISANTI COUNTY

Table 13. Cultural practices at Isanti County, MN. 1988.

Tillage
- No Till
- Spring Disc
- Spring Chisel and disced
- Spring Moldboard

Spring tillage was done on April 26, 1988.
Tillage was followed by a light harrow to level the soil for planting.
Stalks were chopped in the fall on all tillage systems.

Cropping History
- 1986-Soybeans
- 1987-Corn Pioneer 3790

1988 Crop
- Corn-Pioneer 3772

Planting Information for 1987 & 1988 Crop Years

A six row John Deere 7000 planter with 30 inch row spacing and equipped with 2 inch fluted coulters.

Crop	Date	Rate	Harvested	Crop	Date	Rate	Harvested
Corn	May 6, 1987	27,200 plants/A	Oct. 6, 1987	Corn	May 3, 1988	28,500 plants/A	Oct. 14, 1988

1987 Soil Test

Organic Matter	pH	Bray 1 Phosphorus	Potassium	Sulfur	Zinc
		lbs/A		ppm	
Medium	7.0	115	238	15	1.1

Fertilizer 1987

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Actual S	Actual Mg	Date Applied
			lbs/A					
Corn	12-14-26-4-3[1]	277 lbs/A	33	38	73	11	9	May 6, 1987
	82-0-0	146 lbs/A	120	0	0	0	0	June 5, 1987

1. Starter fertilizer applied with the planter 2" beside and 2" below the seed.

Fertilizer 1988

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Actual S	Actual Mg	Date Applied
			lbs/A					
Corn	12-14-26-4-3[1]	277 lbs/A	33	38	73	11	9	May 3, 1988
	82-0-0	220 lbs/A	180	0	0	0	0	June 3, 1988

1. Starter fertilizer applied with the planter 2" beside and 2" below the seed.

Soil

The soil at this site is a Alstad (Aquic Eutroboralfs, fine-loamy, mixed) fine sandy loam, 0 to 2 percent slope. Soil is somewhat poorly drained.

Weed Control

2 qt/A (2 lbs/A) Lasso Micro Tech + 1 qt/A (1 lb/A) Bladex + 1 qt/A (1 lb/A) Atrazine on May 5, 1988.

Table 14. The effect of tillage on soil cover by corn residue on May 27, 1988[1].

	Tillage			
	No Till	Disc	Chisel	Moldboard
Location	%			
In Row	75	38	33	4
Between Row	89	31	25	3

1. Tillage was significant < .100 in all cases, n=32.

Table 15. The effect of tillage on corn stand.

		Tillage					
		No Till	Disc	Chisel	Moldboard		
Year	Date	1000's plants/A				Sig.	n
1987	8/1	22.3	26.6	26.3	26.6	.014	6
1988	6/20	25.5	28.1	26.8	28.4	.002	16
Average		23.9	27.4	26.6	27.5		

Table 16. The effect of tillage on early corn growth on May 27, 1988.

Tillage					
No Till	Disc	Chisel	Moldboard		
leaves/plant				Sig.	n
3.2	4.2	4.2	4.3	.000	60

Table 17. The effect of tillage on corn yields and moisture harvested on Oct. 6, 1987 and Oct. 14, 1988 n=6.

	Tillage				
	No Till	Disc	Chisel	Moldboard	
Year	bu/A				Sig.
1987	157	166	168	168	.004
1988	146	145	147	147	.946
Average	152	156	157	157	
	% moisture				
1987	23.1	22.3	21.7	22.0	.006
1988	21.6	19.9	19.1	18.9	.000
Average	22.4	21.1	20.4	20.5	

The Effect of Tillage on Irrigated Corn Production Following Alfalfa on a Sandy Loam Soil[1]

J.F. Moncrief, M.J. Wiens, and J.J. Kuznia[2]

Abstract: Second year corn grown after alfalfa under irrigation on a sandy loam soil was influenced by tillage system. Emergence was slowed, early growth less, and grain yields reduced with conservation tillage options. Although there was a visual affect of tillage on nitrogen stress in late August it did not affect the nitrogen response of grain yield.

In 1987 plots were established at Staples, MN to evaluate the effect of tillage on the availability of nitrogen to corn from alfalfa the preceding year. This is the second year of that study. Tillage had a major influence on nitrogen available to first year corn (see this publication, 1988) but not on second year corn this year.

Corn was planted with a conventional planter equipped with 2" fluted coulters. Nitrogen was applied at about the 7 leaf stage as broadcast urea prior to irrigation in June (see table 1). A small amount of nitrogen was applied with the planter. A range in broadcast nitrogen rate expected to bracket the optimum was applied each year.

The effect of tillage on "in row" cover is shown in table 2. Corn yields ranged from 140 to 200 bushels per acre in 1987. This resulted in 90% cover with no tillage. Soil cover in the row ranged from 9 to 84%. There does appear to be an interaction between nitrogen rate in 1987 and tillage on soil cover in 1988 (tables 3 and 4). The authors don't have an explanation for the higher level of cover 50 lb N/acre rate with the spring discing treatment.

The effect of "in row" cover on emergence, plant stand, and early growth is shown in tables 5 and 6. Tillage affected emergence. No till corn was not fully emerged until about May 20 which was about ten days behind the moldboard plowing treatment (corn was planted on April 27). There was very little mortality of corn at this site. Growth of no till corn was delayed about 1 leaf per plant on May 9 and the discing treatment was intermediate. On June 10 the spread between moldboard plowing and no tillage was 2.5 leaves.

There was a nitrogen by tillage interaction on visual estimation of nitrogen stress on August 25 (table 7). This followed a similar trend in 1987 although tillage effects were less in 1988. The visual response to applied nitrogen was about three fold for no till corn. The response for corn grown with moldboard plowing was only a factor of two. The disc treatment was again intermediate. Based on these data it does appear that tillage affected the nitrogen response at this point in time.

The main effects of tillage on color and height are shown in table 8. Although no till corn was visually less green plants tended to be taller. The nitrogen response (color and height) is shown in table 9.

Soil samples were taken in one foot increments to a depth of five feet in the spring and fall of 1988. The effect of tillage, nitrogen, and depth on gravimetric water is shown in tables 10, 11, and 12 respectively. The disc treatment had lower levels of soil moisture in the spring and the no till treatment in the fall. The higher nitrogen rate resulted in higher levels of soil water in the spring. Most of the soil water is in the top 2 feet due to the textural horizonation of this soil. The higher levels of soil water with the moldboard plowing treatment were greater in the surface two feet (table 14).
Tillage had a significant effect on grain yields which appeared to be related to plant stand. The delay in

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growth resulted in a difference in grain moisture of 5.7 percent between the tillage extremes. Nitrogen affected grain and stover yields and final stand (table 16). There was no significant interaction between tillage and nitrogen response in 1988 (table 17). In light of the earlier visual nitrogen observations (table 7) this may have been due to tillage effects on stand (table 21) or the highest nitrogen rate was not high enough for the no till system (table 17).

In summary, tillage had a large influence on emergence and early growth of second year corn grown after alfalfa. Conservation tillage options also reduced grain yields. Although there was an effect of tillage on the visual nitrogen response on August 25, there was not an interaction on grain yields. It is suggested that the lack of a tillage influence on the grain nitrogen response may have been due to tillage effects on stand or because the nitrogen rates were not high enough.

WADENA COUNTY

Table 1. Cultural practices at Staples Irrigation Center, Wadena County, MN. 1988.

Tillage	**Previous Crop**	**1988 Crop**
No Till	1984-86 Alfalfa	Corn-Pioneer 3790
Spring Disc-twice on April 27, 1988	1987-Corn	
Moldboard Plow-on April 27, 1988 and then disced once		

Planting and Harvest Date

The planter is a John Deere Max-Emerge planter equipped with 2" fluted coulters.

	Planting		
Crop	Date	Rate	Harvested
Corn	April 27, 1988	35,600 plants/A	September 29, 1988

Fertilizer 1987

Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Actual S	Date Applied
		lbs/A				
17-7-23-6[1]	93 lbs/A	16	6	21	6	May 11, 1987
46-0-0[2]	0 lbs/A	0	0	0	0	June 16, 1987
46-0-0[2]	75 lbs/A	35	0	0	0	June 16, 1987
46-0-0[2]	146 lbs/A	67	0	0	0	June 16, 1987
46-0-0[2]	221 lbs/A	102	0	0	0	June 16, 1987

1. Planter applied 2" below and 2" beside row.
2. Broadcast as urea and irrigated in.

Fertilizer 1988

Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Actual S	Date Applied
		lbs/A				
24-8-15-8[1]	85 lbs/A	20	7	13	7	April 27, 1988
46-0-0[2]	0 lbs/A	0	0	0	0	June 1, 1988
46-0-0[2]	137 lbs/A	63	0	0	0	June 1, 1988
46-0-0[2]	254 lbs/A	117	0	0	0	June 1, 1988
46-0-0[2]	400 lbs/A	184	0	0	0	June 1, 1988

1. Planter applied 2" below and 2" beside row.
2. Broadcast as urea and irrigated in.

Soil

The soil at this site is a Verndale (Udic Argiborolls, coarse-loamy, mixed) sandy loam with a slope of 0 to 2 percent. The soil is well drained.

Weed Control

1.5 pt/A (1.5 lb/A) Dual + 1.3 qt/A (1.3 lbs/A) Bladex on May 14, 1987.

Table 2. The effect of tillage on soil covered by corn residue in Wadena Co. on May 11, 1988, n=32.

Location	Tillage: No Till	Disc	Moldboard	Sig.
	---------- % ----------			
In Row	84.0	63.8	8.5	.000
Between	90.0	56.8	6.4	.000

Table 3. The effect of nitrogen rate on soil cover by corn residue in in Wadena Co. on May 11, 1988, n=24.

Location	Nitrogen rate lbs N/A[1]: 16	51	83	118	Sig.
	---------- % ----------				
In Row	47.3	53.7	51.5	55.8	.150
Between	48.3	57.8	48.5	49.5	.004

1. These are the 1987 N rates.

Table 4. The effect of tillage and nitrogen rate on soil cover by corn residue on May 11, 1988, in Wadena Co., n=8.

	Tillage					
	No Till		Disc		Moldboard	
Nitrogen[3]	In row[1]	Betw row[2]	In row	Betw row	In row	Betw row
	---------- % ----------					
16 lbs/A	75.0	87.0	58.0	49.5	9.0	8.5
51 lbs/A	84.0	93.0	70.5	74.5	6.5	6.0
83 lbs/A	91.5	89.5	55.5	50.0	7.5	6.0
118 lbs/A	85.5	90.5	71.0	53.0	11.0	5.0

1. The p value for the tillage by nitrogen rate interaction is .126.
2. The p value for the tillage by nitrogen rate interaction is .006.
3. These are the 1987 N rates.

Table 5. Effect of tillage on corn population at Wadena Co. 1988, n=16.

Date	Sig. of Tillage	Tillage: No Till	Disc	Moldboard
		--- plants/A x 10^{-3} ---		
May 9	(.000)	5.4	20.3	31.7
May 11	(.005)	10.7	23.8	32.7
May 14	(.048)	20.1	28.7	33.2
May 16	(.196)	26.7	29.0	32.2
May 18	(.396)	28.9	29.3	31.9
May 20	(.615)	30.3	30.2	31.9
May 23	(.529)	30.2	30.2	31.9
May 25	(.427)	29.8	30.2	32.0
May 27	(.498)	29.9	30.0	31.8
June 1	(.423)	29.5	30.2	31.9
June 6	(.475)	29.5	30.3	31.8
June 8	(.393)	29.5	30.2	32.0
June 10	(.403)	29.3	30.2	31.8

Table 6. Effect of tillage on early growth of corn at Wadena Co. 1988, n=16.

Date	Sig. of Tillage	Tillage: No Till	Disc	Moldboard
		---- leaves/plant ----		
May 9	(.000)	0.3	0.8	1.3
May 11	(.000)	0.6	1.3	2.0
May 14	(.000)	1.2	2.0	2.7
May 16	(.000)	1.8	2.7	3.2
May 18	(.000)	2.2	3.0	3.8
May 20	(.001)	2.8	3.3	4.2
May 23	(.000)	3.3	4.0	4.9
May 25	(.001)	3.8	4.5	5.5
May 27	(.002)	4.4	5.1	6.1
June 1	(.001)	6.5	7.4	8.6
June 6	(.000)	8.2	9.1	10.4
June 8	(.001)	8.3	9.6	11.1
June 10	(.000)	8.6	9.7	11.1

Table 7. The effect of tillage and nitrogen rate on plant color on Aug. 25, 1988, at Wadena Co.[1]

	Tillage		
	No Till	Disc	Moldboard
Nitrogen	----- color index[2] -------		
20 lbs/A	3.3	3.8	5.0
80 lbs/A	5.5	6.0	6.8
140 lbs/A	9.0	6.5	7.8
200 lbs/A	9.8	9.3	10.0

1. The p value for the tillage by nitrogen interaction is .010, n=4.
2. Color index ranges from 1=yellow to 10=dark green.

Table 8. The effect of tillage on plant color and height on August 25, 1988, at Wadena Co.

	Tillage			
Variable	No Till	Disc	Moldboard	Sig.
	---- color index[1] ------			
Color	6.9	6.4	7.4	.079
	-------- feet ---------			
Plant height	7.5	7.3	7.2	.127

1. Color index ranges from 1=yellow to 10=dark green, n=16.

Table 9. The effect of nitrogen rate on color and plant height on August 25, 1988, at Wadena Co.

	Nitrogen rate lbs N/A				
	20	80	140	200	
Variable	--- color index[1] ----				Sig.
Color	4.0	6.1	7.8	9.7	.000
	------- feet --------				
Plant height	6.8	7.4	7.5	7.5	.009

1. Color index ranges from 1=yellow to 10=dark green, n=12.

Table 10. The effect of tillage on soil moisture at Wadena Co. in 1988, n=80.

	Tillage			
	No Till	Disc	Moldboard	
Date	-------- %w/w ---------			Sig.
4/14/88	5.2	4.8	5.3	.085
10/25/88	5.0	5.1	6.2	.087

Table 11. The effect of nitrogen rate on soil moisture at Wadena Co. in 1988, n=60.

	Nitrogen rate lbs N/A				
	20	80	140	200	
Date	------- %w/w --------				Sig.
4/14/88	5.0	5.0	5.0	5.3	.089
10/25/88	5.4	5.6	5.5	5.4	.191

Table 12. The effect of depth on soil moisture at Wadena Co. in 1988, n=48.

	Depth (ft.)					
	0-1	1-2	2-3	3-4	4-5	
Date	--------- %w/w ---------					Sig.
4/14/88	9.4	5.7	3.6	3.5	3.4	.000
10/25/88	10.1	6.8	3.6	3.3	3.5	.000

Table 13. The effect of nitrogen rate and tillage on soil moisture at Wadena Co. in 1988.

	4/14[1]			10/25[2]		
	Tillage					
	N-T	Dsc	Mld	N-T	Dsc	Mld
N (lbs/A)	------------ %w/w ------------					
20	5.5	4.7	4.9	4.8	5.3	6.0
80	4.8	5.0	5.2	5.2	5.2	6.3
140	4.9	4.8	5.3	5.0	5.0	6.4
200	5.7	4.5	5.7	5.2	4.9	6.1

1. The p value for the tillage by nitrogen interaction is .002, n=20.
2. The p value for the tillage by nitrogen interaction is .176, n=20.

Table 14. The effect of depth and tillage on soil moisture at Wadena Co. in 1988.

	4/14[1]			10/25[2]		
	Tillage					
	N-T	Dsc	Mld	N-T	Dsc	Mld
Depth (ft.)	------------ %w/w ------------					
0-1	9.6	8.7	9.8	9.8	9.8	10.8
1-2	5.8	5.0	6.3	5.6	6.0	8.6
2-3	3.8	3.3	3.6	3.3	3.2	4.3
3-4	3.6	3.4	3.4	3.1	3.1	3.6
4-5	3.4	3.4	3.3	3.4	3.3	3.7

1. The p value for the tillage by depth interaction is .021, n=16.
2. The p value for the tillage by depth interaction is .000, n=16.

Table 15. Effect of tillage on yield and moisture, and final stand in Wadena Co. on September 29, 1988, n=16.

Variable	No Till	Disc	Moldboard	Sig.
	Tillage			
	bu/A			
Grain:Yield	134.8	147.3	157.1	.004
	%			
Moisture	28.4	23.6	22.7	.000
	t/A			
Stover Yield	2.48	2.61	2.75	.276
	%			
Moisture	65.1	62.4	61.8	.039
	plants/A x 10^{-3}			
Final Stand	29.6	31.7	32.4	.006

Table 16. Effect of nitrogen rate on yield, moisture, and final stand in Wadena Co. on September 29, 1988, n=12.

Variable	20	80	140	200	Sig.
	Nitrogen rate lbs N/A				
	bu/A				
Grain:Yield	94.7	148.8	166.1	176.0	.000
	%				
Moisture	25.0	24.7	24.4	25.6	.316
	t/A				
Stover:Yield	2.12	2.65	2.84	2.84	.000
	%				
Moisture	62.1	62.8	62.4	65.2	.003
	plants/A x 10^{-3}				
Final Stand	29.9	32.1	31.7	31.2	.058

Table 17. The effect of nitrogen rate and tillage on yield at Wadena Co. on September 29, 1988[1].

N (lbs/A)	No Till	Disc	Moldboard
	Tillage		
	bu/A		
20	78.3	93.1	112.6
80	137.7	146.2	162.4
140	155.3	173.0	170.1
200	168.0	176.9	183.2

1. The p value for the tillage by nitrogen interaction is .588, n=4.

Table 18. The effect of nitrogen rate and tillage on grain moisture at Wadena Co. on Sept. 29, 1988[1].

N (lbs/A)	No Till	Disc	Moldboard
	Tillage		
	%		
20	28.6	23.7	22.8
80	27.9	23.7	22.4
140	27.7	23.0	22.7
200	29.6	24.1	23.1

1. The p value for the tillage by nitrogen interaction is .649, n=4.

Table 19. The effect of nitrogen rate and tillage on stover yield at Wadena Co. on Sept. 29, 1988[1].

N (lbs/A)	No Till	Disc	Moldboard
	Tillage		
	tons/A		
20	1.86	2.05	2.45
80	2.58	2.62	2.74
140	2.72	2.94	2.87
200	2.75	2.83	2.93

1. The p value for the tillage by nitrogen interaction is .373, n=4.

Table 20. The effect of nitrogen rate and tillage on stover moisture at Wadena Co. on Sept. 29, 1988[1].

N (lbs/A)	No Till	Disc	Moldboard
	Tillage		
	%		
20	65.2	62.4	58.7
80	64.4	63.0	60.9
140	64.5	60.8	61.9
200	66.2	63.7	65.6

1. The p value for the tillage by nitrogen interaction is .058, n=4.

Table 21. The effect of nitrogen rate and tillage on final stand at Wadena Co. on Sept. 29, 1988[1].

N (lbs/A)	No Till	Disc	Moldboard
	Tillage		
	plants/A x 10^{-3}		
20	26.6	32.7	30.6
80	32.3	30.3	33.7
140	29.4	32.7	32.8
200	29.9	31.0	32.6

1. The p value for the tillage by nitrogen interaction is .019, n=4.

The Effect of Tillage System and Deep Chisel Plowing on Corn Production on a Udollic Ochraqualf Soil[1]

J.F. Moncrief, T.L. Wagar, and J.J. Kuznia[2]

Abstract: Tillage systems were evaluated for corn production on a soil with a thin loess cap over laying dense glacial till with poor internal drainage. Plots were split with deep chisel plowing. Tillage did not affect grain yields. Deep chisel plowing resulted in a 5 bushel per acre increase in yield.

This is the first year of this study. Continuous corn is grown with four tillage systems. Tillage systems are: fall moldboard and chisel plowing, ridge till, and fall disc. In addition each plot is split with a deep fall chisel plowing (8" to 10" deep) done on 28" spacing (same as row spacing).

Soil cover by residue measurements were made after cultivation (table 2). At this point in time the soil cover is similar for all the conservation tillage systems. The cultivation concentrated the residue in the row. These cover measurements would not be expected to be correlated with early growth. Early growth was not affected by tillage (table 3). Corn stands were reduced 2 to 4 thousand plants per acre with the conservation tillage systems.

The effect of tillage on weed severity is shown in table 4. Foxtail is the dominant weed. Ridge tillage resulted in less foxtail.

Grain yields are shown in table 5. There was no significant difference in grain yields due to tillage. Deep chiseling increased yields 5 bushels per acre and reduced grain moisture slightly (table 6). There was no interaction between tillage system and deep chiseling on grain yields (table 7). It should be noted that a split plot design increases the resolution of subplot effects at the expense of the main plots. Average yields between tillage systems ranged about 14 bushels per acre and the deep chiseling subplots only 6 bushel per acre. Tillage effects were not statistically significant but deep chiseling treatments were.

DODGE COUNTY

Table 1. Cultural practices at Dodge County, MN. 1988.

Tillage
- Ridge Till
- Fall Disc-Light spring disc twice
- Fall Chisel Plow-Light spring disc twice
- Fall Moldboard Plow-Light spring disc twice

All plots split with a deep chisel, 8-10 inches deep, done in the fall prior to fall tillage. Shanks are spaced on 28 inch centers and are a point type that run in the center of the row.

All plots were culitvated once and 10 days latter ridges formed.

Preceding Crop
1985-87 Corn

1988 Crop
Corn-Pioneer 3732

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1 This project was supported in part by the Soil Conservation Service. Their support is greatly appreciated. Data collection and information dissemination was aided by Dave H. Hanson, Dodge County Agricultural Extension Agent.

2 John F. Moncrief and Joe J. Kuznia are Associate Professor and Assistant Scientist respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN. 55108. Tim L. Wagar is an Area Crops and Soils Extension Specialist, University of Minnesota, Rochester, MN.

Planting and Harvest Date

A six row John Deere 7000 with 28 inch row spacing was used.

Crop	Planting Date	Planting Rate	Harvested
Corn	April 20, 1988	27,700 plants/A	October 3, 1988

Fertilization History

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5 (lb/A)	Actual K_2O	Date Applied	Method of Application
Corn:	46-0-0	370 lbs/A	170	0	0	April 16, 1987	Broadcast
	7-21-7	10 gal/A	8	24	8	April 29, 1987	Applied with the seed

Fertilizer 1988

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5 (lb/A)	Actual K_2O	Date Applied	Method of Application
Corn:	82-0-0	213 lbs/A	175	0	0	April 5, 1988	Injected
	7-21-7[1]	5.5 gal/A	4	13	4	April 20, 1988	Applied with the seed

Soil

The soil at this site is a Skyberg (Udollic Ochraqualfs, fine-loamy, mixed mesic) silt loam, with 0 to 2 percent slope. This soil is somewhat poorly drained.

Weed Control

1 qt/A (2 lbs/A) Dual + 2.5 lbs/A (2.25 lbs/A) Bladex 90 DF applied on April 23, 1988.

Table 2. Effect of tillage on soil covered by corn residue in Dodge Co. on June 23, 1988[1].

Residue Location	Tillage: Moldboard	Ridge	Disc	Chisel	Sig.
	% cover				
In Row	14.7	35.3	30.7	32.3	.012
Between Row	15.0	22.3	24.7	26.7	.276

1. Cover was measured on subplots without deep chiseling after cultivation, n=12.

Table 3. Effect of tillage on early corn growth and population in Dodge Co. on June 23, 1988[1].

Variable	Tillage: Moldboard	Ridge	Disc	Chisel	Sig.
	leaves/plant				
Growth Stage	6.4	5.7	5.9	6.1	.157
	plants/A x 10^{-3}				
Population	28.0	25.9	25.9	24.3	.043

1. Growth stage and population was measured on subplots without deep chiseling after cultivation, n=12.

Table 4. Effect of tillage on weed severity in corn at Dodge Co. on June 7, 1988[1].

Weed	Tillage: Moldboard	Ridge	Disc	Chisel	Sig.
	% cover				
Foxtail	18.3	5.0	21.7	15.0	.163
Velvetleaf	0.0	0.0	0.0	3.3	
Quackgrass	3.3	0.2	8.3	3.3	.226
Barnyard grass	6.7	0.0	8.7	16.7	
Yellow nutsedge	0.3	0.0	0.0	1.7	

1. Cover by weeds was visually estimated on the entire main tillge plots, n=3.

Table 5. The effect of tillage on corn yield and moisture at Dodge Co. on October 3, 1988[1].

Variable	Tillage: Moldboard	Ridge	Disc	Chisel	Sig.
	bu/A				
Grain:Yield	124.2	118.1	115.3	110.6	.349
	%				
Moisture	16.3	16.9	17.4	16.8	.485

1. Averaged over the deep chisel subplots, n=6.

Table 6. The effect of chisel on corn yield and moisture at Dodge Co. on October 3, 1988, n=12.

	Chisel		
Variable	Deep Chisel	No Chisel	Sig.
	-------- bu/A -------		
Grain:Yield	119.8	114.3	.108
	-------- % ----------		
Moisture	16.6	17.0	.072

Table 7. The effect of tillage system and chiseling on corn yield and moisture at Dodge Co. on October 3, 1988[1].

		Tillage			
Variable		Moldboard	Ridge	Disc	Chisel
		---------- bu/ac ----------			
Grain:Yield	Deep Chisel	129.6	116.5	118.9	114.2
	No Chisel	118.9	119.7	111.6	106.9
		------------ % ----------			
Moisture	Deep Chisel	16.2	16.6	17.4	16.4
	No Chisel	16.5	17.1	17.3	17.1

1. The p value for the tillage by chiseling interaction was .432 and .441 for grain yield and moisture respectively, n=3.

The Effect of Tillage and Cultivation on the Nitrogen Response by Corn Following Alfalfa on a Typic Hapludalf[1]

J.F. Moncrief, J.J. Kuznia, T.L. Wagar, and G.P. Cremers[2]

Abstract: Tillage and cultivation effects on the nitrogen response following alfalfa were evaluated on a silt loam soil in southeastern Minnesota. The nitrogen response was 10 bushels per acre. Tillage and cultivation did not affect the nitrogen response. Tillage did not affect corn yields. Cultivation was responsible for a 20 bushel per acre increase in corn yield largely due to control of woolly cupgrass and did not interact with tillage.

In southeastern Minnesota soils are very vulnerable to erosion. Any sustainable cropping system in this area of the state will include some form of conservation tillage to control erosion. Preliminary data has shown that tillage can greatly affect the amount of nitrogen that is released from alfalfa for succeeding corn crops. The fractured limestone aquifer in this area of the state is also vulnerable to contamination by nitrate nitrogen. In an effort to assess the effect of tillage on the response of corn following alfalfa to applied nitrogen, plots were established in Winona County, Minnesota with a range of tillage from moldboard plowing to a no till approach in the spring of 1988.

A summary of treatments and site history is shown in table 1. This study is located on a dairy farm and the crop rotation has been three years of alfalfa and two years of corn. The soil is a Typic Hapludalf (Seaton silt loam) with good internal drainage. Nitrogen was applied four days before tillage in the spring as broadcast urea. The statistical design is a split split plot with tillage main plots with first subplots cultivation and second subplots nitrogen with four replications. Main tillage plots are 100 by 40 feet, cultivation plots are 100 by 20 feet, and nitrogen plots are 20 by 25 feet.

The existing stand of alfalfa is characterized in table 2. The density of alfalfa ranged from 1.2 to 2.4 crowns per square foot. The two weeds present in the spring were dandelion and bromegrass. There was a positive and negative correlation between alfalfa and dandelions and bromegrass respectively.

Tillage treatments were: moldboard and chisel plowing, heavy disc, and no till. All but the no till treatment received one pass with a light finishing disc before planting. The effect of an aggressive cultivation was also evaluated. All plots were split with one cultivation with a ridge till cultivator on June 20.

There was .6 to .8 leaf less growth by the no till corn on June 20 (table 5). This occurred even though the "in row" soil cover by crop residue was only 6 to 8% higher than the disc and chisel systems (table 3). The planter used at this site is equipped with small clearing discs. The width of the cleared area over the row was only about 4 to 6 inches. This may have been partially responsible for the delayed growth. Tillage did not affect plant stand. The drought stress in 1988 did affect the mortality of corn at this site (table 6). Corn stands went from 28,000 to 22,000 plants per acre over the growing season, drop of 28 per cent.

Soil water content to a depth of 5 feet is shown in tables 7, 8, and 9. The initial water content in the spring before establishment of the tillage treatments was low throughout the profile due to extraction by the alfalfa the previous year (table 7 and 9). At the end of the season the no till treatment had higher levels of soil moisture. The no till plots had higher levels of soil water in the 2 to 5 foot depth. This suggests that corn grown with this system had less roots at these depths. The authors do not have an explanation for the interaction of tillage and cultivation illustrated in table 8 at this time.

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1 This project is supported in part by the following: United States Fish and Wildlife Service, Minnesota Department of Agriculture, and the Soil Conservation Service. Their support is greatly appreciated. Data collection was assisted by Neil R. Broadwater and Stanley F. Musielewicz, the Winona County Agricultural Extension Agent and Winona Soil Conservationist respectively. This project would not have been possible without their help.

2 John F. Moncrief, Joe J. Kuznia, and Greg P. Cremers are Associate Professor and Assistant Scientists, respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN. 55108. Tim L. Wagar is an Area Crops and Soils Extension Specialist, University of Minnesota, Rochester, MN.

The dominate weed at this site is woolly cupgrass. Tillage did not affect the density or species of weeds present (tables 10 and 11). Cultivation had a large influence on weeds however (table 12). Woolly cupgrass is very difficult to control in corn chemically. There was no interaction between tillage and cultivation on effectiveness of weed control.

Tillage influenced corn phenology (table 13). Differences in plant water stress due to tillage were not present on July 12.

Tillage did not affect grain or stover yields (table 14). No till grown corn had 3 percent higher grain moisture however. There was a small but statistically significant response to applied nitrogen (table 15). Tillage did not affect the nitrogen response.

The main effects of cultivation and the interaction with tillage on yield and moisture is shown in table 16. The average cultivation response was 20 bushels per acre. The moldboard and no till systems resulted in about a 25 bushel per acre cultivation response. The disc system resulted in only a 10 bushel per acre response to cultivation.

Cultivation increased final plant stands 1.2 thousand plants per acre. The large yield increases due to cultivation is primarily due to control of woolly cupgrass. Increases in final stand to a lesser extent may have been responsible for the increase in yield with the moldboard and chisel systems.

In summary there was no effect of tillage on corn yields following alfalfa on a silt loam soil in southeastern Minnesota. Tillage did not affect corn stands but mortality was 28% over the growing season. At the end of the season soil water was higher at the 2 to 5 feet depth with the no tillage system. The response to nitrogen was 10 bushels per acre and not affected by tillage. Cultivation was responsible for a 20 bushel per acre yield response primarily due to control of woolly cupgrass. Cultivation also increased final corn stands by about a thousand plants per acre.

WINONA COUNTY

Table 1. Cultural practices at Winona County, MN. 1988.

Tillage

No Till
Spring Disc-heavy disc followed by a light finishing disc
Spring Chisel Plowed-then a light finishing disc once
Spring Moldboard Plowed-then a light finishing disc once
All tillage was done just prior to planting on May 2, 1988

Cropping History

1979-81 Alfalfa, 1982-83 Corn,
1984 Oats and Alfalfa, 1985-87 Alfalfa

Manure History

20 loads of solid dairy manure (300 bu. spreader) in 1980, 1982, and 1983

1988 Crop

Corn Pioneer 3737

Planting Information for 1988 Crop Year

A four row International 800 planter with 38 inch row spacing and equiped with factory clearing disks.

Crop	Date	Rate	Harvested
Corn	May 2, 1988	30,500 plants/A	October 6, 1988

Fertilizer 1988

Crop	Material Analysis	Rate	Actual N	P_2O_5	K_2O	S	Zn	Date Applied	Method of Application
			-------	lbs/A	--------				
Corn	16-42-5-7-20	110 lbs/A	18	46	6	8	22	May 2, 1988	Starter 2" x 2" with planter
	46-0-0	65 lbs/A	30	0	0	0	0	April 29, 1988	Broadcast
	46-0-0	130 lbs/A	60	0	0	0	0	April 29, 1988	Broadcast
	46-0-0	196 lbs/A	90	0	0	0	0	April 29, 1988	Broadcast

Soil

Seaton (Typic Hapludalfs, fine-silty, mixed, mesic) silt loam, 3-6% slope, soil is well drained.

Weed Control

Applied 2 qt/A (1.5 lb/A) Roundup + .5 pt/A (.25 ai/A) Banvel + .5 pt/A (.5 lb/A) 2,4-D on April 29, 1988.
Applied 3 pt/A (1.5 lb/A) Prowl + 2 lb/A (1.8lb/A) Bladex 90 DF on May 18, 1988.
Applied 50% Roundup on non-cultivated rows with a hand held rope wick on July 8, 1988.
Main tillage plots were split with cultivation on June 20, 1988.

Table 2. Variability of alfalfa stand and weeds present prior to establishment of tillage treatments at Winona Co. April 21, 1988, n=16.

Weed	Rep 1	stdv	2	stdv	3	stdv	4	stdv	Sig.
	------	------	plants/square	foot	------				
Alfalfa	1.2	.62	1.8	.44	2.6	.61	2.4	.44	.000
Dandelion	0.4	.26	0.5	.27	1.1	.39	2.6	.72	.000
Bromegrass	3.1	1.96	2.0	1.43	2.3	1.68	1.4	1.04	.030

Table 3. Effect of tillage on soil covered by alfalfa residue in Winona Co.

	Tillage NoTill	Disc	Chisel	Moldbd	Sig.	n
5/18/88	-------	% cover	-------			
In Row	14.0	8.0	6.0	1.5	.003	8
Betwn Row	62.0	10.0	14.0	5.0	.000	8
6/20/88[1]						
In Row	48.0	8.8	8.3	3.8	.000	32
Betwn Row	37.0	8.6	7.5	3.5	.000	32

1. Averaged over cultivation.

Table 4. Effect of tillage and cultivation on soil covered by alfalfa residue at Winona Co. June 20, 1988, n=16.

	Tillage No Till	Disc	Chisel	Moldboard	Sig.[1]	Cultivation	Sig.[2]
In row	-------	% cover	-------			- % cover--	
Cultivation	43.5	7.8	8.0	3.8	.026	15.8	.013
No cultivation	52.5	9.8	8.5	3.8		18.6	
Between row							
Cultivation	22.3	7.0	5.8	2.8	.000	9.4	.000
No cultivation	51.8	10.3	9.3	4.3		18.9	

1. This is the p value of the interaction between tillage and cultivation, n=16.
2. This is p value of the main effect of cultivation, n=64.

Table 5. Effect of tillage on early corn growth and population at Winona Co. on June 20, 1988.

Variable	Tillage NoTill	Disc	Chisel	Moldbd	Sig.	n
	----	leaves/plant	----			
Stage	8.0	8.6	8.9	8.8	.000	80
	-- plants/A x 10^{-3}		------			
Stand	23.8	25.4	25.9	25.5	.199	16

Table 6. Effect of time and tillage on corn mortality in Winona Co. 1988.

Variable	Tillage No Till	Disc	Chisel	Moldboard	Sig.	n
	------	plants/A x 10^{-3}		--------		
May 18	28.0	29.5	28.9	27.8	.580	8
June 20	23.8	25.4	25.9	25.5	.199	16
Oct. 7	22.1	22.4	22.9	23.7	.334	64

Table 7. Effect of tillage on the average soil moisture to a depth of five feet in Winona Co. 1988.

	Tillage					
	No Till	Disc	Chisel	Moldboard		
Variable	%w/w				Sig.	n
4/20/88[1]	15.8	16.2	16.4	15.8	.597	20
11/9/88	22.2	20.6	20.0	20.0	.003	40

1. Soil samples were taken before tillage.

Table 8. Effect of tillage and cultivation on soil moisture in Winona Co. Nov. 9, 1988.[1]

	Tillage			
	No Till	Disc	Chisel	Moldboard
	%w/w			
Cultivation	22.2	20.7	20.7	19.7
No cultivation	22.1	20.5	19.4	20.3

1. The p value of the tillage by cultivation interaction is .030, n=20.

Table 9. Effect of tillage and depth on soil water at Winona Co. 1988.

	Tillage									
	No Till		Disc		Chisel		Moldboard		Depth	
	Spring[1]	Fall[2]	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Depth (feet)	% moisture									
0-1	13.8	24.7	14.2	24.6	14.1	24.3	14.0	25.1	14.0	24.7
1-2	15.9	24.2	16.4	23.8	17.0	23.7	16.0	22.6	16.3	23.6
2-3	16.1	19.2	16.9	16.5	17.0	15.8	16.3	14.3	16.5	16.4
3-4	16.8	19.7	16.7	17.5	17.4	16.6	16.8	16.6	16.9	17.6
4-5	16.7	23.1	16.9	20.8	16.6	19.8	15.7	21.3	16.5	21.3
Average	15.9	22.2	16.2	20.6	16.4	20.0	15.8	20.0	16.1	20.7

1. This is before establishment of tillage treatments. The p value of spring sampling (April 21, 1988) for the tillage by depth interaction is .993, n=4; and for depth .003, n=16.
2. The p value of fall sampling (November 9, 1988) for the tillage by depth interaction is .001, n=8; and for depth .001, n=32.

Table 10. Effect of tillage on cover by weeds in corn at Winona Co. on June 20, 1988, (observations made before cultivation.), n=4.

	Tillage				
	No Till	Disc	Chisel	Moldboard	
Weed	% cover				Sig.
Pigweed	0.8	0.5	3.3	0.5	.344
Lambsquarter	0.3	1.0	0.3	0.7	.455
Velvetleaf	2.0	3.7	3.0	5.3	.353
Wcupgrass	50.0	48.8	47.5	46.3	.995
Smartweed	0.0	0.3	0.0	0.3	
Alfalfa	2.3	0.0	0.0	0.0	
Horsetail	6.3	0.0	0.3	0.0	
Yelnutsedge	0.0	0.0	0.3	0.0	

Table 11. Effect of tillage on cover by weeds in corn at Winona Co. July 8, 1988[1]. n=8.

	Tillage				
	No Till	Disc	Chisel	Moldboard	
Weed	% cover				Sig.
Wcupgrass	38.1	29.1	32.5	25.4	.276
Alfalfa	1.3	0.3	0.3	0.3	.016
Pigweed	0.0	0.0	0.6	0.0	
Velvetleaf	0.0	0.0	0.0	0.2	

1. Values are averaged over cultivation. The p value for the tillage by cultivation interaction was < .100 for all weed species, n=8.

Table 12. Effect of cultivation on cover by weed in corn at Winona Co. July 8, 1988[1].

	Cultivation		
	Cult.	No Cult.	
Weed	-- % cover -----		Sig.
Wcupgrass	10.4	52.2	.000
Alfalfa	0.4	0.6	.343
Pigweed	0.0	0.3	.343
Velvetleaf	0.0	0.1	.356

1. The tillage by cultivation interaction has a p value of .260, n=16.

Table 13. Effect of tillage on corn phenology and water stress in Winona Co. July 12, 1988, n=8.

	Tillage				
Variable	No Till	Disc	Chisel	Moldboard	Sig.
Percent Silked Plants	0.0	9.4	18.8	37.5	.046
Silk Stage[1]	1.0	1.8	1.8	2.3	.005
Tassle Stage[2]	1.6	3.6	3.5	3.5	.007
	--------- (-bars) ----------				
Leaf water potential	12.1	11.7	12.4	12.3	.486

1. Silk stage:1=no silk, 2=silk emerging 0-1", 3=silk emerged 1-3", 4=silk red, 5=silk brown.
2. Tassle stage:1=no tassle, 2=spike, 3=expanding, 4=pollen shed, 5=tassel brown.

Table 14. Effect of tillage on grain and stover yields and moisture, in Winona Co. 1988, n=64.

	Tillage				
	No Till	Disc	Chisel	Moldboard	
Variable	---------- bu/A ----------				Sig.
Grain:Yield	94.2	102.1	99.8	101.2	.746
	---------- % ----------				
Moisture	19.1	16.6	16.4	16.1	.000
	---------- t/A ----------				
Stover:Yield	1.62	1.77	1.69	1.71	.463
	---------- % ----------				
Moisture	49.2	49.2	51.7	48.8	.221

Table 15. Effect of nitrogen rate on grain and stover yields and moisture in Winona Co. on Oct 7, 1988, n=64.

	Nitrogen Rate lbs./A[1]					
	0	30	60	90		
Variable	---------- bu/A -------				Nrate[2]	NxT[3]
Grain:Yield	95.7	96.1	100.5	105.0	.010	.591
	---------- % ----------					
Moisture	17.1	17.5	16.7	16.9	.119	.485
	---------- t/A ----------					
Stover:Yield	1.66	1.66	1.73	1.73	.316	.244
	---------- % ----------					
Moisture	49.9	49.6	49.2	50.2	.569	.873

1. And additional 18 lbs/A was applied with the starter fertilizer.
2. The p values for nitrogen rate.
3. The p value for the tillage by nitrogen interaction.

Table 16. Effect of tillage and cultivation on yield, moisture and final stand in Winona Co. on Oct.7, 1988.

	Tillage (n=32)									Cultivation (n=128)		
	No Till		Disc		Chisel		Moldboard					
Variable	Cult.	No Cult.	Cult.	No Cult.	Cult.	No Cult.	Cult.	No Cult.	Sig.[1]	Cult.	No Cult.	Sig.[2]
	---------- bu/A ----------											
Grain:Yield	106.2	82.1	107.7	96.5	109.5	90.1	114.0	88.5	.038	109.4	89.3	.000
	---------- % ----------											
Moisture	18.9	19.3	16.9	16.2	17.0	15.8	15.7	16.5	.010	17.1	17.0	.476
	---------- t/A ----------											
Stover:Yield	1.68	1.56	1.72	1.81	1.72	1.66	1.77	1.65	.024	1.72	1.67	.051
	---------- % ----------											
Moisture	50.2	48.3	50.3	48.1	51.8	51.5	49.9	47.7	.432	50.6	48.9	.002
	---------- plants/A x 10^{-3} ----------											
Stand	21.8	22.4	22.8	22.1	24.2	21.7	24.7	22.7	.152	23.4	22.2	.026

1. This is the p value of the interaction of tillage and cultivation.
2. This is the p value of the main effect of cultivation.

The Effect of Tillage and Cultivation on Corn Production on a Typic Argiudoll in Southeastern Minnesota[1]

J.F. Moncrief, T.L. Wagar, and J.J. Kuznia[2]

Abstract: Tillage did not affect continuous corn yields on a Typic Argiudoll soil in southeastern Minnesota. Tillage and cultivation affected the level of velvetleaf and giant foxtail differently. Discing resulted in the highest levels of velvetleaf. The no till system resulted in the highest levels of giant foxtail. Cultivation did not reduce velvetleaf stands with no tillage but was effective with other systems. Giant foxtail was reduced with cultivation in all tillage systems.

This is the fourth year of a study designed to evaluate tillage and cultivation on corn production in southeastern Minnesota. The soil is a deep silt loam soil with a high intrinsic yield potential. The planter used is a conventional planter equipped with clearing discs to clean the row area.

The soil cover in the row ranged from 6% to 43% for the moldboard and no till systems respectively (table 2). The disc and chisel systems resulted in similar cover in the row (about 25%). Early growth was not affected until "in row " cover was greater than 30% (no till system-table 3). Plant population was not affected by tillage. This site received 1.68 inches of rain (see weather summary of tillage studies this publication) shortly after planting which was likely responsible for the lack of tillage and residue effects on stand establishment.

The dominate weeds at this site are foxtail and velvet leaf. Early weed growth was not affected by tillage treatments (table 4). At harvest there was a tillage affect on both of these species (table 5). Moldboard plowed plots had the fewest weeds and no till the most. Cultivation reduced both foxtail and velvet leaf densities to slight (table 6).

There was an interaction between tillage and cultivation response (table 7). There were no foxtail in moldboard plots likely due to lower seed reserve and more effective herbicide control. The disc and chisel treatments had intermediate levels of foxtail and similar control with cultivation. No till plots had severe levels of foxtail. Although cultivation reduced the foxtail it was not entirely effective in controlling this weed. The cultivator used at this site is a conventional cultivator (no coulters or wide sweeps). A conservation tillage cultivator would have done a much better job.

The velvet leaf was the most prevalent in the disc and chisel treatments where cultivation was not done. The moldboard plowing and no till treatments without cultivation resulted in about the same amount of velvet leaf. The highest infestation of velvet leaf occurred in the disced plots without cultivation. The lack of control with cultivation in no till plots is due to the conventional cultivator used that is not designed for this system.

Grain yields and moisture are shown in table 8. There was no significant effect of tillage on grain yields although the yield trend appeared to follow the weed observations. In light of the small effect of residue on early growth it is surprising to have a 4% spread in grain moisture which closely follows "in row" cover. The average cultivation response was about 13 bushels per acre (table 9).

The interaction between cultivation and tillage was not statistically significant (table 10). This may have been due more to the three replications at this site. However, the cultivation response across tillage systems

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1 This project is supported in part by the Soil Conservation Service. Their support is greatly appreciated. Data collection was aided by the Fillmore County Extension and SCS office. This project would not have been possible without this assistance.

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followed similar trends to weed observations. Corn grown with moldboard plowing had a response to cultivation of 5 bushels per acre (fewest weeds). The chisel and disc systems resulted in 18 bushels per acre. The foxtail and velvetleaf was a problem for the chisel system and velvetleaf a problem for disc system. The no till grown corn response to cultivation was intermediate at 11 bushels per acre. The velvet leaf was not controlled with cultivation. Most of the response was due to foxtail control.

FILLMORE COUNTY

Table 1. Cultural practices at Fillmore County, MN. 1988.

Tillage
- No Till
- Fall Disc-Light disc in the spring
- Fall Chisel Plow-Light disc in the spring
- Fall Moldboard Plow-Light disc in the spring

Cropping History
1985-87 Corn

1988 Crop
Corn-Pioneer 3737

Cultivation
Each plot was split with cultivation on June 14, 1988.

Planting and Harvest Date
Planter was a John Deere Max-Emerge 4 row (38") planter equipped with John Deere row cleaners.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 3, 1988	28,000 plants/A	October 4, 1988

Fertilization History
1983-injected 5-6000 gal/ac of liquid dairy manure.

	Material		Actual			
			N	P_2O_5	K_2O	
Crop	Analysis	Rate	---	lbs/A	----	Date Applied
Corn:	16-41-8[1]	125 lb/A	20	51	10	May 6, 1985
	82-0-0	134 lb/A	110	0	0	May 22, 1985
Corn:	9-23-30[1]	125 lb/A	11	29	38	May 7, 1986
	82-0-0	244 lb/A	200	0	0	May 22, 1986
Corn:	9-23-30[1]	100 lb/A	9	23	30	April 29, 1987
	82-0-0	232 lb/A	190	0	0	May 12, 1987

1. Applied 2" beside and 2" below seed.

Fertilizer

	Material		Actual			
			N	P_2O_5	K_2O	
Crop	Analysis	Rate	---	lbs/A	----	Date Applied
Corn:	9-23-30[1]	100 lbs/A	9	23	30	May 3, 1988
	82-0-0	232 lb/A	190	0	0	June 9, 1988

1. Applied 2" beside and 2" below seed.

Soil
Tama (Typic Argiudolls, fine-silty, mixed, mesic) and Downs (Mollic Hapludalfs, fine-silty, mixed, mesic) silt loams, eroded, 2 to 6 percent slopes. Soil is well drained.

Weed Control

1 qt/A (2 lbs/A) Dual + 2.5 qts/A (2.5 lbs/A) Bladex on May 6, 1988.

Insect Control

6.9 lbs/A (1 lb/A) of Counter 15G at time of planting.

Table 2. Effect of tillage on soil covered by corn residue in Fillmore Co. on June 9, 1988, n=12.

	Tillage				
	No Till	Disc	Chisel	Moldboard	
Residue Location	% cover				Sig.
In Row	43.0	25.3	28.3	6.0	.000
Between Row	71.3	37.7	29.0	6.7	.000

Table 3. Effect of tillage on early corn growth and population in Fillmore Co. on June 9, 1988.

	Tillage					
	No Till	Disc	Chisel	Moldboard		
Variable	leaves/plant				Sig.	n
Growth Stage	5.5	5.8	5.8	5.7	.004	60
	plants/A x 10^{-3}					
Population	27.9	27.4	26.6	26.3	.300	12

Table 4. Effect of tillage on weed severity in corn at Fillmore Co. on June 9, 1988, n=3.

	Tillage				
	No Till	Disc	Chisel	Moldboard	
Weed	% cover				Sig.
Velvetleaf	6.7	15.0	13.3	5.7	.158
Foxtail	11.0	4.3	8.0	9.3	.875
Yellwnutedge	0.0	0.0	0.0	0.7	
Dandelion	0.2	0.3	0.0	0.2	
Milkweed	0.2	0.0	0.0	0.0	

Table 5. Effect of tillage on weed severity in corn at Fillmore Co. on Oct. 4, 1988, n=6.

	Tillage				
	No Till	Disc	Chisel	Moldboard	
Weed	weed severity[1]				Sig.
Velvetleaf	2.3	3.2	2.5	1.7	.010
Foxtail	4.3	1.0	1.7	0.0	

1. Weed severity scale; 1=slight to 5=severe.

Table 6. Effect of cultivation on weed severity in corn at Fillmore Co. on Oct 4, 1988, n=12.

	Cult.	No Cult.	
Weed	weed severity[1]		Sig.
Velvetleaf	1.8	3.0	.001
Foxtail	1.3	2.3	.013

1. Weed severity scale; 1=slight to 5=severe.

Table 7. Effect of tillage and cultivation on weeds in corn at Fillmore Co. on Oct. 4, 1988[1].

		Tillage			
		No Till	Disc	Chisel	Moldboard
Weed		weed severity[2]			
Foxtail	Cultivation	3.7	0.7	0.7	0.0
	No Cultivation	5.0	1.3	2.7	0.0
Velvetlf	Cultivation	2.3	2.0	1.7	1.3
	No Cultivation	2.3	4.3	3.3	2.0

1. The p value for the tillage by cultivation interaction is .023, n=3.
2. Weed severity scale; 1=slight and 5=severe.

Table 8. Effect of tillage on yield and moisture in Fillmore Co. on Oct. 4, 1988, n=6.

	Tillage				
	No Till	Disc	Chisel	Moldboard	
Variable	bu/A				Sig.
Grain Yield	101.9	97.3	103.1	110.6	.511
	%				
Moisture	20.5	18.6	18.6	16.6	.000

Table 9. Effect of cultivation on corn yield and moisture at Fillmore Co. on Oct. 4, 1988, n=12.

	Cult.	No Cult.	
Variable	bu/A		Sig.
Grain Yield	109.9	96.5	.001
	%		
Moisture	18.6	18.5	.659

Table 10. Effect of tillage and cultivation on corn yield and moisture at Fillmore Co. on Oct. 4, 1988.

		Tillage				
		No Till	Disc	Chisel	Moldboard	
Variable		bu/A				Sig.[1]
Grain Yield	Cultivation	107.5	106.8	112.3	113.2	
	No Cultivation	96.3	87.9	93.9	108.1	.165
		%				
Moisture	Cultivation	20.6	18.7	18.5	16.7	
	No Cultivation	20.3	18.5	18.6	16.5	.944

1. This is the p value for the cultivation by tillage interaction, n=3.

EFFECT OF TILLAGE AND SWINE MANURE ON N UPTAKE AND CORN YIELD[1]

J.R.Joshi, J.F.Moncrief, D.A.Andow, J.B.Swan, and G.L.Malzer[2]

Abstract: This was the second year of the study initiated in 1987 in Goodhue County to evaluate the effects of tillage, and rate and frequency of injected liquid swine manure on corn. Averaged grain yields were lower than normal ranging from 90 bu/A for anhydrous ammonia (170 lbs N/A) to 77 bu/A for low rate of manure (92 lbs N/A). Ridge till resulted in about 16 bu/A increase over chisel plow. Most growth and yield parameters were higher during the year of application of manure or fertilizer than in the year following application. Soil moisture both in fall and spring was fairly uniform throughout the profile. Soil N levels were about twice as high in fall than in spring.

INTRODUCTION

In 1987, a study was initiated in Goodhue County, MN to evaluate the effects of tillage and frequency of manure application on corn yield and N uptake. This was the second and completion year of initial establishment of the treatments.

Liquid swine manure is injected every alternate years (on an even and odd year basis) at two rates (high manure, approximately 12,000 gal/A, and low manure, approximately 7,300 gal/A) on ridge till and chisel till treatment. Additional treatments included a fertilized treatment, applied annually and every alternate year with anhydrous ammonia at a recommended rate of 170 lbs N/A, and a check treatment receiving neither manure nor fertilizer. Various cultural practices followed are summarized in Table 1. These observations include fall and spring soil sampling to a depth of 5' to monitor profile N.

RESULTS

Residue Cover. Residue cover measurements were made on June 15 on treatments receiving manure at high and low rates, annual anhydrous ammonia and check(Table 2). In general, residue was higher between the rows than in the rows. Exception to this was observed in anhydrous treatment in ridge till where residue was higher in the rows. Since anhydrous was applied before these measurements, residue may have been swept in the rows during the operation. Ridge till had higher residue between the rows; whereas, chisel plowed treatments had higher residue in the rows with the exception of the anhydrous treatment in ridge till.

Early Whole Plant Analysis. The results of dry matter and N analysis made on early whole plant samples taken on July 15 are summarized in Table 3. Anhydrous treatment yielded highest dry matter, N concentration in the tissue and total N uptake at this stage. High rate of manure yielded higher dry matter, tissue N and N uptake in the year of application, but lower in the year after application of manure when compared to the low rate of manure. Tillage did not affect total dry matter and N uptake but ridge till had significantly greater N in the tissue than the chisel treatment.

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Leaf Water Potential. In order to measure the moisture stress in the plants, leaf water measurements were made on July 27 and the results are presented in Table 4. Tillage had no significant effect on leaf water stress. Fertilized treatment showed highest stress followed by those receiving manure at high rates and then by those receiving low rates of manure. The stress was greatest in the year of application than in the year after except in anhydrous treatment where the results were opposite, especially in the chisel plow.

Plant Population and Stover Yield. Total plant population at harvest was higher in the ridge treatment than the chisel treatment (Table 5) but the difference was not significantly different. Similarly, manure applied at higher rate had higher population, the difference not being significant. Stover dry matter was higher with chisel plow with regard to tillage and with anhydrous ammonia with regards to fertility treatments. There was a significant difference in stover yield due to the year of application-higher yields in the application year than the carry over year. Stover moisture was not affected by tillage or N treatments.

Grain Yields, Grain Moisture and Total Dry Matter. The summary of total grain yields, grain moisture and total dry matter is given in Table 6. Ridge till yielded about 16 bu/A more grains than chisel plow, the greatest yield being in anhydrous treatment in the year of application. The high rate of manure had generally higher yields than the low rate except in the ridge till treatment that received manure at low rate in 1988. Grain moisture was greater in the year after application of manure or fertilizer than the year of application. Total dry matter was greater for the year of application than year after. Tillage had no significant effect on grain moisture or total dry matter. Chisel treatment yielded higher dry matter in the application year for high manure, and both in the year of and year after application of anhydrous ammonia.

Grain N (1987). The results of the analysis of grain samples from 1987 season are presented in Table 7. Anhydrous treatment had higher grain N in the year of application followed by high rate of manure and the low rate of manure. In the year after application, however, low rate of manure had higher grain N than the high rate. Tillage had no significant effect on grain N.

Grain and Stover N (1988). Neither grain nor stover N were affected by tillage in 1988 (Table 8). The highest grain N concentration was observed in anhydrous treatment followed by high rate and then low rate of manure, respectively. Also, it was higher in the year of application than the year after application. Stover N followed the similar trend except in the year after application when low rate of manure had higher stover N than the high rate of manure. Highest N uptake was associated with anhydrous treatments followed by low manure treatment and finally the high manure treatments. The difference between these manure treatments was particularly striking in the ridge till applied with low manure, the results being similar to grain yields.

Harvest Index. Tillage had marked influence on the harvest index, a ratio of total grain dry matter to that of total dry matter (grain and stover combined, Table 9). Ridge till had in higher index values than the chisel treatment, indicative of the higher grain yields as compared to stover yields in chisel plow. The harvest index was higher in the year of application than the year after application of manure or fertilizer.

Soil Moisture. Gravimetric soil moisture of the samples taken to a depth of 5 ft before planting in the third week of April are summarized in Table 10. Soil moisture increased gradually with depth in the profile, and ranged from 19.4% in the top 6" to 23.9% in the bottom 3 ft increment. Tillage had no significant effect on soil moisture.

In fall, the soil moisture in the top 1 ft ranged from 21.5 to 23.6% (wt./wt., Table 11). The moisture up to top 2 ft. were fairly uniform underlain by slightly drier region below (2-4 ft), moisture ranging from 16.4 to 21.1%. Soil moisture in the lowest 1 ft depth was same as in the surface. Soil moisture was not affected by tillage or location of samples with respect to row position. Manure applied at the high rate maintained higher soil moisture throughout the profile than the anhydrous application. In the check treatment, moisture throughout the profile was fairly uniform - similar to the surface levels.

Soil Nitrogen (Spring). The results of the soil analysis for N in 5 ft soil profile is given in Table 12. Main effects of tillage was not significant in any N forms. Anhydrous ammonia resulted in highest soil N followed by low rate of manure (Table 13). The high rate of manure had lowest N. Probably this high rate of N in the profile is probably the reason for higher yields in the low rate over the high rate of manure applied. About 1/3 of soil N was in nitrate form in the anhydrous treatment; whereas, most of the N in the manure treatment was in ammonium form. There was a tillage by depth interaction (Table 14) with respect to nitrate-N, ridge till had higher nitrate in all depths except the 1-2 ft increment where chisel plow exceeded the ridge till. N levels in the year of application were higher in the top 2 ft but less below that as compared to carry over manure treatment (Table 15). The nitrate levels were higher throughout the profile with anhydrous in both tillages; however, high rate of manure had higher nitrate-N in ridge till and the low rate of manure had higher nitrate-N in the chisel treatment.

Soil Nitrogen (Fall). Total, ammonium and nitrate N levels in the 5 ft profile were higher in fall than in spring (Table 17). Although there was no significant effect of tillage or N rate on any of these forms of N, anhydrous treatment had higher N than manure or check in ridge till and almost no difference in chisel treatment (Table 18). Ridge till had higher N in each depth of the profile (Table 19). Anhydrous treatment had generally higher N levels throughout the profile except in the 3-4 ft increment where high rate of manure had higher N than both anhydrous and check (Table 20). Check treatment had higher N in the first two feet than the high rate of manure. More N in was present between the rows up to 3 feet but less below that than in-row samples (Table 21). Manure treatment had higher N deeper in the profile (>3 ft) in the row but had lower N between the rows than check or anhydrous treatments (Table 22). Total N was highest between the rows in the anhydrous treatment, and check treatment was the lowest. Manure treatments were intermediate.

Table 1. Cultural practices at Goodhue County, MN 1988.

Tillage
Ridge Till-cultivated June 22
Chisel Plow-Chiseled on May 16

Cropping History
Corn since 1974
1988-Corn Pioneer 3737

Manure Application
Injected liquid swine manure with following rate and analysis on May 4-5, 1988.

		Rate		
		Mean	StDev	n
High Rate				
Manure	(gal/A)	11988	779	8
Total-N	(lbs/A)	152	10	8
NH_4-N	(lbs/A)	71	4	8
Low Rate				
Manure	(gal/A)	7272	448	8
Total-N	(lbs/A)	92	6	8
NH_4-N	(lbs/A)	43	3	8

Planting Information for 1988 Crop Year
A two row Series 1 Econo till planter equipped with a 2" fluted coulter.

Crop	Date	Rate	Harvested
Corn	May 18,1988	32,000 plants/A	October 8-10, 1988

Fertilizer 1988

Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied	Method of Application
		---	lb/A	---		
82-0-0	207 lbs/A	170	0	0	May 26, 1988	Injected

Soil

Seaton (Typic Hapludalfs, fine-silty, mixed, mesic) silt loam, Mt. Carroll (Mollic Hapludalfs, fine-silty, mixed, mesic) silt loam and a Port Byron (Typic Hapludolls, fine-silty, mixed, mesic) silt loam.

Insect Control

9 lbs/A (1.35 lb/A) Counter 15G applied on May 18, 1988.

Table 2. Surface residue cover as affected by tillage, and N source and rate of application in Goodhue Co. MN on June 15, 1988.

	Residue Cover			
	Ridge Till		Chisel	
Rate & and Source of N	In Row	Bet rows	In Row	Bet rows
	%			
Manure (High rate)	7.0	36.0	11.0	7.0
Manure (Low rate)	8.8	27.2	10.0	21.0
Anhy.Amm. (annual)	35.0	28.0	15.0	19.0
Check	13.3	42.7	14.4	20.8

Table 3. The effect of tillage, and N source and rate on stover dry matter, stover N, and N uptake in Goodhue Co. MN on July 15, 1988.

		STOVER DRY MATTER			N CONCENTRATION			N UPTAKE		
Rate & Source of N	Year[1]	Ridge	Chisel	Mean	Ridge	Chisel	Mean	Ridge	Chisel	Mean
		g/plant			%			mg/plant		
Manure	Yr.of	28.3	40.6	34.4	2.25	1.64	1.95	643	679	661
(Low rate)	Yr.after	25.1	26.2	25.7	2.06	1.74	1.90	521	452	487
	Mean	26.7	33.4	30.1	2.16	1.69	1.92	582	566	574
Manure	Yr.of	31.7	42.4	37.0	2.14	1.86	2.00	671	774	722
(High rate)	Yr.after	21.6	24.3	22.9	1.93	1.67	1.80	414	395	405
	Mean	26.6	33.3	30.0	2.04	1.76	1.90	542	585	563
Anhydrous	Yr.of	33.0	37.6	35.3	2.68	2.33	2.51	889	872	880
Ammonia	Yr.after	38.7	41.6	40.1	2.40	1.86	2.13	927	757	842
	Mean	35.8	39.6	37.7	2.54	2.10	2.32	908	815	861

Pr>F

	Tillage (T)	N Rate (N)	Year (Y)	T*N	T*Y	Y*N	Y*N*T
Dry matter	.214	.233	.216	.749	.363	.059	.134
N conc.	.025	.010	.019	.574	.889	.468	.446
N uptake	.805	.027	.095	.544	.623	.093	.941

[1] Year refers to the year of application of the biennial treatments.

Table 4. The effect of tillage, and N source and rate of application on leaf water potential in Goodhue Co.,MN, on July 27, 1988.

Rate & Source of N	Year[1]	LEAF WATER POTENTIAL Ridge	Chisel	Mean	Source	Pr>F
		----	(-bar)	----		
Manure	Yr.of	14.3	15.4	15.2	Tillage (T)	.619
(Low rate)	Yr.after	14.6	13.2	14.9	N Rate (N)	.096
	Mean	14.5	14.3	13.9	Year (Y)	.763
Manure	Yr.of	15.5	15.3	15.4	T*N	.119
(High rate)	Yr.after	13.2	14.0	13.6	T*Y	.276
	Mean	14.3	14.6	14.5	Y*N	.005
Anhydrous	Yr.of	14.9	14.7	14.6	Y*N*T	.295
Ammonia	Yr.after	14.3	16.1	15.8		
	Mean	14.6	15.4	15.2		

[1] Year refers to the year of application of the biennial treatments.

Table 5. The effect of tillage and N source and rate on total plant population at harvest, stover dry matter, and stover moisture at harvest in Goodhue Co. MN in 1988.

Rate & Source of N	Year[1]	PLANT POPULATION Ridge	Chisel	Mean	STOVER DRY MATTER Ridge	Chisel	Mean	STOVER MOISTURE Ridge	Chisel	Mean
		- plants/A*10^{-3} -			---- tons/A ----			---- % ----		
Manure	Yr.of	27.2	25.7	26.5	1.74	1.94	1.84	51.6	44.7	48.2
(Low rate)	Yr.after	26.7	25.6	26.2	1.40	1.66	1.53	53.3	47.3	50.3
	Mean	27.0	25.6	26.3	1.57	1.80	1.68	52.5	46.0	49.3
Manure	Yr.of	27.5	27.1	27.3	1.47	2.06	1.77	46.5	46.3	46.4
(High rate)	Yr.after	27.4	26.4	26.9	1.35	1.55	1.45	45.6	49.4	47.5
	Mean	27.4	26.8	27.1	1.41	1.81	1.61	46.1	47.8	47.0
Anhydrous	Yr.of	26.7	25.6	26.2	1.76	2.08	1.92	49.9	51.2	50.6
Ammonia	Yr.after	26.2	25.0	25.6	1.80	2.22	2.01	49.9	51.0	50.5
	Mean	26.5	25.3	25.9	1.78	2.15	1.97	49.9	51.1	50.5
Mean		27.0	26.0	26.5	1.59	1.92	1.75	49.5	48.3	48.9

Pr>F

	Tillage (T)	N Rate (N)	Year (Y)	T*N	T*Y	Y*N	Y*N*T
Population	.145	.474	.232	.804	.996	.953	.722
Stover dry matter	.051	.039	.019	.679	.696	.022	.191
Stover moisture	.219	.243	.322	.081	.241	.341	.479

[1] Year refers to the year of application of the biennial treatments.

Table 6. The effect of tillage and N frequency and rate on grain yields, grain moisture and total dry matter in Goodhue Co. MN in 1988.

		GRAIN YIELD			GRAIN MOISTURE			TOTAL DRY MATTER		
Rate &		Ridge	Chisel	Mean	Ridge	Chisel	Mean	Ridge	Chisel	Mean
Source of N	Year[1]	bu/A			%			tons/A		
Manure	Yr.of	109.5	68.5	89.3	22.1	25.7	23.9	4.39	3.16	3.77
(Low rate)	Yr.after	74.8	53.2	64.0	27.2	26.6	26.9	3.20	2.61	3.90
	Mean	92.2	60.8	76.6	24.6	26.2	25.4	3.80	2.88	3.34
Manure	Yr.of	98.1	97.0	97.6	24.4	22.9	23.7	3.69	4.25	3.97
(High rate)	Yr.after	74.7	69.3	72.0	25.4	24.9	25.2	3.01	2.89	2.95
	Mean	86.4	83.1	84.8	24.9	23.9	24.5	3.35	3.57	3.46
Anhydrous	Yr.of	129.3	110.7	120.0	25.6	27.0	26.3	4.98	5.08	5.03
Ammonia	Yr.after	103.0	96.4	99.6	25.5	26.0	25.8	4.37	4.75	4.56
	Mean	116.1	103.5	109.8	26.6	26.5	26.1	4.67	4.92	4.79
Mean		98.2	82.6	90.4	25.0	25.5	25.5	3.94	3.79	3.86

Pr>F

	Tillage(T)	N Rate(N)	Year(Y)	T*N	T*Y	Y*N	Y*N*T
Grain Yield	.035	.003	.030	.152	.161	.772	.338
Grain moisture	.571	.187	.029	.647	.307	.059	.528
Total dry matter	.424	.105	.028	.105	.806	.426	.079

[1] Year refers to the year of application of the biennial treatments.

Table 7. The effect of tillage, N source and frequency of application on grain N in Goodhue Co. MN in 1987.

		GRAIN N				
Rate &		Ridge	Chisel	Mean		
Source of N	Year[1]	(%)			Source	Pr>F
Manure(Low rate)	Yr.of	1.58	1.53	1.56	Tillage(T)	.757
	Yr.after	1.60	1.54	1.57	N rate (N)	.082
	Mean	1.59	1.54	1.57	Year (Y)	.044
Manure(High rate)	Yr.of	1.55	1.61	1.58	T*N	.003
	Yr.after	1.43	1.41	1.42	T*Y	.649
	Mean	1.49	1.51	1.50	Y*N	.009
Anhydrous	Yr.of	1.71	1.70	1.71	Y*N*T	.711
Ammonia	Yr.after	1.45	1.48	1.47		
	Mean	1.58	1.59	1.59		

[1] Year refers to the year of application of the biennial treatments.

Table 8. The effect of tillage and N rate and source on grain N, stover N, grain N recovery, and total N uptake in Goodhue Co. MN in 1988.

Rate & Source of N	Year[1]	GRAIN N Ridge	GRAIN N Chisel	STOVER N Ridge	STOVER N Chisel	GRAIN N UPTAKE Ridge	GRAIN N UPTAKE Chisel	TOTAL N UPTAKE Ridge	TOTAL N UPTAKE Chisel
		---- % ----		---- % ----		-- lbs/A --		-- lbs/A --	
Manure	Yr.of	1.42	1.33	0.63	0.57	73.5	43.1	95.5	65.2
(low rate)	Yr.after	1.27	1.24	0.49	0.56	44.9	31.2	58.7	49.8
	MEAN	1.35	1.29	0.56	0.57	58.9	37.1	76.5	57.6
Manure	Yr.of	1.29	1.40	0.53	0.60	59.9	64.2	75.4	88.9
(high rate)	Yr.after	1.22	1.26	0.46	0.45	43.1	41.3	55.5	55.3
	MEAN	1.26	1.33	0.50	0.53	51.5	52.3	65.6	71.5
Anhydrous	Yr.of	1.51	1.51	0.72	0.71	92.3	79.1	117.7	108.6
Ammonia	Yr.after	1.37	1.39	0.58	0.73	66.7	63.4	87.6	95.8
	MEAN	1.44	1.45	0.65	0.72	79.1	71.0	102.2	101.9

Pr>F

Source	Tillage (T)	N Rate (N)	Year (Y)	T*N	T*Y	Y*N	Y*N*T
Grain N	.422	.003	.010	.141	.900	.947	.662
Stover N	.220	.029	.113	.611	.368	.811	.226

[1] Year refers to the year of application of the biennial treatments.

Table 9. Total grain dry matter and harvest index as affected by tillage, and N source and rate of application in Goodhue Co. MN in 1988.

Rate & Source of N	Year[1]	HARVEST INDEX Ridge	HARVEST INDEX Chisel	HARVEST INDEX Mean
Manure	Yr.of	0.59	0.35	0.47
(Low rate)	Yr.after	0.54	0.37	0.46
	Mean	0.57	0.36	0.46
Manure	Yr.of	0.59	0.50	0.55
(High rate)	Yr.after	0.55	0.45	0.50
	Mean	0.57	0.47	0.52
Anhydrous	Yr.of	0.65	0.59	0.62
Ammonia	Yr.after	0.58	0.52	0.55
	Mean	0.61	0.55	0.58
Mean		0.58	0.46	0.52

[1] Year refers to the year of application of the biennial treatments.

Table 10. The effect of tillage, and N source and rate on soil moisture in Goodhue Co. MN on April 19-21, 1988.

Rate & Source of N	Year[1]	0-6 in. Ridge	0-6 in. Chisel	6-12 in. Ridge	6-12 in. Chisel	1-2 ft Ridge	1-2 ft Chisel	2-5 ft Ridge	2-5 ft Chisel
		% (wt./wt.)							
Manure	Yr.of	20.2	19.8	22.2	21.7	22.6	22.1	23.5	22.9
(Low rate)	Yr.after	20.8	19.9	22.1	21.4	22.3	22.3	23.9	23.4
	MEAN	20.5	19.9	22.2	21.6	22.5	22.2	23.7	23.2
Manure	Yr.of	19.4	19.8	21.3	22.0	22.3	21.9	23.4	23.3
(High rate)	Yr.after	19.9	19.1	21.4	19.9	21.5	21.8	22.7	23.4
	MEAN	19.7	19.5	21.4	21.0	21.9	21.9	23.1	23.4
Anhydrous	Yr.of	19.5	21.2	21.0	21.6	21.9	22.2	23.6	23.8
Ammonia	Yr.after	19.9	19.1	21.5	21.9	21.8	22.5	23.5	23.5
	MEAN	19.7	20.2	21.3	21.8	21.9	22.4	23.6	23.7

Pr>F

Source	Tillage (T)	N Rate (N)	Year (Y)	T*N	T*Y	Y*N	Y*N*T
0-6in	.791	.629	.614	.530	.158	.710	.546
6-12in	.802	.515	.378	.526	.141	.213	.561
1-2′	.933	.396	.625	.181	.185	.701	.873
2-5′	.927	.749	.947	.446	.155	.258	.410

[1] Year refers to the year of application of the biennial treatments.

Table 11. Gravimetric soil moisture as affected by tillage, and N source and rate of application in Goodhue Co. MN on Oct 31-Nov 1, 1988.

Rate & Source[1]	Row[2]	0-1 FT Ridge	0-1 FT Chisel	1-2 FT Ridge	1-2 FT Chisel	2-3 FT Ridge	2-3 FT Chisel	3-4 FT Ridge	3-4 FT Chisel	4-5 FT Ridge	4-5 FT Chisel
		% (wt./wt.)									
Manure	IR	22.7	22.8	23.6	23.6	20.4	19.7	19.3	18.3	21.2	22.4
(High)	BR	22.3	23.0	22.6	23.1	18.3	18.7	18.3	17.6	22.4	22.5
Anhydr.	IR	21.4	22.6	21.7	22.4	17.1	16.9	16.4	17.7	19.1	22.0
ammonia	BR	21.9	22.5	21.5	22.0	17.6	16.0	18.3	17.8	20.2	21.5
Check	IR	22.3	21.8	23.3	22.6	21.1	18.7	20.2	19.7	20.1	22.5
	BR	22.6	21.8	22.9	23.0	21.0	19.9	20.3	20.0	20.9	23.0

Pr>F

Source	Tillage (T)	N Rate (N)	Depth (D)	T*N	T*D	D*N	D*N*T
Moisture (avg. over row)	.965	.102	.000	.751	.668	.004	.930

[1] Only the treatments of the year of application.
[2] Row position for soil sampling, IR=in row and BR=between rows.

Table 12. The effect of tillage, and N source and rate on soil profile N in Goodhue Co. MN on April 19-21, 1988.

N Rate & Source of N	Year[1]	0-6 in. Ridge	0-6 in. Chl	0-6 in. Mean	6-12 in. Ridge	6-12 in. Chl	6-12 in. Mean	1-2 ft Ridge	1-2 ft Chl	1-2 ft Mean	2-5 ft Ridge	2-5 ft Chl	2-5 ft Mean	0-5 ft Ridge	0-5 ft Chl	0-5 ft Mean
		lbs/A														
		TOTAL-N														
Manure	Yr.aft	6.9	4.4	5.7	6.6	5.9	6.2	11.9	10.9	11.4	33.9	25.5	29.7	59.3	46.7	53.0
(High rate)	Yr.of	5.4	4.5	5.0	7.9	4.6	6.2	14.2	9.7	12.0	30.9	26.6	28.7	58.4	45.4	51.9
	MEAN	6.2	4.5	5.3	7.3	5.3	6.2	13.0	10.3	11.7	32.4	26.1	29.2	58.9	46.2	52.4
Anhydrous	Yr.aft	6.7	4.3	5.5	7.0	6.7	6.8	12.4	9.7	11.0	52.2	32.2	42.2	78.3	52.9	65.5
ammonia	Yr.of	11.7	6.1	8.9	9.8	7.9	8.9	23.7	36.6	30.1	36.1	31.4	33.8	81.3	82.0	81.7
	MEAN	9.2	5.2	7.2	8.4	7.3	7.9	18.0	23.1	20.6	44.1	31.8	38.0	79.7	67.4	73.7
Manure	Yr.aft	6.2	6.6	6.4	5.6	7.2	6.4	10.6	10.6	10.6	35.9	28.3	32.1	58.3	52.7	55.5
(low rate)	Yr.of	6.1	5.9	6.0	6.3	6.6	6.4	11.8	11.2	11.5	28.3	26.3	27.3	52.5	50.0	51.2
	MEAN	6.2	6.2	6.2	6.0	6.9	6.4	11.2	10.9	11.1	32.1	27.3	29.7	55.5	51.3	53.4
		AMMONIUM-N														
	Year	Ridge	Chl	Mean	Ridge	Chl	Mean	Ridge	Chl	Mean	Ridge	Chl	Mean	Ridge	Chl	Mean
Manure	Yr.aft	5.1	3.9	4.5	5.4	5.3	5.4	10.1	10.4	10.2	28.0	24.7	26.3	48.6	44.3	46.4
(High rate)	Yr.of	3.6	3.9	3.8	4.8	4.5	4.6	10.8	9.4	10.1	24.9	25.8	25.4	44.1	43.6	43.9
	MEAN	4.4	3.9	4.1	5.1	4.9	5.0	10.4	9.9	10.2	26.5	25.2	25.9	46.4	43.9	45.2
Anhydrous	Yr.aft	4.8	3.6	4.2	5.4	5.8	5.6	9.6	8.0	9.3	26.9	30.0	28.4	46.7	47.4	47.5
ammonia	Yr.of	9.3	4.9	7.1	5.3	5.6	5.4	9.9	9.3	9.6	23.6	26.3	25.0	48.1	46.1	47.1
	MEAN	7.0	4.2	5.6	5.3	5.7	5.5	9.7	9.1	9.4	25.2	28.2	26.7	47.2	47.2	47.2
Manure	Yr.aft	4.5	3.6	4.0	4.6	5.0	4.8	8.7	8.6	8.7	29.2	24.4	26.8	47.0	41.6	44.3
(low rate)	Yr.of	5.4	4.7	5.1	4.7	5.7	5.2	9.7	10.1	9.9	25.8	22.4	24.1	45.6	42.9	44.3
	MEAN	4.9	4.2	4.6	4.6	5.3	5.0	9.2	9.4	9.3	27.5	23.4	25.5	46.2	42.3	44.4
		NITRATE-N														
	Year	Ridge	Chl	Mean	Ridge	Chl	Mean	Ridge	Chl	Mean	Ridge	Chl	Mean	Ridge	Chl	Mean
Manure	Yr.aft	1.8	0.4	1.1	1.2	0.5	0.8	1.9	0.4	1.2	5.9	0.8	3.3	10.8	2.1	6.4
(High rate)	Yr.of	1.8	0.7	1.2	3.1	0.2	1.6	3.4	0.4	1.9	5.9	0.8	3.3	14.2	2.1	8.0
	MEAN	1.8	0.6	1.2	2.1	0.4	1.2	2.6	0.4	1.5	5.9	0.8	3.3	12.4	2.2	7.2
Anhydrous	Yr.aft	1.9	0.6	1.2	1.6	0.9	1.2	2.7	0.8	1.8	25.3	2.2	13.8	31.5	4.5	18.0
ammonia	Yr.of	2.4	1.2	1.8	4.5	2.3	3.4	13.7	27.3	20.5	12.6	5.1	8.9	33.2	35.9	34.6
	MEAN	2.1	0.9	1.5	3.1	1.6	2.3	8.2	14.1	11.1	19.0	3.6	11.3	32.4	20.2	26.2
Manure	Yr.aft	1.8	2.9	2.4	1.1	2.4	1.7	1.9	3.3	2.6	6.8	3.9	5.3	11.6	12.5	12.0
(low rate)	Yr.of	0.6	1.2	0.9	1.6	0.9	1.2	2.1	1.0	1.6	2.5	3.9	3.2	6.8	7.0	6.9
	MEAN	1.2	2.0	1.6	1.3	1.6	1.5	2.0	2.1	2.1	4.6	3.9	4.3	9.1	9.6	9.5

Pr>F

Source	Tillage (T)	N Rate (N)	Year (Y)	T*N	T*Y	Y*N	Y*N*T	Depth (D)	T*D	N*D	Y*D	T*N*D	T*Y*D	N*Y*D	T*N*Y*D
Total-N	.237	.086	.570	.655	.213	.363	.668	.001	.169	.399	.036	.452	.266	.108	.824
NH_4-N	.440	.782	.309	.745	.770	.798	.845	.001	.851	.972	.004	.325	.638	.569	.973
NO_3-N	.234	.072	.472	.223	.373	.436	.379	.029	.021	.032	.128	.005	.426	.119	.667

[1] Year refers to the year of application of the biennial treatments.

Table 13. The effect of rate and source of N on soil N in Goodhue Co.,MN, in 5' depth (avg. over tillage) on April 19-21, 1988.

Rate & Source of N	Total-N	NH_4-N	NO_3-N
	--------	lbs/A	------
Manure (low)	67.0	55.0	12.0
Manure (high)	65.5	56.5	9.0
Anhydrous	92.0	59.0	33.0
Pr>F			
N Rate and source	.0857	.7823	.0719

Table 14. The effect of tillage and depth on nitrate-N (avg. over N treatments) in Goodhue Co. MN on April 19-21, 1988.

Depth	Ridge Till	Chisel
	----- lbs/A	------
0-6"	1.7	1.2
6-12"	2.1	1.2
1-2'	4.3	5.5
2-5'	9.8	2.8
Till*depth Pr>F=.0212		

Table 15. Effect of depth and N rate and source on soil N in Goodhue Co. on April 21, 1988.

Depth	Yr.	Total-N	NH_4-N	NO_3-N
		--------	lbs/A	------
0-6"	Yr aft.	5.9	4.3	1.6
	Yr of	6.6	5.3	1.3
0-12"	Yr aft.	6.5	5.3	1.2
	Yr of	7.2	5.1	2.1
1-2'	Yr aft.	11.2	9.3	1.9
	Yr of	17.9	9.9	8.0
2-5'	Yr aft.	34.7	27.2	7.5
	Yr of	30.0	24.8	5.2
	Pr>F	.0358	.0037	.1228

Table 16. The effect of depth, tillage and N source and rate on nitrate N in Goodhue Co. MN on April 19-21, 1988.

	Ridge Till			Chisel		
Depth	Manure (L)	Manure (H)	Anhy	Manure (L)	Manure (H)	Anhy
			lbs/A			
0-6"	6.1	6.1	9.2	6.2	4.5	5.2
6-12"	6.0	7.3	8.5	6.9	5.3	7.3
1-2'	11.2	13.0	17.8	11.6	10.3	23.1
2-5'	32.1	32.4	44.1	27.3	26.1	31.9

Pr>F Till*N Rate*Depth= .005

Table 17. The effect of tillage, and N source and rate on soil profile N in Goodhue Co. MN on Oct 31-Nov 1, 1988.

N Rate & Source[1]	Row[2]	0-1 FT Ridge	0-1 FT Chl	0-1 FT Mean	1-2 FT Ridge	1-2 FT Chl	1-2 FT Mean	2-3 FT Ridge	2-3 FT Chl	2-3 FT Mean	3-4 FT Ridge	3-4 FT Chl	3-4 FT Mean	4-5 FT Ridge	4-5 FT Chl	4-5 FT Mean	0-5 FT Ridge	0-5 FT Chl	0-5 FT Mean
		lbs/A																	
		TOTAL-N																	
Manure	IR	18.7	18.7	18.7	15.5	16.1	15.8	15.6	16.0	15.8	12.5	11.7	12.1	12.2	12.3	12.3	74.5	74.8	74.7
(High)	BR	18.9	19.4	19.1	15.5	16.2	15.8	14.4	15.2	14.8	10.0	10.4	10.1	11.6	12.0	12.8	70.4	73.2	71.7
	MEAN	18.8	19.0	18.9	15.5	16.2	15.8	15.0	15.6	15.3	11.2	10.9	11.1	11.9	12.1	12.0	72.4	73.8	73.2
Anhydr.	IR	22.1	19.0	20.2	16.4	16.0	16.2	14.6	14.1	14.3	10.8	11.1	10.9	10.9	11.7	11.8	74.8	71.9	73.4
ammonia	BR	51.9	21.4	36.7	20.9	15.9	18.4	15.2	14.6	14.9	10.9	10.1	10.5	12.0	11.6	11.8	110.9	73.6	92.3
	MEAN	37.0	20.2	28.6	18.6	16.0	17.3	14.9	14.3	14.6	10.9	10.6	10.7	11.4	11.7	11.6	92.8	72.8	82.8
Check	IR	19.7	18.1	18.9	16.3	15.0	15.7	15.6	13.2	14.4	11.2	10.1	10.6	12.6	12.2	12.4	75.4	68.6	72.0
	BR	22.8	16.7	19.8	18.6	16.2	17.4	15.6	14.2	14.9	10.6	11.1	10.9	11.6	9.9	10.8	79.2	68.1	73.5
	MEAN	21.2	17.4	19.3	17.5	15.6	16.6	15.6	13.7	14.6	10.9	10.6	10.7	12.1	11.1	11.6	77.3	68.4	72.8
		AMMONIUM-N																	
	Row	Ridge	Chl	Mean	Ridge	Chl	Mean	Ridge	Chl	Mean	Ridge	Chl	Mean	Ridge	Chl	Mean	Ridge	Chl	Mean
Manure	IR	15.3	16.4	15.8	13.6	15.0	14.3	14.2	14.9	14.6	11.3	10.7	11.0	10.8	11.6	11.2	65.2	68.6	66.9
(High)	BR	15.8	17.2	16.5	15.9	15.0	15.5	13.1	14.8	13.9	8.6	9.4	9.0	10.3	11.3	10.8	63.7	67.7	65.7
	MEAN	15.6	16.8	16.2	14.8	15.0	14.9	13.7	14.8	14.2	10.0	10.1	10.0	10.5	11.4	11.0	64.5	68.1	66.3
Anhydr.	IR	18.3	17.4	17.9	13.9	15.2	14.4	12.5	13.3	12.9	8.6	9.7	9.2	8.9	10.6	9.8	62.2	66.2	64.2
ammonia	BR	25.6	18.1	21.8	15.7	15.1	15.4	13.9	13.2	13.5	9.3	9.2	9.2	9.6	10.9	10.3	74.1	66.5	70.3
	MEAN	22.0	17.8	19.9	14.8	15.2	15.0	13.2	13.2	13.2	8.9	9.4	9.2	9.3	10.8	10.1	68.2	66.4	67.3
Check	IR	17.0	16.7	16.9	15.4	13.9	14.6	14.2	12.3	13.2	9.8	7.6	8.7	10.7	11.3	11.0	67.1	61.8	64.5
	BR	19.1	15.0	17.0	16.2	14.6	15.4	13.4	13.3	13.4	8.8	9.9	9.3	10.1	34.2	22.2	67.6	87.0	77.3
	MEAN	18.1	15.8	17.0	15.8	14.2	15.0	13.8	12.8	13.3	9.3	8.7	9.0	10.4	22.8	16.6	67.4	74.3	70.9
		NITRATE-N																	
	Row	Ridge	Chl	Mean	Ridge	Chl	Mean	Ridge	Chl	Mean	Ridge	Chl	Mean	Ridge	Chl	Mean	Ridge	Chl	Mean
Manure	IR	3.3	2.5	2.9	1.9	0.6	1.2	1.4	1.2	1.3	1.2	0.9	1.0	1.4	0.6	1.0	9.2	5.8	7.5
(High)	BR	3.0	2.1	2.6	1.4	1.2	1.3	1.3	0.4	0.9	1.4	0.7	1.0	1.3	0.7	1.0	8.7	5.1	6.9
	MEAN	3.2	2.3	2.7	1.6	0.9	1.3	1.4	0.8	1.1	1.3	0.8	1.0	1.4	0.7	1.0	8.9	5.5	7.2
Anhydr.	IR	3.8	1.5	2.7	2.4	0.7	1.6	2.0	0.7	1.4	2.1	1.4	1.8	2.0	1.2	1.6	12.3	5.5	8.9
ammonia	BR	26.4	3.4	14.9	5.3	0.7	3.0	1.3	1.4	1.4	1.7	1.1	1.4	2.4	0.6	1.5	37.1	7.2	22.2
	MEAN	15.1	2.4	8.8	3.8	0.7	2.3	1.7	1.1	1.4	1.9	1.2	1.6	2.2	0.9	1.6	24.7	6.3	15.5
Check	IR	2.6	1.4	2.0	0.8	1.2	1.0	1.5	0.8	1.2	1.3	4.4	2.8	1.9	0.9	1.4	8.1	8.7	8.4
	BR	3.7	1.9	2.8	2.4	1.6	2.0	2.1	0.8	1.5	1.8	1.2	1.5	1.4	2.6	2.0	11.4	8.1	9.3
	MEAN	3.2	1.6	2.4	1.6	1.4	1.5	1.8	0.9	1.3	1.6	2.8	2.2	1.6	1.7	1.7	9.8	8.4	9.1

Pr>F

Source	Tillage(T)	N Rate(N)	Row(R)	T*N	T*R	R*N	R*N*T	Depth(D)	T*D	N*D	R*D	T*N*D	T*R*D	N*R*D
Total-N	.279	.333	.233	.074	.311	.122	.163	.001	.018	.003	.017	.132	.272	.036
NH_4-N	.401	.599	.327	.526	.487	.427	.370	.001	.318	.442	.515	.930	.139	.0001
NO_3-N	.214	.122	.218	.152	.353	.411	.310	.026	.168	.200	.144	.275	.387	.194

[1] Only the treatments of the year of application.
[2] Position of soil sampling with respect to row, IR=in row, BR= between rows.

Table 18. The effect of N source and rate on total soil N averaged over tillage in 5' depth in Goodhue Co. MN on Oct 31-Nov 1, 1988.

N rate	Ridge Till	Chisel
	------- lbs/A -----	
Manure (High)	72.5	73.5
Anhydrous	93.0	73.0
Check	77.0	68.5

Pr>F =.074

Table 19. The effect of tillage and depth on on soil N averaged over N treatments in Goodhue Co. MN on Oct 31-Nov 1, 1988.

	Ridge Till	Chisel
Depth	------- lbs/A -----	
0-1'	25.7	18.9
1-2'	17.2	15.9
2-3'	15.1	14.5
3-4'	10.9	10.8
4-5'	11.7	11.6

Pr>F =.018

Table 20. Effect of N source and depth on total soil N averaged over tillage in Goodhue Co. MN on Oct 31-Nov 1, 1988.

	Manure (H)	Anhydr	Check
Depth	----------	lbs/A	-------
0-1'	19.0	28.7	19.3
1-2'	15.8	17.3	16.6
2-3'	15.3	14.6	14.6
3-4'	11.0	10.8	10.7
4-5'	12.0	11.6	11.5

Pr>F =.003

Table 21. Effect of location of sampling on total soil N averaged over no till and chisel, and N rate and source in Goodhue Co.

	In Row	Between rows
Depth	------- lbs/A ------	
0-1'	19.4	25.2
1-2'	15.8	17.2
2-3'	14.9	14.9
3-4'	11.2	10.5
4-5'	11.9	11.5

Pr>F=.017

Table 22. Effect of N source and rate, sampling location and depth on total N (avg over tillage) in Goodhue Co. on Oct 31- Nov 1, 1988.

	Check		Manure (H)		Anhydrous	
	--------------		lbs/A		--------------	
Depth	IR[1]	BR	IR	BR	IR	BR
0-1'	18.9	19.8	18.7	19.1	20.5	36.7
1-2'	15.7	17.4	15.8	15.8	16.2	18.4
2-3'	14.4	14.9	15.8	14.8	14.3	14.9
3-4'	10.6	10.9	12.0	10.1	10.9	10.6
4-5'	12.4	10.8	12.2	11.8	11.3	11.8

Pr>F=.003

[1] IR= in row, BR=between rows.

EFFECT OF TILLAGE AND FREQUENCY OF MANURE APPLICATION ON THE AVAILABILITY OF N TO CORN[1]

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Abstract: A study to determine the effect of the frequency of liquid dairy manure application on corn yield, N uptake and N levels was initiated in Goodhue county in 1983. Despite the severe drought of 1988, the yields obtained at this site were comparable to previous years. Annual application of manure produced greater grain yields, stover dry matter, N uptake and harvest index than biennial manure or the annual fertilizer check. These effects were not significantly different with respect to the two tillage systems (no till and chisel plow), although no till had higher grain and stover moisture and greater soil water content in November than did chisel tillage. A residual effect from additional potassium was reflected in higher grain yields and higher plant population at harvest. At the spring sampling soil water was uniform with depth. Only the upper two feet of soil was recharged at the fall sampling. The soil nitrogen levels were not affected by tillage. Total profile N was highest in the ammonium nitrate plots which had more than twice the N as NO_3 of any of the manure treatments both in the spring and fall. Soil N levels were 2 to 3 times higher in the fall than in the spring.

INTRODUCTION

The objective of the study is to determine the effects of tillage and frequency of manure application on corn yields, N uptake, and soil nitrogen levels. The site is located on a Timula silt loam on the Dale Flueger Farm near Redwing, MN in Goodhue Co. The study was initiated in 1983.

Liquid dairy manure is injected either annually, biennially or triennially on chisel-plowed treatments and annually or biennially on no-till treatments. A check treatments which does not receive any nitrogen and a fertilized check treatment which received ammonium nitrate annually at the rate of 210 lbs N/A on no till plots and 170 lbs N/A on chisel plots are included in the study. Cultural practices are similar to previous years (Table 1). Since tillage is associated with manure injection, no till plots are not 'no till' in the strict sense. In 1988, the no till plots were ridged for improved weed control which changed the tillage comparison to ridge till vs. chisel tillage system.

Manure treatments were split with 0 and 200 lbs K_2O in the previous years. The application of this extra potassium has been stopped since 1987. To evaluate residual effects of additional potassium data in this report are presented on split basis with respect to K_2O rates whenever possible.

Profile nitrogen was measured on spring and fall soil sampling to the 5 ft depth on April 14-15, 1988 and November 2-3, 1988, respectively.

RESULTS

Residue Cover. Residue cover measurements from biennial manure treatments are presented in Table 2. No till receiving manure in 1987 (year after manure application) had higher residue cover than any other treatment. No till had higher residue levels both in and between the rows than chisel tillage except for in row cover during year of application where chisel had higher in row residue cover.

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[2] Graduate Research Assistant, Professor, and Associate Professors, respectively, Soil Science Department, Univ. of Minnesota, St. Paul, MN, 55108.

Early Whole Plant Analysis. Total dry matter, tissue N and N uptake of the early whole plant samples (10 plants/plot) taken on July 13-14 are presented in Table 3. Chisel plowing resulted in significantly higher dry matter and total N uptake. Annual application of manure had greater dry matter and N uptake than any other treatment (manure or fertilizer) followed by the year of manure application. Year after manure application and fertilized treatments had lower dry matter and N uptake than the other treatments. The N concentration in the fertilized treatments, however, was higher than the carry over manure treatments.

Plant Population and Stover Yield. Table 4 summarizes the total plant population, stover yields, and stover moisture at harvest. Tillage had no significant influence on plant population or stover dry matter. Stover moisture was significantly greater on no till treatments than chisel.

Previous years potassium affected plant population; however the population of the fertilizer treatments was unaffected by additional potassium. Population increased 4 to 12,000 plants/A where 200 lbs/A K_2O was applied annually on previous year manure application.

The stover yields were highest for the annual manure and fertilized treatments and lowest on year after manure treatment.

Grain Yields, Grain Moisture and Total Dry Matter. Tillage did not significantly affect grain yields and total dry matter (Table 5), but had a significant effect on grain moisture. No till treatments had higher grain moisture than chisel. Annual manure treatment had the greatest average grain and stover yields. Year after manure had the lowest grain and dry matter yields. Year of application and fertilized treatments were intermediate in yield and dry matter. Grain moisture was highest in the no till treatments on the fertilizer treatments followed by carry over manure treatments which had the greatest in row cover. Previous K_2O fertilization significantly increased grain yields.

Grain and Stover N (1987). The results of the N concentration analysis of grain and stover from 1987 are included in this report (Table 6). Both grain and stover N were higher for the manure applied treatments than the carry over treatments. Additional potassium interacted significantly with manure application-higher stover and grain N in the manure applied treatments but lower values in the carry over manure treatments with the addition of potassium. An interaction was observed between tillage, additional K and manure application on stover N. The effect of tillage was nonsignificant on N concentration.

Grain and Stover N (1988). As in 1987, tillage had no significant effect on grain and stover N concentration in 1988 (Table 7); manure had a highly significant effect on grain and stover N. Additional potassium did not affect grain and stover N.

Harvest Index. Tillage did not influence grain and stover yield but tillage had a marked effect on harvest index (Table 8). The analysis of harvest index, a ratio of total grain dry matter to that of total dry matter (grain and stover), shows that no till treatments had more grain per total dry matter than the chisel treatments. The carry over manure treatments had a higher harvest index than any other N treatments.

Soil Water Sampling. Suction water samplers were established on manure and check treatments to monitor nitrate in soil water at 5 ft depth. Due to the drought, it was difficult to obtain samples. The nitrate concentration on the five sample dates is given in Table 9. Annual application of manure had greater nitrate concentrations than other manure treatments. N concentration generally declined with time; however it is difficult to infer any trend from these limited samples.

Soil Moisture. Tensiometers were installed in various manure treatments to monitor soil moisture throughout the season. Because of this years drought, the soil matric potential was more negative than the tensiometer range. Gravimetric soil moisture was taken before planting in April and after harvest in November (Tables 10 and 11). The soil moisture ranged from 20.4 to 23.3% (wt./wt. basis) in April across all tillage and N treatments.

In the first week of November, soil moisture differed markedly by depth with greater moisture in the upper 2 feet depth due to water recharge from fall precipitation. No till treatments had generally higher moisture in the profile than chisel plowing although the difference was not significant. Soil water was not significantly different for in row or between row positions. Check treatments and carry over manure treatments had higher moisture in the top 3 ft depth than any other treatments. However, the ammonium nitrate treatment had lower water content than other treatments in the depth below 3 ft.

Soil Nitrogen (Spring). Soil N analysis data for 0-6", 6-12", 1-2' and 2-5' depth measured in the spring 1988 are presented in Table 12. The ammonium nitrate fertilized treatment had at least twice the amount of total N that was present in any of the manure treatments. Most of this difference was in the lower 3 ft depth. Tillage and N treatments were not significantly different. About 2/3 of the total N in manure treatments was in ammonium form; whereas, more than half was in nitrate form in the fertilizer treatments.

Soil Nitrogen (Fall). A summary of soil N sampled in and between the rows at 1 ft increment to the five feet depth is given in Table 13. The effect of tillage on profile N was not significant. Total nitrogen in the profile was higher for the ammonium nitrate than manure or check treatments (Table 14). Manure applied treatments had higher N than carry over or check. Most of the N in manure treatments was in the ammonium form while more than two thirds of N was in the nitrate form in the fertilizer treatment. There was a significant difference in N due to position of sampling-more N in between the rows than in the row(Table 15). Ammonium nitrate resulted in higher total N between the rows while manure application resulted in higher total N in the row (Table 16). Check and carry over manure did not yield any difference due to row position. About half of the total N in the profile was in the top two feet depth (Table 17). There was greater N in the ammonium form in the rows than between the rows, and greater N in the nitrate form between the rows than in the rows throughout the profile (Table 18). No till treatments had higher N in the rows while Chisel treatments had higher levels between the rows (Table 19).

Table 1. Cultural practices at Goodhue County, MN. IN 1988.

Tillage	**Cropping History**
No Till (Ridged in 1988 on June 29)	Corn since 1981-P 3906.
Chisel Plow-Chiseled on May 16,1988.	1988- Corn Pioneer 3737

Manure Application

Injected liquid dairy manure at the following rate and analysis on May 2,1988.

		Rate		
		Mean	St.Dev	n
Manure	(gal/A)	8623	1010	15
Total-N	(lbs/A)	175	21	15
NH_4-N	(lbs/A)	69	8	15

Planting Information for 1988 Crop Year

A four row 38 inch Hinecker Series 1 Econo Till planter with clearing disks raised.

Planting Date	Rate	Harvested
May 17, 1988	30,000 plants/A	October 7-8, 1988

Fertilizer 1988

Material Analysis	Rate	Tillage	Actual N	Actual P_2O_5 (lb/A)	Actual K_2O	Date Applied	Method of Application
34-0-0	618 lbs/A	No Till	210	0	0	May 12, 1988	Broadcast before tillage on
	500 lbs/A	Chisel	170	0	0		fertilized check treatments

Soil

Timula (Typic Eutrochrepts, coarse-silty, mixed, mesic) silt loam, 2 to 12% slope. Soil is well drained.

Insect Control

6.5 lbs/A (.98 lb/A) Lorsban 15G applied on May 17, 1988.

Weed Control

3 qts/A (3 lbs/A) Lasso + 2.5 qts/A (2.5 lbs/A) bladex + 1 qt/A (.75 lb/A) Roundup on May 20,1988.

Table 2. Residue cover as affected by tillage, row position and manure application in Goodhue County, MN on June 6, 1988.

Location[1]	Year[2]	No Till	Chisel	Mean
			%	
In Row	Year after	67.0	38.0	52.5
	Year of	5.0	9.0	7.0
Between rows	Year after	60.0	22.0	41.0
	Year of	18.0	8.0	13.0

Significance of residue cover

Source	In row	Bet. rows
Tillage (T)	.264	.079
Year (Y)	.184	.156
T*Y	.437	.295

[1] Position of measurements with respect to rows.
[2] Manure applied in the spring of 1987 (year after) and 1988 (year of).

Table 3. Early whole plant analysis as affected by tillage, and N source and frequency of application in Goodhue Co. MN on July 13-14, 1988.

Frequency[1] & Source of N	DRY MATTER No Till	DRY MATTER Chisel	DRY MATTER Mean	N CONCENTRATION No Till	N CONCENTRATION Chisel	N CONCENTRATION Mean	N UPTAKE No Till	N UPTAKE Chisel	N UPTAKE Mean
		g/plant			%			mg/plant	
Manure (Yr.after)	42.9	47.3	45.1	1.76	1.61	1.68	758	760	759
Manure (Yr.of)	51.9	56.1	54.0	1.98	1.92	1.95	1031	1080	1055
Manure (Annual)	54.0	61.1	56.4	2.06	2.16	2.10	1113	1318	1181
Ammonium Nitrate	32.6	46.0	39.3	2.32	2.01	2.17	744	929	836
Mean	43.4	52.6	48.7	2.03	1.93	1.98	911	1022	958

Pr>F

	Till (T)	Freq. (F)	T*F
Dry matter	.015	.019	.780
N conc.	.105	.001	.099
N uptake	.059	.005	.568

[1] Manure applied in the spring of 1987 (year after) and 1988 (year of).

Table 4. Total plant population, stover yield, and moisture as influenced by tillage, and N source and frequency of application in Goodhue Co. MN on Oct 11, 1988.

		PLANT POPULATION			STOVER DRY MATTER			STOVER MOISTURE		
Frequency & Source of N	K_2O lb/A	No Till	Chisel	Mean	No Till	Chisel	Mean	No Till	Chisel	Mean
		-- plants/A*10^{-3} --			------ tons/A -----			------- % -------		
Manure[1]	0	21.5	26.6	24.0	1.3	1.7	1.5	48	45	46
(Yr. after)	200	33.4	30.7	32.0	1.2	1.6	1.4	50	48	49
	Mean	27.5	28.6	28.0	1.2	1.7	1.5	49	47	48
Manure	0	27.2	23.7	25.5	1.8	1.8	1.8	49	44	47
(Yr. of)	200	25.8	27.5	26.6	1.9	1.8	1.8	51	47	49
	Mean	26.5	25.6	26.1	1.8	1.8	1.8	50	45	48
Manure	0	25.2	25.8	25.4	2.3	1.9	2.1	52	50	51
(Annual)	200	28.4	28.7	28.5	1.8	1.9	1.9	54	52	53
	Mean	26.7	27.3	26.9	2.1	1.9	2.0	53	51	52
Ammonium	0	25.2	27.8	26.5	-	-	-	-	-	-
Nitrate	200	26.0	27.1	26.6	1.8	2.0	1.9	58	48	53
	Mean	25.6	27.4	26.5	1.8	2.0	1.9	58	48	53
Mean		26.6	27.2	26.9	1.8	1.8	1.8	52	48	50

	Pr>F						
	Till (T)	Freq. (F)	T*F	K rate (K)	K*T	K*F	K*F*T
Plant population	.713	.648	.901	.062	.490	.006	.058
Stover dry matter	.683	.103	.361	.493	.570	.828	.630
Stover moisture	.048	.253	.810	.358	.934	.980	.920

[1]Manure applied in the spring of 1987 (year after) and 1988 (year of).

Table 5. Grain yields, grain moisture, and total dry matter as influenced by tillage, and N source and frequency of application in Goodhue Co. MN in 1988.

Frequency[1] & Source of N	K_2O lb/A	GRAIN YIELDS No Till	GRAIN YIELDS Chisel	GRAIN YIELDS Mean	GRAIN MOISTURE No Till	GRAIN MOISTURE Chisel	GRAIN MOISTURE Mean	TOTAL DRY MATTER No Till	TOTAL DRY MATTER Chisel	TOTAL DRY MATTER Mean
		bu/A			%			tons/A		
Manure	0	111.4	126.0	118.7	23.0	19.0	21.0	4.0	4.8	4.4
(Yr. after)	200	137.7	125.2	131.5	20.9	17.8	19.3	4.4	4.6	4.5
	Mean	124.6	125.6	125.1	22.0	18.4	20.2	4.3	4.7	4.5
Manure	0	148.6	130.6	139.6	18.9	18.7	18.8	5.4	5.0	5.2
(Yr. of)	200	139.2	143.8	141.5	19.0	18.4	18.7	5.1	5.0	5.1
	Mean	143.9	137.2	140.5	18.9	18.6	18.7	5.3	5.0	5.1
Manure	0	144.8	133.2	140.9	19.6	18.0	19.1	5.7	5.1	5.4
(Annual)	200	158.0	139.1	151.3	18.5	20.0	19.0	5.4	5.2	5.3
	Mean	151.1	136.2	146.0	19.1	19.0	19.1	5.6	5.1	5.4
Ammonium	0	126.0	129.1	127.6	32.1	21.5	26.8	-	-	-
Nitrate	200	145.3	144.4	144.9	29.0	18.9	23.9	5.2	5.4	5.3
	Mean	135.7	136.8	136.2	30.5	20.2	25.4	5.2	5.4	5.3
Mean		141.1	133.9	137.9	22.0	19.0	20.7	5.1	5.0	5.1

Pr>F

	Till (T)	Freq. (F)	T*F	K rate (K)	K*T	K*F	K*F*T
Grain Yields	.553	.081	.685	.045	.357	.727	.374
Grain moisture	.036	.000	.071	.164	.673	.168	.529
Total dry matter	.621	.208	.332	.827	.761	.920	.835

[1] Manure applied in the spring of 1987 (year after) and 1988 (year of).

Table 6. Grain N, and stover N as influenced by tillage, and N source and frequency of application in Goodhue Co. MN in 1987.

Frequency[1] & Source of N	K_2O lb/A	N CONC.-GRAIN N-T	N CONC.-GRAIN Chisel	N CONC.-GRAIN Mean	N CONC.-STOVER N-T	N CONC.-STOVER Chisel	N CONC.-STOVER Mean
		%			%		
Manure	0	1.86	1.79	1.83	0.55	0.53	0.54
(Yr. after)	200	1.73	1.71	1.72	0.42	0.52	0.47
	Mean	1.80	1.75	1.78	0.49	0.53	0.51
Manure	0	1.94	1.89	1.91	0.64	0.67	0.66
(Yr. of)	200	1.98	1.93	1.96	0.67	0.64	0.66
	Mean	1.96	1.91	1.94	0.66	0.66	0.66
Manure	0	1.98	1.95	1.97	0.66	0.65	0.66
(Annual)	200	1.97	1.99	1.98	0.67	0.67	0.67
	Mean	1.98	1.97	1.98	0.67	0.66	0.67

Significance	Grain N	Stover N
Tillage (T)	.359	.579
Freq (F)	.040	.002
T*F	.901	.697
K Rate (K)	.374	.262
K*T	.545	.090
K*F	.041	.092
K*F*T	.905	.049

[1] Manure applied in the spring of 1986 (year after) and 1987 (year of).

Table 7. Grain N, stover N, grain N uptake, total N uptake as influenced by tillage, and N source and frequency of application in Goodhue Co. MN in 1988.

		GRAIN N			STOVER N			GRAIN N UPTAKE			TOTAL N UPTAKE		
Frequency[1] &	K_2O	NT	Chl	Mean	NT	Chl	Mean	NT	Chl	Mean	NT	Chl	Mean
Source of N	lb/A		%			%			lbs/A			lbs/A	
Manure	0	1.3	1.3	1.3	0.5	0.5	0.5	69	79	74	82	96	90
(Yr. after)	200	1.4	1.4	1.4	0.5	0.5	0.5	88	80	84	99	95	97
	Mean	1.3	1.3	1.4	0.5	0.5	0.5	78	80	79	90	96	93
Manure	0	1.5	1.5	1.5	0.7	0.6	0.6	105	92	99	129	113	121
(Yr. of)	200	1.5	1.5	1.5	0.7	0.6	0.7	100	106	103	126	129	128
	Mean	1.5	1.5	1.5	0.7	0.6	0.7	103	99	101	127	121	124
Manure	0	1.6	1.6	1.6	0.8	0.7	0.8	108	100	104	145	128	137
(Annual)	200	1.6	1.5	1.5	0.7	0.6	0.7	116	99	108	141	124	133
	Mean	1.6	1.6	1.5	0.8	0.7	0.8	112	100	106	143	127	135

Pr>F

	Till (T)	Freq. (F)	T*F	K rate (K)	K*T	K*F	K*F*T
Grain N	.950	.000	.782	.861	.746	.515	.847
Stover N	.463	.007	.853	.220	.809	.180	.912

[1] Manure applied in the spring of 1987 (year after) and 1988 (year of).

Table 8. Total grain dry matter and harvest index as influenced by tillage, and N source and frequency of application in Goodhue Co. MN in 1988.

HARVEST INDEX				
Frequency[1] &	K_2O	No Till	Chisel	Mean
Source of N	lb/A			
Manure	0	0.69	0.66	0.67
(Yr. after)	200	0.74	0.65	0.70
	Mean	0.72	0.65	0.69
Manure	0	0.67	0.64	0.65
(Yr. of)	200	0.63	0.65	0.64
	Mean	0.65	0.64	0.65
Manure	0	0.61	0.64	0.62
(Annual)	200	0.66	0.63	0.65
	Mean	0.63	0.63	0.63
Ammonium	0	-	-	-
Nitrate	200	0.66	0.64	0.65
	Mean	0.66	0.64	0.65
Mean		0.67	0.64	0.66

[1] Manure applied in the spring of 1987 (year after) and 1988 (year of).

Table 9. Nitrate levels in water samples collected from suction water samplers placed at 5 ft depth as affected by tillage, and frequency of manure application in Goodhue Co. MN in 1988.

Tillage	Frequency[1] and Source of N	7/28	8/05	8/11	8/24	11/22	Weighted Mean
		Nitrate Concentration[2] (ppm)					
No Till	Annual	17.8 (2)	-	8.7 (1)	14.5 (1)	10.3 (1)	13.4
	Biennial (Yr of)	11.8 (2)	-	10.7 (1)	-	-	11.5
	Biennial (Yr aft)	-	19.2 (1)	15.8 (1)	9.8 (1)	3.8 (1)	10.4
	Mean	14.8	19.2	11.7	12.2	7.1	11.8
Chisel	Annual	46.8 (1)	-	-			46.8
	Biennial (Yr of)	7.1 (1)	17.7 (2)	-	3.4 (1)	2.3 (1)	8.4
	Biennial (Yr aft)	11.6 (1)	21.2 (3)	8.2 (1)	7.4 (1)	0.4 (1)	12.3
	Mean	21.8	19.8	8.2	5.4	1.4	22.5
Mean (Weighted)		12.8	19.7	10.9	8.8	4.2	17.3

[1] Manure applied in the spring of 1987 (year after) and 1988 (year of).
[2] The numbers in the parentheses are the number of observations. Missing numbers indicate that there was not enough sample in the samplers.

Table 10. Soil moisture as affected by tillage, and N source and frequency of application in Goodhue Co. MN on April 14-15, 1988.

Frequency[1] & Source of N	0-6 in. No Till	0-6 in. Chisel	6-12 in. No Till	6-12 in. Chisel	1-2 ft No Till	1-2 ft Chisel	2-5 ft No Till	2-5 ft Chisel
	% (wt./wt.)							
Manure (Yr. after)	22.5	22.4	22.2	22.3	23.3	22.1	21.6	21.1
Manure (Yr. of)	23.0	20.9	21.1	22.0	22.5	21.9	21.4	21.7
Manure (Annual)	22.1	22.2	22.1	21.6	22.4	21.6	22.7	20.5
Ammonium Nitrate	22.4	22.0	22.8	21.7	22.6	22.1	24.9	20.4
Mean	22.5	21.9	22.1	21.9	22.7	21.9	22.7	20.9

Source	Pr>F
Tillage (T)	.177
Frequency and source of N (F)	.482
T*F	.395
Depth (D)	.197
T*D	.102
F*D	.594
T*F*D	.019

[1] Manure applied in the spring of 1986 (year after) and 1987 (year of).

Table 11. Soil moisture as affected by tillage, and N source and frequency of application in Goodhue Co. MN on Nov 2-3, 1988, n=3.

Freq[1] & Source	ROW[2]	0-1 FT NT	0-1 FT Chl	0-1 FT Mean	1-2 FT NT	1-2 FT Chl	1-2 FT Mean	2-3 FT NT	2-3 FT Chl	2-3 FT Mean	3-4 FT NT	3-4 FT Chl	3-4 FT Mean	4-5 FT NT	4-5 FT Chl	4-5 FT Mean
		% (wt./wt.)														
Manure	IR	20.7	20.6	20.7	21.0	20.5	20.8	17.1	14.8	16.0	16.2	13.6	14.9	16.8	16.3	16.6
(Yr.aft)	BR	21.6	20.9	21.2	21.1	19.9	20.5	17.7	15.1	16.4	16.7	14.5	15.6	16.4	16.6	16.5
	Mean	21.2	20.7	21.0	21.1	20.2	20.7	17.4	14.9	16.2	16.4	14.0	15.2	16.6	16.5	16.6
Manure	IR	21.4	20.6	21.0	20.5	19.8	20.2	15.2	14.5	14.9	16.9	16.2	16.6	19.1	17.0	19.0
(Yr.of)	BR	21.2	19.2	20.0	19.5	19.2	19.4	14.0	14.3	14.2	15.7	16.5	16.1	17.6	17.5	17.6
	Mean	21.3	19.9	20.6	20.0	19.5	19.8	14.6	14.4	14.5	16.3	16.9	16.6	18.3	17.2	17.8
Check	IR	19.3	22.4	20.9	19.5	19.2	19.4	15.6	13.8	14.7	16.1	14.2	15.2	15.6	14.7	15.2
	BR	20.6	19.9	20.3	20.7	19.6	20.2	17.6	15.5	16.6	17.0	14.3	15.7	14.6	14.3	14.5
	Mean	20.0	21.1	20.6	20.2	19.4	19.8	16.6	14.7	15.7	16.5	14.3	15.4	15.1	14.5	14.8
Ammonium	IR	21.9	20.3	21.1	20.7	19.3	20.0	14.4	13.0	13.7	14.1	11.5	12.8	15.1	13.4	14.3
Nitrate	BR	20.5	20.0	20.4	20.0	20.3	20.2	14.8	11.7	13.3	14.0	12.3	12.8	14.8	16.0	14.1
	Mean	21.2	20.2	20.7	20.4	19.8	20.1	14.6	12.3	13.5	14.1	11.9	13.0	14.9	14.7	14.8

Source	In Row	Bet Row	Mean
Tillage (T)	.414	.462	.435
Frequency and source of N(F)	.331	.610	.484
T*F	.261	.558	.751
Depth(D)	.000	.000	.000
T*D	.306	.791	.756
F*D	.061	.112	.086
T*F*D	.631	.681	.634

[1] Manure applied in the spring of 1987 (year after) and 1988 (year of).
[2] Location of sampling with respect to the row position, IR=in row, and BR=between rows.

Table 12. Soil nitrogen as affected by tillage, and N source and frequency of application in Goodhue Co. MN on April 14-15, 1988, n=2.

Frequency[1] & Source of N	Depth	TOTAL-N No Till	TOTAL-N Chisel	NH_4-N No Till	NH_4-N Chisel	NO_3-N No Till	NO_3-N Chisel
		lb/A					
Manure	0-6"	8.9	7.6	5.1	4.9	3.7	2.8
(Yr. after)	6-12"	5.9	7.3	4.2	4.8	1.7	2.4
	1-2′	10.8	9.7	7.8	6.9	3.0	2.8
	2-5′	22.1	24.5	19.8	17.6	2.2	6.9
TOTAL	(0-5′)	47.7	49.1	36.9	34.2	10.6	14.9
Manure	0-6"	10.5	5.6	6.9	3.6	3.6	2.0
(Yr. of)	6-12"	6.2	5.7	4.0	3.4	2.2	2.3
	1-2′	12.7	8.5	7.2	7.1	5.5	1.4
	2-5′	28.2	24.3	21.0	21.3	7.2	3.0
TOTAL	(0-5′)	57.6	44.1	39.1	35.4	18.5	8.7
Manure	0-6"	5.3	7.1	4.8	4.4	0.5	3.0
(Annual)	6-12"	4.3	4.0	3.9	3.3	0.7	1.0
	1-2′	8.4	7.8	7.4	6.2	1.0	1.6
	2-5′	20.2	39.6	17.2	31.4	3.0	8.2
TOTAL	(0-5′)	38.2	58.5	33.3	45.0	4.9	13.5
Ammonium	0-6"	9.7	11.2	5.0	6.9	4.7	4.3
Nitrate	6-12"	9.9	13.8	4.0	3.7	5.9	10.1
	1-2′	23.8	24.3	9.0	8.3	14.8	16.0
	2-5′	62.4	59.1	23.2	21.7	39.2	37.4
TOTAL	(0-5′)	105.8	108.4	41.2	40.6	64.6	67.8

Source	Total-N	NH_4-N	NO_3
Tillage (T)	.9712	.9554	.7306
Frequency and source of N(F)	.1844	.6910	.2281
T*F	.5244	.6304	.5465
Depth (D)	.0156	.0001	.3007
T*D	.7160	.8537	.6772
F*D	.4148	.7001	.5198
T*F*D	.4974	.3322	.4747

[1] Manure applied in the spring of 1986 (year after) and 1987 (year of).

Table 13. Soil nitrogen tests as affected by tillage, N source and frequency of application in Goodhue Co. MN on Nov 2-3, 1988, n=3.

N Freq[1] & Source	ROW[2]	0-1 FT NT	0-1 FT CH	1-2 FT NT	1-2 FT CH	2-3 FT NT	2-3 FT CH	3-4 FT NT	3-4 FT CH	4-5 FT NT	4-5 FT CH	0-5 FT NT	0-5 FT CH
TOTAL-N (lbs/A)													
Manure	IR	56.8	29.5	33.1	21.6	13.8	16.7	10.6	14.0	13.6	14.5	127.9	96.3
(Yr.aft)	BR	22.2	33.6	17.8	24.2	13.1	15.1	9.3	14.3	12.7	14.8	75.1	102.0
	MEAN	**39.5**	**31.6**	**25.5**	**22.9**	**13.5**	**15.9**	**10.0**	**14.3**	**13.2**	**14.7**	**101.5**	**99.2**
Manure	IR	21.6	18.5	17.2	13.8	15.0	13.7	14.2	12.2	14.4	13.6	82.4	71.8
(Yr.of)	BR	24.5	17.6	16.9	13.2	15.7	13.1	13.7	9.3	13.6	12.8	84.4	66.0
	MEAN	**23.1**	**18.1**	**17.1**	**13.5**	**15.4**	**13.4**	**14.0**	**10.8**	**14.0**	**13.2**	**83.4**	**68.9**
Check	IR	17.3	15.8	15.0	16.1	15.7	13.3	12.2	11.8	12.2	12.0	73.5	69.0
	BR	18.5	18.2	16.1	15.2	14.6	14.6	12.0	12.8	12.3	12.6	72.4	73.4
	MEAN	**17.9**	**17.0**	**15.6**	**15.7**	**15.2**	**14.0**	**12.1**	**12.3**	**12.3**	**12.3**	**72.9**	**71.2**
Ammonium	IR	69.0	35.5	20.6	22.3	25.5	17.2	34.5	23.4	39.9	46.6	213.1	145.0
Nitrate	BR	75.3	73.5	48.6	69.5	35.9	45.6	27.9	45.2	25.4	66.4	189.5	300.2
	MEAN	**72.2**	**54.5**	**34.6**	**45.9**	**30.7**	**31.4**	**31.2**	**34.3**	**32.7**	**56.5**	**201.3**	**222.5**
AMMONIUM-N	ROW	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH
Manure	IR	16.2	18.2	13.0	15.0	12.2	13.8	9.8	12.6	12.5	13.0	63.7	72.6
(Yr.aft)	BR	14.8	16.9	12.5	14.5	11.8	13.0	8.5	12.8	12.3	13.0	59.9	70.2
	MEAN	**15.5**	**17.6**	**12.8**	**14.8**	**12.0**	**13.4**	**9.2**	**12.7**	**12.4**	**13.0**	**61.8**	**71.4**
Manure	IR	18.3	13.0	15.9	12.7	14.2	12.7	12.8	11.7	13.6	12.5	74.8	62.6
(Yr.of)	BR	20.8	15.0	14.7	11.5	14.8	11.8	11.2	8.2	13.0	11.0	74.5	57.5
	MEAN	**19.6**	**14.0**	**15.3**	**12.1**	**14.5**	**12.3**	**12.0**	**10.0**	**13.3**	**11.8**	**74.7**	**60.1**
Check	IR	13.6	13.2	13.2	15.0	13.2	12.2	10.5	11.1	10.7	11.3	61.2	62.8
	BR	14.9	14.5	14.3	13.6	13.7	13.5	10.3	10.6	11.1	11.0	64.3	63.2
	MEAN	**14.3**	**13.9**	**13.8**	**14.3**	**13.5**	**12.9**	**10.4**	**10.9**	**10.9**	**11.2**	**62.8**	**63.0**
Ammonium	IR	22.9	17.5	15.1	12.5	14.2	12.5	12.5	11.5	13.0	11.0	77.7	65.0
Nitrate	BR	15.1	16.2	16.2	13.8	12.8	12.2	10.1	9.8	11.5	13.6	65.7	65.6
	MEAN	**19.0**	**16.9**	**15.7**	**13.2**	**13.5**	**12.4**	**11.3**	**10.7**	**12.3**	**12.3**	**71.7**	**65.3**
NITRATE-N	ROW	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH	NT	CH
Manure	IR	40.6	11.2	20.2	6.6	1.6	2.9	0.7	1.4	1.1	1.5	64.2	23.6
(Yr.aft)	BR	7.4	16.7	5.4	9.7	1.2	2.1	0.9	1.5	0.4	1.9	15.3	31.9
	MEAN	**24.0**	**14.0**	**12.8**	**8.2**	**1.4**	**2.5**	**0.8**	**1.5**	**0.8**	**1.7**	**39.8**	**27.8**
Manure	IR	3.4	5.5	1.2	1.1	0.8	1.0	1.4	0.5	0.9	1.1	7.7	9.2
(Yr.of)	BR	3.7	2.6	2.2	1.7	0.9	1.2	2.5	1.1	0.6	1.9	9.9	8.5
	MEAN	**3.6**	**4.1**	**1.7**	**1.4**	**0.9**	**1.1**	**2.0**	**0.8**	**0.8**	**1.5**	**9.0**	**8.9**
Check	IR	3.7	2.6	1.7	1.1	2.5	1.1	1.7	0.7	1.5	0.6	11.1	6.1
	BR	3.6	3.8	1.7	1.6	0.9	1.1	1.6	2.2	1.2	1.6	9.0	10.3
	MEAN	**3.7**	**3.2**	**1.7**	**1.4**	**1.7**	**1.1**	**1.7**	**1.5**	**1.4**	**1.1**	**10.1**	**8.2**
Ammonium	IR	46.0	18.0	5.5	9.8	11.3	4.7	22.1	12.0	26.9	36.0	111.8	80.5
Nitrate	BR	60.2	57.3	32.1	55.8	23.1	33.4	17.8	35.4	14.0	52.8	147.2	231.1
	MEAN	**53.1**	**37.7**	**18.8**	**32.8**	**17.2**	**19.1**	**20.0**	**23.7**	**20.5**	**44.4**	**129.5**	**157.8**

Pr>F	Till(T)	Freq(F)	T*F	Row(R)	T*R	F*R	T*F*R	Depth(D)	R*D	T*R*D	F*R*D
Total-N	.7042	.0001	.7818	.0353	.1786	.0664	.5649	.0005	.0536	.0125	.3175
NH_4-N	.2715	.2655	.1313	.1037	.6992	.0862	.0169	.0116	.3006	.5448	.0007
NO_3-N	.8888	.0001	.7401	.0325	.1674	.0585	.6418	.0250	.0374	.0474	.2888

[1] Manure applied in the spring of 1987 (year after) and 1988 (year of).

[2] Location of sampling with respect to the row position, IR=in row, and BR=between rows.

Table 14. Effect of source and frequency of N on soil N averaged over chisel and no till treatments in 5' depth in Goodhue Co., MN Nov 2-3, 1988.

N Freq[1] & Source	Total-N	NH_4-N	NO_3-N
		lbs/A	
Manure (Yr of)	100.5	66.5	34.0
Manure (Yr after)	77.0	67.5	9.0
Check	72.0	63.0	9.0
Ammon. nitrate	212.0	68.5	142.5
Pr>F for Freq.	.0001	.2655	.0001

[1] Manure applied in the spring of 1987 (year after) and 1988 (year of).

Table 15. Effect of position of soil sampling on soil total-N averaged over tillage and N treatments in 5' depth in Goodhue Co. MN, on Nov. 2-3, 1988.

Position	Total-N	NH_4-N	NO_3-N
		lbs/A	
In Row	107.0	67.5	39.5
Bet rows	123.5	65.0	58.5
Pr>F	.0353	.1037	.0325

Table 16. Effect of source and frequency of N and row position on soil N in 5' depth averaged over tillage in in Goodhue Co. MN on Nov. 2-3, 1988.

N Frq[1] & Source	Row[2]	Total-N	NH_4-N	NO_3-N
			lbs/A	
Manure (Yr of)	IR	112.0	68.0	44.0
	BR	88.5	65.0	23.5
Manure (Yr after)	IR	77.0	68.5	8.5
	BR	75.0	66.0	9.0
Check	IR	70.0	62.0	8.5
	BR	73.5	63.5	9.5
Ammon. nitrate	IR	167.0	71.0	96.0
	BR	256.5	65.5	191.0
	Pr>F	.0664	.0862	.0585

[1] Manure applied in the spring of 1987 (year after) and 1988 (year of).
[2] Location of sampling with respect to the row position, IR=in row, and BR=between rows.

Table 17. Soil profile N at various depths averaged over tillage, and N treatments in Goodhue Co. MN on Nov 2-3, 1988.

Depth (ft)	Total-N	NH_4-N	NO_3-N
		lbs/A	
0-1	34.2	16.3	17.9
1-2	23.8	14.0	9.9
2-3	18.7	13.0	5.6
3-4	17.4	10.9	6.5
4-5	21.1	12.1	9.0
Pr>F	.0005	.0116	.0250

Table 18. Soil profile N with respect to row position at various depth in averaged over tillage and N treatments in Goodhue Co. on Nov 2-3, 1988.

Depth Feet	Row[1]	Total-N	NH_4-N	NO_3-N
		lbs/A		
0-1	IR	33.0	16.6	16.4
	BR	35.4	16.0	19.4
1-2	IR	20.0	14.0	5.9
	BR	27.7	13.9	13.8
2-3	IR	16.4	13.1	3.2
	BR	20.9	13.0	8.0
3-4	IR	16.6	11.6	5.1
	BR	18.1	10.2	7.9
4-5	IR	20.8	12.1	8.7
	BR	21.3	12.0	9.3
	Pr>F	.0536	.3006	.0374

[1] Location of sampling with respect to IR=in row, and BR=between rows.

Table 19. Soil profile N as affected by tillage and row position of sampling averaged over N averaged over N treatments in Goodhue Co. MN on Nov 2-3, 1988.

		NO TILL			CHISEL		
Depth Feet	Row[1]	Total-N	NH_4-N	NO_3-N	Total-N	NH_4-N	NO_3-N
		lbs/A					
0-1	IR	41.2	17.8	23.4	24.8	15.5	9.3
	BR	35.1	16.4	18.7	35.7	15.7	20.1
1-2	IR	21.5	14.3	7.2	18.4	13.8	4.7
	BR	24.9	14.4	10.4	30.5	13.3	17.2
2-3	IR	17.5	13.4	4.0	15.2	12.8	2.4
	BR	19.8	13.3	6.5	22.1	12.6	9.5
3-4	IR	17.9	11.4	6.5	15.3	11.7	3.6
	BR	15.7	10.0	5.7	20.4	10.4	10.1
4-5	IR	20.0	12.4	7.6	21.6	11.8	9.8
	BR	16.0	12.0	4.0	26.7	12.1	14.5
	Pr>F	.0125	.5448	.0474			

[1] Location of samples with respect to row position, IR=in row, and BR=between rows.

The Effect of Tillage on Corn and Soybean Production on a Typic Hapludalf in Southeastern Minnesota[1]

J.F. Moncrief, T.L. Wagar, and J.J. Kuznia[2]

Abstract: A range in tillage from chisel plowing to no till was evaluated for corn and soybean production on a well drained silt loam soil in southeastern Minnesota. Although tillage did affect early corn growth it did not affect corn yields or grain moisture. Tillage affected early growth of soybeans and yields. The soybeans grown with a no till and ridge till system resulted in a five bushel per acre reduction in yield. It is suggested that the yield loss was due to increased weed competition by velvet leaf and row spacing for the ridge till and no till systems respectively.

This is the fifth year of a study to evaluate tillage effects on crop production in a corn-soybean rotation in southeastern Minnesota. For the fifth year tillage has not affected corn yields. The primary affect on soybean yields has been a row spacing response to narrow rows (30" vs 8") of 10 percent.

Tillage ranges from no till to chisel plowing. The planter at this site is a conventional planter equipped with 2" fluted coulters. The reduction of "in row" cover by crop residue was much greater for soybean residue than corn residue (table 4). There was a 20% cover reduction by soybean residue with the ridge till and no till systems. Cover was similar in and between the row for these two systems following corn. In row cover by crop residues was correlated with early growth of corn and soybeans (table 5). When in row cover by soybean residue was less than 20%, corn growth was not affected. No till grown corn had about .4 leaves per plant less growth on July 6. Other systems had similar growth. No till and ridge till soybeans which both had about 55% "in row" cover had about one half trifoliate less than chisel plowed or spring disced grown soybeans which resulted in about 25% cover by corn residue.

Increased tillage resulted in reduced corn stands (chisel plowing and spring discing). The stand differences due to tillage did not affect corn yields. Soybean stands were not affected by tillage.

The weed pressure at this site is generally low (tables 6, 7, and 8). Tillage had little influence on weed species present or their densities in corn. Elimination of full width tillage (no till and ridge till) resulted in increased dandelions (table 6). Spring discing increased volunteer corn in soybeans (table 7). A similar trend in tillage effects on dandelions occurred in the soybeans. The no till and ridge till systems had the most and least weeds in soybeans respectively. Weed densities are low but in this dry year it is likely that the moderate level of weeds in the no till soybeans (bottom of table 8) may have been responsible for the five bushel per acre reduction in yield with this system.

Grain yields and moisture are shown in tables 9 and 10 for corn and soybeans respectively. Corn yields were not affected by tillage. The delayed early growth associated with the no till system (.4 leaves per plant) did not result in an increase in grain moisture. The no till and ridge till grown soybeans resulted in about a 5 bushel per acre reduction in yield. It is likely that the row spacing difference (30" vs 8") is responsible for the reduction in yield with the ridge till system. The similar reduction in yield with no till grown soybeans (5 bushels per acre) is probably due to increased velvet leaf competition.

In summary, for the fifth year tillage has not affected corn yields following soybeans on a well drained silt loam soil in southeastern Minnesota. Soybean yields were five bushels per acre less with a no till and ridge till system. The probable causal agent is increased weed competition by velvet leaf and row spacing for the no till and ridge till systems respectively.

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WABASHA COUNTY

Table 1. Cultural practices for Wabasha County, MN in 1988.

Tillage

No Till
Ridge Till-all but no till corn plots were cultivated
and then ridges formed on June 15, 1988
-soybeans ridge formed on July 11, 1988
Spring Disc-corn and soybeans were disced in the spring then
field cultivated prior to planting
Chisel-chisel plowed in the fall and field cultivated in the spring

Cropping History

1983-Sweet Clover
1984-87 Corn-Soybean rotation

Crops 1988

Corn-Pioneer 3737
Soybeans-Pioneer 1677

Planting and Harvest Date

The planter used on all corn plots and ridge till soybean plots was a John Deere Max-Emerge six row (30") planter equipped with 2" fluted coulters. The planter used on no till, spring disc, and chisel plow soybean plots was a Tye No Till Drill with 8" row spacing.

Crop	Planting Date	Planting Rate	Harvested
Corn	May 5, 1988	27,700 plants/A	October 13, 1988
Soybeans	May 12, 1988	210,000 plants/A	October 13, 1988

Fertilization History For Corn

Material Analysis	Rate	Actual N	Actual P_2O_5 (lbs/A)	Actual K_2O	Date Applied
28-0-0[1]	7 gal/A	75	0	0	May 14, 1984
7-21-7	12.5 gal/A	10	29	10	May 16 & 18, 1984
7-21-7[2]	25 gal/A	20	60	20	May 13, 1985
82-0-0	170 lbs/A	140	0	0	June 19, 1985
46-0-0	337 lbs/A	155	0	0	April 24, 1986
9-23-30[2]	170 lbs/A	15	39	51	May 5, 1986
9-23-30[2]	130 lbs/A	12	30	39	April 30, 1987
82-0-0	159 lbs/A	130	0	0	June 8, 1987

1. Nitrogen was not applied to chisel plowed plots in 1984.
2. Placement 2" beside and 2" below seed.

Fertilizer Applied to Corn in 1988

Material Analysis	Rate	Actual N	Actual P_2O_5 (lbs/A)	Actual K_2O	Date Applied
5-14-42[1]	95 lbs/A	5	13	40	May 5, 1988
82-0-0	183 lbs/A	150			April 22, 1988

1. Placement 2" beside and 2" below seed.

Soil

Fayette (Typic Hapludalfs, fine-silty, mixed, mesic) silt loam.

Weed Control

Corn

1 qt/A (2 lbs/A) Dual + 3 qt/A (3 lbs/A) Bladex broadcast with the planter on May 5, 1988.

Soybeans

1.3 qts/A (1 lb/A) Roundup + 1 pt/A (.5 lb/A) 2,4-D May 12, 1988.
1 pt/A (.5 lb/A) Basagran + .5 pt/A (.125 lb/A) Blazer + 1 qt/A oil concentrate on June 1, 1988.
1 pt/A (.5 lb/A) Basagran + 1 pt/A (.188 lb/A) Poast + 1 qt/A Dash oil concentrate + 1 gal/A 28% on June 11, 1988.

Soil Test

Table 2. Soil test results for corn to be planted following soybeans on April 16, 1987.

		Tillage				
	Sig. of	No Till	Disc	Ridge	Chisel	Avg
Nutrient	Tillage	---------	lbs/A	-----	-----	-----
P	(.256)	64	58	57	54	58
K	(.833)	220	209	204	201	208

Table 3. Soil test results for soybeans to be planted following corn on April 16, 1987.

		Tillage				
	Sig. of	No Till	Disc	Ridge	Chisel	Avg
Nutrient	Tillage	---------	lbs/A	-----	-----	-----
P	(.602)	62	66	67	60	64
K	(.075)	215	187	200	177	195

Table 4. Effect of tillage on soil covered by corn and soybean residue in Wabasha Co. on July 6, 1988, n=16.

	Soybean Residue in Corn						Corn Residue in Soybeans					
	Tillage						Tillage					
	No Till	Disc	Ridge	Chisel			No Till	Disc	Ridge	Chisel		
Residue Location	-------	% cover	-------	-------	Sig.	n	-------	% cover	-------	-------	Sig.	n
In Row	28.3	19.8	21.0	8.8	.000	16	55.5	26.6	52.5	27.0	.000	16
Between Row	48.3	27.5	40.8	10.5	.000	16	59.0	23.5	55.3	29.8	.000	16

Table 5. Effect of tillage on corn and soybean growth stage and population in Wabasha Co. on July 6, 1988.

	Crop											
	Corn						Soybean					
	Tillage						Tillage					
Variable	No Till	Disc	Ridge	Chisel			No Till	Disc	Ridge	Chisel		
	-------	leaves/plant	-------	-------	Sig.	n	-------	nodes/plant	-------	-------	Sig.	n
Growth Stage	4.3	4.8	4.7	4.7	.000	80	2.6	2.9	2.4	2.8	.000	80
	-----	plants/A x 10^{-3}	-----	-----			--	plants/A x 10^{-3} n=16	----			
Population	24.2	22.3	23.5	21.1	.103	16	133.8	134.5	155.3	152.9	.429[1]	16

1. The ridge till treatment was excluded from the statistical analysis for soybean stands.

Table 6. Effect of tillage on the percent cover by weeds in corn at Wabasha Co. on July 7, 1988, n=4.

	Tillage				
	No Till	Disc	Ridge	Chisel	
Weed	-------	% cover	-------	-------	Sig.
Velvetleaf	2.0	2.5	1.8	2.3	.681
Lambsquarter	0.0	0.3	3.5	2.3	
Milkweed	0.3	0.8	0.3	0.3	.516
White Cockle	0.0	1.5	1.8	0.5	
Pigweed	0.0	0.0	1.3	1.5	
Quackgrass	0.8	0.8	0.8	2.5	.591
Canada Thist	1.8	0.3	1.3	0.8	.185
Dandelion	2.0	0.5	1.8	0.3	.012
Curly Dock	0.0	0.0	0.0	0.3	
Smartweed	0.0	0.0	0.5	0.3	
Yellow Nutedg	0.0	0.3	0.0	0.0	
Sow thistle	0.0	0.0	0.0	0.3	
Ragweed	0.0	0.0	0.3	0.0	
Lfy Spurge	0.0	0.0	0.3	0.0	
Boxelder	0.3	0.0	0.0	0.0	

Table 7. Effect of tillage on the percent cover by weeds in soybeans at Wabasha Co. on July 7, 1988, n=4.

	Tillage				
	No Till	Disc	Ridge	Chisel	
Weed	-------	% cover	-------	-------	Sig.
Lambquarter	0.0	0.0	0.0	0.8	
Milkweed	1.0	0.5	0.5	0.8	.855
White Cockle	0.3	0.3	1.5	0.5	.179
Pigweed	0.0	0.0	0.0	0.8	
Quackgrass	0.8	1.0	1.3	2.3	.715
Canada Thist	0.3	0.0	0.3	0.3	
Dandelion	3.3	0.8	1.5	0.5	.155
Curly Dock	0.0	0.5	0.0	0.0	
Burdock	0.0	0.5	0.0	0.0	
Vol Corn	0.3	4.8	0.3	1.0	.000
Shep. Purse	0.0	0.0	0.3	0.0	

Table 8. Effect of tillage on weed ranking in soybeans at Wabasha Co. on Oct. 13, 1988, n=4.

	Tillage				
	No Till	Disc	Ridge	Chisel	
Weed	weed severity[1]				Sig.
Pigweed	0.8	1.5	0.3	1.1	.055
Velvetleaf	1.9	0.0	0.3	0.9	
Foxtail	0.0	0.0	0.3	0.0	
Milkweed	0.4	0.3	0.0	0.0	
Canada Thist	0.0	0.0	0.3	0.0	
Vol Corn	0.0	0.0	0.3	0.0	
Overall Weeds Avg. tillage	2.3	1.5	1.0	1.5	.074

1. Weed severity scale; 1=slight, 2.5=moderate, and 5=heavy.

Table 9. Effect of tillage on corn yields and moisture in Wabasha Co. on Oct. 13, 1988, n=4.

	Tillage				
	No Till	Disc	Ridge	Chisel	
Variable	bu/A				Sig.
Grain Yield	143.5	148.2	141.5	143.0	.761
	%				
Moisture	16.4	16.1	15.7	16.4	.492

Table 10. Effect of tillage on soybean yields and moisture in Wabasha Co. on Oct. 13, 1988, n=4.

	Tillage				
	No Till	Disc	Ridge	Chisel	
Variable	bu/A				Sig.
Grain Yield	41.4	44.8	39.6	45.6	.058
	%				
Moisture	9.2	9.1	8.8	8.9	.122

The Effect of Tillage on Soybean Production on an Aquic Argiudoll[1]

J.F. Moncrief, T.J. Arlt, T.L. Wagar, and J.J. Kuznia[2]

Abstract: Tillage affected early soybean growth and grain yields on a Aquic Argiudoll soil in Southcentral Minnesota. Moldboard plowing resulted in the highest growth and yields followed by a ridge till system. Other tillage treatments resulted in yields that were ten bushels per acre less.

Tillage plots were established in Steele county, MN. in 1985 on an Aquic Argiudoll (Le Sueur, clay loam) soil. Corn and soybeans have been grown in rotation.

The soil cover measurements in table 2 were made after cultivation. Residue has been concentrated in the row. The "in row" cover in this table would not be expected to be correlated with the early growth in table 3. The soybeans grown with moldboard plowing are about one node ahead of most other tillage treatments. The ridge till soybeans were intermediate in growth on this date (June 23). It is likely that the early growth followed "in row" cover before cultivation. Tillage did not affect soybean stands.

This site is relatively weed free (table 4).

Soybean yields followed the early growth observations in table 3. Moldboard plowing resulted in the highest yields followed by soybeans grown with ridge till (table 5). The other tillage treatments are a distant third. The authors do not have an explanation for the yield differences at this time.

STEELE COUNTY

Table 1. Cultural practices at Steele County, MN. 1988.

Tillage
- No Till
- Ridge Till
- Spring Disc-Field cultivated prior to planting
- Fall Chisel Plow-Field cultivated prior to planting
- Fall Moldboard Plow-Field cultivated prior to planting
  - Cultivated tillage plots and formed ridges on June 22, 1988.

Cropping History
1985-Corn, 1986-Soybeans, 1987-Corn

1988 Crop
Soybeans-Pioneer 1677

Planting and Harvest Date
Planter used on was a Hiniker Econotill planter with 30 inch row spacing.

	Planting		
Crop	Date	Rate	Harvested
Soybeans	May 19, 1988	180,000 plants/A	October 7, 1988

Weed Control
4 qts/A (4 lbs/A) Lasso applied on May 20, 1988.
1 pt/A (.188 lb/A) Poast + 2 pts/A Oil applied on June 19, 1988.

Soil
Le Sueur (Aquic Argiudolls, fine-loamy, mixed, mesic) clay loam, 2 to 4 percent slopes. Soil is moderately well drained to somewhat poorly drained.

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1 Support for this project was in part provided by the Soil Conservation Service which is greatly appreciated.

2 John F. Moncrief and Joe J. Kuznia are an Associate Professor and Assistant Scientist respectively. Tim J. Arlt is the County Agricultural Agent in Steele Co. MN. Tim L. Wagar is an Area Crops and Soils Extension Agent at Rochester, MN.

Fertilization History

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied	Method of Application
			---	lbs/A	----		
	0-0-60	250 lbs/A	0	0	150	Fall 1984	Broadcast
Corn:	7-21-7[1]	10 gals/A	8	24	8	April 29, 1985	Applied with the seed.
	82-0-0	163 lbs/A	134	0	0	May 30, 1985	Injected
Soybeans	none						
Corn:	0-0-60	250 lbs/A	0	0	150	pre-plant 1987	Broadcast
	82-0-0	159 lbs/A	130	0	0	June 5, 1987	Injected

Table 2. Effect of tillage on soil covered by corn residue in Steele Co. on June 23, 1988.

Location[1]	Tillage Mldbd	Chisel	Ridge	NoTill	SprDsc	Sig.
	------------		cover	------------		
In Row	3.7	41.3	53.0	67.0	39.0	.000
Between Row	1.0	11.3	44.7	24.7	9.7	.000

1. Corn was cultivated on June 22, 1988 which concentrated the residue in the row area, n=12.

Table 3. Effect of tillage on early growth of soybean and population in Steele Co. on June 23, 1988, n=12.

Variable	Tillage Mldbd	Chisel	Ridge	NoTill	SprDsc	Sig.
	-----------		nodes/plant	--------		
Stage	5.3	4.3	4.8	4.3	4.3	.000
	----------		plants/A x 10^{-3}	-----		
Pop.	146.4	129.5	126.3	139.3	129.8	.281

Table 4. Effect of tillage on weed severity in soybeans at Steele Co. on June 23, 1988, n=3.

Weed	Tillage Moldboard	Chisel	Ridge	No Till	Spring Disc	Sig.
	---------------		% cover	-----------------		
Foxtail	0.5	8.3	5.3	17.3	5.2	.522
Milkweed	0.0	0.2	0.2	0.0	0.0	
Pigweed	0.0	0.2	0.3	0.0	0.0	
Lambsquarter	0.0	0.3	5.3	2.0	0.0	
Vol. Corn	0.2	2.3	0.0	0.0	3.3	
Ragweed	0.0	0.0	6.0	5.7	0.0	
Marestail	0.0	0.0	0.7	9.0	0.0	
F. Pennycress	0.0	0.0	0.0	1.0	0.0	
Quackgrass	0.0	0.0	0.0	0.3	0.0	
Burdock	0.0	0.0	0.2	0.0	0.0	
Cocklebur	0.0	0.0	1.7	5.0	0.0	
Canada Thistle	0.0	0.0	0.2	0.2	0.0	

Table 5. Effect of tillage on soybean yields and moisture at Steele Co. on October 7, 1988, n=3.

Variable	Tillage Moldboard	Chisel	Ridge	No Till	Spring Disc	Sig.
	-----------------		bu/A	-----------------		
Grain:Yield	44.8	31.1	40.5	28.7	22.8	.081
	-------------------		%	-------------------		
Moisture	9.0	9.3	9.1	9.0	9.0	.027

Conservation Tillage Demonstration/Research in the Clearwater River Watershed-1988[1]

J.F. Moncrief, J.J. Kuznia, and M.B. Kells[2]

Abstract: Tillage was evaluated in the Clearwater River Watershed in Central Minnesota. Although tillage affected early growth of corn, yields were not affected. Soybean yields were not affected by tillage at two sites but ridge till grown soybeans resulted in higher yields at a third likely due to better weed control. Corn grown with ridge till and no till systems responded to row placed phosphorus over spring broadcast phosphorus on a soil testing 25 lbs P/acre. Soybeans did not respond to applied phosphorus. Ridge till corn and soybeans were not adversely affected by combine traffic on ridges in the fall of 1987.

In recent years there has been concern for the water quality in the Clearwater River Chain of Lakes due to entry of phosphorus from various sources. There has been entry of phosphorus from agricultural sources due largely to erosion. Phosphorus from agricultural activities that enter water bodies is usually associated with the sediment that is carried off fields during heavy rainfall. Most will agree that the solution to this problem is at the source. In the case of the agricultural contribution, erosion control in conjunction with banded phosphorus applications is the obvious answer. Phosphorus is applied below the surface and erosion is controlled with crop residue.

Most will also agree that the most cost effective method of controlling erosion is by crop residue management with conservation tillage. In an effort to evaluate conservation tillage options under the specific conditions of the watershed, plots were established in Stearns and Wright counties in the spring of 1986 and in Meeker county in the fall of 1986. Corn and soybeans were grown at Meeker and Wright counties every year and alternated at the Stearns county site. The tillage systems that were evaluated were: Moldboard and chisel plowing, ridge till,and no till. Soybeans were planted with a no till drill in all treatments except the ridge till.

Meeker County

The soil ranges in texture from clay loam to fine sandy loam. The planter used was a conservation tillage planter equipped with clearing discs, smooth coulter-gauge wheel, and a 2" fluted coulter. In row soil cover by crop residue was greater than 35% for the no till system with both sources of residue (table 4). Tillage affected early growth and soybean population (table 5). Conservation tillage systems showed delayed growth but much higher stands than moldboard plowing.

Ammonium polyphosphate broadcast in the spring increased soybean stands with all but the chisel system (table 6). This trend is also apparent in table 7. Phosphorus increased soybean stands with ridge tillage but did not affect early soybean growth (table 8).
When in row cover by soybean residue was less than 20% early corn growth was not affected (table 9). Corn stands were not affected by tillage at this site. Method of phosphorus application did not affect early growth very much (table 10). Moldboard plowing had more growth with broadcast phosphorus and ridge tillage corn grew better with row placed phosphorus. Chisel and no till systems showed no effect of method of placement.

This site has very few weeds (tables 11, and 12). The only tillage effect on the weeds is the increased volunteer corn in soybeans with the chisel system.

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1 Support for this project was provided by the following: the Minnesota Pollution Control Agency, the Clearwater River Watershed District, the Soil Conservation Service, and the Soil and Water Conservation Districts of Meeker, Stearns, and Wright Counties. Their support is greatly appreciated. This project would not have been possible without the assistance provided by SCS and SWCD staff in Meeker, Stearns, and Wright Counties in the treatment establishment and data collection.

2 John F. Moncrief and Joe J. Kuznia are an Associate Professor and Assistant Scientist respectively in the Department of Soil Science, University of Minnesota, St. Paul, MN. 55108. Mary B. Kells is the Tri-County Conservation Project Coordinator, St. Cloud, MN.

Corn grain yields and moisture are shown in table 13. There was no effect of tillage on corn grain yields. Grain moisture was increased almost 5% as tillage was reduced from moldboard plowing to no till and followed "in row" cover trends. Tillage affects on grain moisture did not follow early growth trends however.

There was a tillage by method of phosphorus placement interaction with grain yields (table 14). Corn grown with the no till and ridge till systems responded to row applied over broadcast phosphorus even though the broadcast rate was double that of row applied. Corn grown with the chisel and moldboard plowing systems did not show a difference in yield due to phosphorus placement.

There was no effect of tillage on soybean yield or grain moisture even though there was large differences in early growth (table 15). Soybeans did not respond to applied phosphorus (table 16) or method of placement (table 17 and 18).

Ridge till plots were split with a traffic variable in the fall of 1987 at harvest. One third and one half of the corn and soybean plots (for 1988) were tracked by the combine. Yields were hand harvested to measure the effect of this treatment before combining in 1988 to measure the general tillage effects. Some research suggests that compaction due to traffic may reduce the availability of phosphorus. For this reason method of phosphorus application was also used as a variable. The results of this study are shown in tables 19 and 20 for the corn and soybeans respectively. Traffic by the combine on the ridges the year before did not affect corn or soybean yields. There was an advantage to row phosphorus over broadcast for corn but it did not interact with the traffic variable.

In summary tillage did not affect corn or soybean yields although it did have an influence on early growth. Row applied phosphorus with the planter was important for corn grown with no till and ridge tillage systems. Soybeans did not respond to phosphorus. Traffic by the combine in 1987 on the ridge did not affect the yields of corn or soybeans in 1988.

MEEKER COUNTY

Table 1. Cultural practices at Meeker County MN. 1988.

Tillage
- No Till
- Ridge Till
- Fall Chisel Plowed-Field cultivated prior to planting
- Fall Moldboard Plowed-Field cultivated prior to planting
  - Ridged corn plots on June 14, 1988.
  - Ridged soybean plots on July 7, 1988.

Cropping History
Corn-soybean rotation since 1978.

1988 Crop
Corn-Pioneer 3737
Soybeans-Pioneer 1677

Planting and Harvest Dates
Corn-was planted with a two row Hiniker Series 1 EconoTill planter with 30 inch row spacing.
Soybeans-ridge till was planted with a two row Hiniker Series 1 EconoTill planter with 30 inch row spacing and all other tillage treatments were planted with a Tye No Till drill with 8 inch row spacing.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 5, 1988	32,000 plants/A	September 24, 1988
Soybeans	May 5, 1988	225,000 plants/A	September 24, 1988

Fertilizer History

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			---	lbs/A	----	
Corn:	82-0-0	183 lbs/A	150	0	0	Spring
	4-15-40[1]	250 lbs/A	10	38	100	Planting
Corn:	4-15-40	300 lbs/A	12	45	120	October 27, 1986
	7-21-7[1]	17 gal/A	13	40	13	April 28, 1987
	82-0-0	159 lbs/A	130	0	0	May 15, 1987
Soybeans:	4-15-40	300 lbs/A	12	45	120	October 27, 1986
	0-46-0[2]	45 lbs/A	0	21	0	May 5, 1987

1. Planter placement 2" beside and 2" below row.
2. Drill soybeans were split with row fertilizer which was surface banded ahead of and incorporated by the fluted coulters.

1988 Fertilizer

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied	Method of Application
			---	lbs/A	----		
Corn:	10-34-0	19 gals/A	22	76	0	April 28, 1988	Broadcast
	10-34-0	9 gals/A	11	36	0	May 5, 1988	Row placement 2" x 2"
	82-0-0	183 lbs/A	150	0	0	June 7, 1988	Anhydrous applicator
Soybeans:	10-34-0	10 gals/A	12	40	0	April 28, 1988	Broadcast
	10-34-0	5 gals/A	6	20	0	May 5, 1988	Row placement 2" x 2"
	0-46-0	358 lbs/A	0	165	0	May 5, 1988	Surface banded ahead of and incorporated by 2" fluted coulters

Soil

The soils present at this site are as follows: 29% of plot area is Delft (Cumulic Haplaquolls, fine-loamy, mixed, mesic) clay loam, 43% is Koronis (Mollic Haplaudalfs, fine-loamy, mixed, mesic) fine sandy loam, and the remaining 28% is Marcellon (Aquic Argiudolls, fine-loamy, mixed, mesic) loam.

Weed Control

Corn

1 qt/A (2 lbs/A) Dual + 2 qts/A (2 lbs/A) Bladex applied on May 11, 1988.

Soybeans

1.5 qts/A (1.125 lbs/A) Roundup applied to No Till and Ridge Till plots on May 11, 1988.
1 pt/A (.5 lb/A) Basagran + .5 pt/A (.125 lb/A) Blazer + 1 qt/A oil concentrate on May 31, 1988.
1 pt/A (.5 lb/A) Basagran + 1 pt/A (.188 lb/A) Poast + 1 qt/A Dash oil concentrate + 1 gal/A 28% on June 10, 1988.

Soil Test

Table 2. Soil test results for corn following soybeans on April 7, 1987.

Nutrient	Tillage: No Till	Ridge	Chisel	Moldboard	Avg.	Sig.
	---	lbs/A	---	---		
P	21.2	25.2	27.9	22.8	24.4	.862
K	182.7	177.6	173.1	146.2	169.9	.258

Table 3. Soil test results for soybeans following corn on April 7, 1987.

Nutrient	Tillage: No Till	Ridge	Chisel	Moldboard	Avg.	Sig.
	---	lbs/A	---	---		
P	26.0	20.6	32.7	23.7	25.5	.262
K	208.7	234.9	200.1	173.1	204.2	.016

Table 4. Effect of tillage on soil covered by corn and soybean residue in Meeker Co. in 1988, n=16.

	Soybean Residue in corn 6/14/88					Corn residue in soybean 6/16/88				
	Tillage					Tillage				
	No Till	Ridge	Chisel	Moldboard		No Till	Ridge	Chisel	Moldboard	
Residue Location	% cover				Sig.	% cover				Sig.
In Row	66.8	20.8	18.8	0.8	.000	73.5	21.8	33.3	10.5	.000
Between Row	59.5	36.8	14.8	1.5	.000	58.8	53.5	23.3	9.8	.000

Table 5. Effect of tillage on early growth of soybean and population in Meeker Co. on June 16, 1988, n=24.

	Tillage				
	No Till	Ridge[1]	Chisel	Moldboard	
Variable	nodes/plant				Sig.
Growth Stage	4.1	4.0	4.5	5.0	.016
	plants/A x 10^{-3}				
Population	123.5	146.5	124.6	97.4	.042

1. Ridge till was excluded in statistical analysis for soybeans.

Table 6. Effect of tillage and fertilizer on soybean population in Meeker Co. on June 16, 1988[1].

	Tillage				
	No Till	Ridge	Chisel	Moldboard	Average
Fertilizer[2]	plants/A x 10^{-3}				
Broadcast	145.3	155.9	115.9	117.5	133.7
No Fertilizer	98.0	126.3	133.9	93.1	112.8

1. The p value for the main effect of population for fertilizer and tillage by fertilizer interaction is .016, (n=32), .051, (n=8) respectively.
2. Fertilizer was broadcast as 10-34-0 at 40 lbs P_2O_5/A.

Table 7. Effect of tillage and fertilizer interaction on soybean population in Meeker Co. on June 16, 1988[1].

	Tillage			
	No Till	Chisel	Moldboard	Average
Fertilizer[2]	plants/A x 10^{-3}			
Broadcast	145.3	115.9	117.5	126.3
Row	127.3	124.1	81.6	111.0
No Fertilizer	98.0	133.9	93.1	108.3

1. The p value for the main effect of population for fertilizer and tillage by fertilizer interaction is .077 (n=24), .027, (n=8) respectively.
2. Fertilizer was broadcast as 10-34-0 at 40 lbs P_2O_5/A, and a row rate of 0-46-0 at 165 lbs P_2O_5/A.

Table 8. Effect of fertilizer on soybean population and early growth with a ridge tillage system at Meeker Co. on June 16, 1988.

	Ridge Till	
	Population[1]	Growth stage[2]
Fertilizer[3]	plants/A x 10^{-3}	nodes/plant
Broadcast	155.9	3.9
Row	157.3	4.0
No Fertilizer	126.3	4.0

1. The p value for population is .008, n=8.
2. The p value for growth stage is .807, n=80.
3. Fertilizer was broadcast as 10-34-0 at 40 lbs P_2O_5/A, and a row rate of 10-34-0 at 20 lbs P_2O_5/A.

Table 9. Effect of tillage on corn early growth and population in Meeker Co. on June 14, 1988.

Variable	No Till	Ridge	Chisel	Moldboard	Sig.	n
	Tillage					
	------- leaves/plant -------					
Growth Stage	6.9	7.5	7.4	7.5	.007	160
	------ plants/A x 10^{-3} ------					
Population	30.5	31.6	31.4	32.6	.647	16

Table 10. Effect of tillage and fertilizer on corn early growth at Meeker Co. on June 14, 1988[1].

Fertilizer[2]	No Till	Ridge	Chisel	Moldboard	Avg
	Tillage				
	------- leaves/plant -------				
Broadcast	6.9	7.4	7.4	7.7	7.3
Row	6.9	7.6	7.4	7.4	7.3

1. The p value for the main effect of corn growth for fertilizer and tillage by fertilizer interaction is .420 (n=320), .038, (n=80) respectively.
2. Fertilizer was broadcast as 10-34-0 at 76 lbs P_2O_5/A, and a row rate of 10-34-0 at 36 lbs P_2O_5/A.

Table 11. Effect of tillage on weeds present in corn at Meeker Co. on June 22, 1988, n=4.

Weed	No Till	Ridge	Chisel	Moldboard	Sig.
	Tillage				
	---------- % cover ----------				
Foxtail	8.3	0.3	8.9	9.3	.385
Horsetail	3.9	1.1	8.5	3.8	.215
Lambsquarter	0.0	0.0	0.0	0.3	
Ragweed	0.0	0.0	0.0	0.2	
Vol. Soybean	0.0	0.0	0.3	0.0	
Nutsedge	0.0	0.1	0.3	0.3	

Table 12. Effect of tillage on weeds present in soybeans at Meeker Co. on June 22, 1988, n=4.

Weed	No Till	Ridge	Chisel	Moldboard	Sig.
	Tillage				
	---------- % cover ----------				
Vol. Corn	0.3	0.1	4.5	0.5	.001
Foxtail	8.8	4.5	8.0	5.5	.795
Quackgrass	0.5	0.0	0.5	0.3	
Horsetail	0.6	1.8	0.0	0.3	
Lambsquarter	0.0	0.0	0.0	0.1	
Milkweed	0.0	0.0	0.1	0.0	

Table 13. Effect of tillage on corn yields and moisture in Meeker Co. on Sept. 24, 1988, n=8.

Variable	NoTill	Ridge	Chisel	Moldbd	Sig.
	Tillage				
	--------- bu/A ---------				
Grain Yield	38.8	44.1	40.6	44.9	.179
	---------- % ----------				
Moisture	30.1	28.1	27.6	25.5	.001

Table 14. Effect of tillage and fertilizer on corn yield and moisture at Meeker Co. on Sept. 24, 1988.

	Fertilizer[3]	NoTill	Ridge	Chisel	Moldbd	Avg[2]
		Tillage[1]				
		--------- bu/A ---------				
Grain Yield	Broadcast	34.3	39.5	41.1	43.8	39.7
	Row	43.3	48.7	40.1	46.0	44.5
		---------- % ----------				
Moisture	Broadcast	30.2	28.6	27.9	25.5	28.1
	Row	29.9	27.7	27.4	25.5	27.6

1. The p level of yield and moisture for the tillage by fertilizer interaction is .064 and .680, (n=4) respectively.
2. The p level of yield and moisture for the main effect of fertilizer is .006 and .117, (n=16) respectively.
3. Fertilizer was broadcast as 10-34-0 at 76 lbs P_2O_5/A, and a row rate of 10-34-0 at 36 lbs P_2O_5/A.

Table 15. Effect of tillage on soybean yield and moisture in Meeker Co. on Sept. 24, 1988, n=8.

Variable	NoTill	Ridge[1]	Chisel	Moldbd	Sig.
	bu/A				
Grain Yield	15.2	13.8	13.8	13.6	.367
	%				
Moisture	12.5	12.3	11.8	12.6	.442

1. Ridge till was excluded in statistical analysis for soybeans.

Table 16. Effect of tillage and fertilizer on soybean yield and moisture in Meeker Co. on Sept. 24, 1988.

	Fertilizer[3]	NoTill	Ridge	Chisel	Moldbd	Avg[2]
		Tillage[1] bu/A				
Grain Yield	Broadcast	13.5	14.1	12.3	13.4	13.3
	No Fertilizer	16.8	13.5	15.3	13.8	14.9
		%				
Moisture	Broadcast	12.6	12.2	11.9	13.0	12.4
	No Fertilizer	12.5	12.3	11.7	12.1	12.1

1. The p value of yield and moisture for the tillage by fertilizer interaction is .534 and .358, (n=4) respectively.
2. The p value of yield and moisture for the main effect of fertilizer is .202 and .180, (n=16) respectively.
3. Fertilizer was broadcast as 10-34-0 at 40 lbs P_2O_5/A.

Table 17. Effect of tillage and fertilizer on soybean yield and moisture in Meeker Co. on Sept. 24, 1988.

	Fertilizer[3]	NoTill	Chisel	Moldbd	Avg[2]
		Tillage[1] bu/A			
Grain Yield	Broadcast	13.5	12.3	13.4	13.1
	Row	15.9	12.8	13.5	14.1
	No Fertilizer	16.8	15.3	13.8	15.3
		%			
Moisture	Broadcast	12.6	11.9	13.0	12.5
	Row	12.7	11.8	12.1	12.2
	No Fertilizer	12.5	11.7	12.1	12.1

1. The p level of yield and moisture for the tillage by fertilizer interaction is .783 and .334, (n=4) respectively.
2. The p level of yield and moisture for the main effect of fertilizer is .196 and .128, (n=12) respectively.
3. Fertilizer was broadcast as 10-34-0 at 40 lbs P_2O_5/A, and a row rate of 0-46-0 at 165 lbs P_2O_5/A.

Table 18. Effect of fertilizer on soybean yield and moisture in ridge till at Meeker Co. on Sept. 24, 1988, n=4.

Fertilizer[3]	Ridge Till: Grain Yield[1]	Moisture[2]
	bu/A	%
Broadcast	14.1	12.2
Row	14.5	12.1
No Fertilizer	13.5	12.3

1. The p level for yield is .872.
2. The p level for moisture is .775.
3. Fertilizer was broadcast as 10-34-0 at 40 lbs P_2O_5/A, and a row rate of 10-34-0 at 20 lbs P_2O_5/A.

Table 19. Effect of traffic and fertilizer on ridge till corn yield and moisture at Meeker Co. on Sept. 21, 1988[1].

	Fertilizer[5]	Traffic[2]	No Traffic	Avg[3]
		bu/A		
Grain Yield	Broadcast	40.1	45.1	42.6
	Row	46.5	43.8	45.1
	Average[4]	43.3	44.5	
		%		
Moisture	Broadcast	33.3	33.1	33.2
	Row	30.4	30.4	30.4
	Average	31.9	31.8	

1. Ridge till plots were split with a traffic variable. One third of the ridges were tracked by the combine on September 30 at harvest in 1987.
2. The p level of yield and moisture for the traffic by fertilizer interaction is .342 and .849, (n=8) respectively.
3. The p level of yield and moisture for the main effect of fertilizer is .513 and .010, (n=16) respectively.
4. The p level of yield and moisture for the main effect of traffic is .719, and .851, (n=16) respectively.
5. Fertilizer was broadcast as 10-34-0 at 76 lbs P_2O_5/A, and a row rate of 10-34-0 at 36 lbs P_2O_5/A.

Table 20. Effect of traffic and fertilizer on ridge till on soybeans yield and moisture at Meeker Co. on Sept. 24, 1988[1].

	Fertilizer[5]	Traffic[2]	No Traffic	Avg[3]
		bu/A		
Grain Yield	Broadcast	11.9	12.3	12.1
	Row	12.0	11.8	11.9
	No Fertilizer	12.0	11.7	11.8
	Average[4]	12.0	11.9	
		%		
Moisture	Broadcast	15.5	15.1	15.3
	Row	14.8	16.6	15.7
	No Fertilizer	14.0	14.2	14.1
	Average	14.8	15.3	

1. Ridge till plots were split with a traffic variable. One third of the ridges were tracked by the combine on September 30 at harvest in 1987.
2. The p level of yield and moisture for the traffic by fertilizer interaction is .750 and .549, (n=8) respectively.
3. The p level of yield and moisture for the main effect of fertilizer is .811 and .815, (n=16) respectively.
4. The p level of yield and moisture for the main effect of traffic is .719, and .248, (n=24) respectively.
5. Fertilizer was broadcast as 10-34-0 at 40 lbs P_2O_5/A, and a row rate of 10-34-0 at 20 lbs P_2O_5/A.

Stearns County

The soil at this site is coarse textured and shallow over gravel. Less than 2" of rain fell in June and July at this site. Soybeans were grown after corn in 1987. With the exception of the ridge till system there is little difference between "in row" and "between row" cover (table 22). Early soybean growth was correlated to "in row" cover. Tillage did not affect soybean stands (table 23). Weed observations were made 12 days after post emergence herbicides were applied (table 24). Foxtail is the dominate weed at this site and was higher under no till and chisel plowing conditions. There was very little weeds with the ridge till system. During this dry year cultivation was a very effective method of weed control.

Although soybean yields were very low, they were highest with the ridge till system (table 25). This is likely due to better weed control and less harvest loss. The foxtail growth in the early season before post emergence herbicides were applied likely depleted crucial soil water with all the systems but ridge till. Also soybeans were taller with this system and easier to combine.

STEARNS COUNTY

Table 21. Cultural practices at Stearns County, MN. 1988.

Tillage
- No Till
- Ridge Till
- Chisel Plowed and disced on May 12, 1988.
- Moldboard Plowed and disced on May 12, 1988.

Cropping History
1981-red clover and oats, 1982-corn, 1983-soybeans, 1984-corn, 1985-corn, 1986-soybeans, 1987-corn

1988 Crop
Soybeans - Pioneer 1677

Planting and Harvest Dates
Ridge till plots were planted with a four row Buffalo Till planter equipped with 12" sweeps at a 38"row spacing. All other soybean treatments were planted with a Tye No Till drill with 8" row spacing equipped with 2" fluted coulters.

	Planting			
Crop	Date	Planter	Rate	Harvested
Soybeans	May 13, 1988	Row	198,000 plants/A	October 12, 1988
	May 13, 1988	Drill	224,400 plants/A	October 12, 1988

Fertilization History
The fertilization history at this site is as follows: 1981-none, 1982-low rate of dry starter, 1983-low rate of starter and 0-0-60, 1984-4 gal/A of 9-18-9 only, 1985-60 lbs/A of N and 4 gal/a of 9-18-9, 1986-all soybean plots were split with and without a row fertilizer treatment at planting, and in 1987 all corn plots were split with three rates of starter.

				Actual			
	Material			N	P_2O_5	K_2O	
Crop	Analysis	Rate	Tillage	---	lbs/A	---	Date Applied
Soybeans	9-18-9[1]	4 gal/A	Ridge Till	4	8	4	May 16, 1986
	0-0-60[2]	90 lbs/A	All Others	0	0	54	May 16, 1986
Corn	Starter Fertilizer Treatments						
	9-18-9[1]	0 gal/A	All	0	0	0	April 29, 1987
	9-18-9[1]	4.9 gal/A	All	4.7	10	4.7	April 29, 1987
	9-18-9[1]	9.7 gal/A	All	9.3	18.5	9.3	April 29, 1987
	Nitrogen Management						
	28-0-0	11 gal/A	No Till[3]	33	0	0	June 1, 1987
	28-0-0	11 gal/A	All Others[4]	33	0	0	June 1, 1987
	28-0-0	11 gal/A	No Till[3]	33	0	0	June 25, 1987
	28-0-0	11 gal/A	All Others[4]	33	0	0	June 25, 1987

1. Planter placement 1" below the seed.
2. Potash was surface banded ahead of and incorporated by the fluted coulters.
3. Nitrogen was surface banded.
4. Nitrogen was surface banded and incorporated by cultivation.

Soil
The soils at the Stearns County site are Fairhaven (Typic Hapludolls) loam which is well drained on 54 percent of the plot. Estherville (Typic Hapludolls) sandy loam which is somewhat excessively drained on 36 percent of the plot, Hawick (Entic Hapludolls) loamy sand, this soil is excessively drained on the remaining 10 percent of the plot. The slope average for all three soils is 2.5 percent with the the highest being 4 percent.

Weed Control

1.5 qts/A (1.125 lbs/A) Roundup + 1 gal/A 28% applied to no till and ridge till on May 11, 1988.
1 pt/A (.5 lb/A) Basagran + .5 pt/A (.125 lb/A) Blazer + 1 qt/A oil concentrate on May 31, 1988.
1 pt/A (.5 lb/A) Basagran + 1 pt/A (.188 lb/A) Poast + 1 qt/A Dash oil concentrate + 1 gal/A 28% on June 10, 1988.

Table 22. Effect of tillage on soil covered by corn residue in soybeans in Stearns Co. on June 15, 1988, n=16.

	Tillage				
	No Till	Ridge	Chisel	Moldboard	
Residue Location	% cover				Sig.
In Row	72.0	36.0	25.0	5.3	.000
Between Row	73.8	48.0	22.0	2.5	.000

Table 23. Effect of tillage on early growth of soybeans and population in Stearns Co. on June 16, 1988, n=80.

	Tillage				
	No Till	Ridge	Chisel	Moldboard	
Variable	nodes/plant				Sig.
Growth Stage	2.8	3.4	3.2	3.6	.000
	plants/A x 10^{-3}				
Population	225.3	170.1	250.6	265.3	.126[1]

1. The ridge till treatment was excluded from the statistical analysis.

Table 24. Effect of tillage on percent cover by weeds in soybeans at Stearns Co. on June 22, 1988, n=4.

	Tillage				
	No Till	Ridge	Chisel	Moldboard	
Weed	% cover				Sig.
Vol Corn	0.1	0.0	0.9	1.0	
Foxtail	80.0	2.5	50.0	18.8	.000
Quackgrass	0.3	0.0	0.0	0.3	
Milkweed	4.0	0.3	1.0	1.1	.102

Table 25. Effect of tillage on soybean yield and moisture in Stearns Co. on October 12, 1988, n=4.

	Tillage				
	No Till	Ridge	Chisel	Moldboard	
Variable	bu/A				Sig.
Grain Yield	1.5	4.0	0.9	1.6	.006
	%				
Moisture	10.5	11.0	11.0	11.7	.157

Wright County

The soil at this site has very little storage capacity and less than an inch of rain fell in June and July (see weather data from tillage studies this publication). For these reasons there was no corn grain yield and very little soybean grain yield at this site. It is useful however to see how tillage affected growth under the extreme drought conditions.

The cover by corn and soybean residue and the corresponding early growth are shown in tables 27 and 28 respectively. Soil cover by crop residue without tillage was 94% and 57% for the corn and soybean residue sources respectively. The "in row" soil cover in the no till treatment was reduced 37% and 13% for corn and soybean residue respectively. The planter at this site is equipped with add on 10" sweeps that can be raised hydraulically. The cover in and between the row with the ridge till, moldboard, and chisel systems was similar for both sources of residue.

Early corn growth was similar for all systems except moldboard plowing which had about .5 leaves per plant more growth on June 16. It is unusual that the ridge till cover in the row was similar to that of the moldboard plowing system but early growth was not similar. The early growth of the soybeans did follow "in row" cover trends (ridge till and moldboard plowing are similar). Tillage did not affect plant populations for either crop on the June 16 date although the trend was for higher corn stand with the no till treatment. Since the ridge till soybeans were planted with a planter and other treatments with a no till drill a comparison between these treatments cannot be made.

Corn was relatively weed free (good herbicide control) and there were no tillage effects on species or density of weeds present (table 29). This site received 1.29 inches of rain shortly after planting (see weather summary for tillage sites, this publication). Soybean weed observations were made 12 days after an application of post emergence herbicide and weeds were still present (table 30). Foxtail growth was similar in all systems but the ridge till. This reflects the aggressive cultivation that is associated with this system. Volunteer corn was higher in chisel and moldboard plowed plots.

Corn yield and final stand are shown in tables 31 and 32. There were no ears formed and only half the corn produced tassels. For this reason dry matter production was used to assess tillage effects. Tillage affected dry matter yields, plant size, and final stand. Dry matter production was higher with the ridge till and no till treatments. This was due to less mortality and larger plants. Stand losses between June 16 and September 28 were 0, 1, 3, and 3 thousand plants per acre for the no till, ridge till, chisel, and moldboard plowing treatments respectively (tables 28 and 31).

Soybean yields were all less than 2 bushels per acre and not affected by tillage (table 33).

WRIGHT COUNTY

Table 26. Cultural practices at Wright County, MN. 1988.

Tillage
- No Till
- Ridge Till
- Chisel Plow-October 8, 1987.
- Moldboard Plow-October 8, 1987.

Preceding Crops
- Corn-soybean rotation since 1982.

1988 Crops
- Corn - Pioneer 3737
- Soybeans - Pioneer 1677

Planting and Harvest Dates

Soybeans-Ridge till plots were planted with a John Deere Maxemerge planter equipped with Buffalo Till ridge cleaners with 10" sweeps. All other plots were planted with a Tye No Till drill with 8" row spacing equipped with 2" fluted coulters.
Corn-Ridge till plots were planted with a John Deere Maxemerge planter equipped with Buffalo Till ridge cleaners with 10" sweeps. All other plots were planted with the John Deere Maxemerge planter but the sweeps were raised.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 6, 1988	29,900 plants/A	September 28, 1988
Soybeans	May 12, 1988	225,000 plants/A	October 8, 1988

Fertilization History

Since 1983 both corn and soybeans received 100 to 150 lbs/ac of a 5-12-36 fertilizer applied with the planter. Prior to that only the corn received fertilizer with the planter. 1986 was fertilized as follows:

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			---	lbs/a	----	
Corn:	8-23-30[1]	140 lbs/A	11	32	42	May 2, 1986
	28-0-0[2] UAN	37 gal/A	110	0	0	June 13, 1986
Corn:	8-20-32[1]	140 lbs/A	11	28	45	May 4, 1987
	82-0-0	183 lbs/A	150	0	0	June 15, 1987

1. Planter placement 2" beside and 2" below row.
2. Surface banded between rows.

1988 Fertilizer

Corn plots were split with stater fertilizer.

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			---	lbs/A	----	
Corn:	9-20-33[1]	140 lbs/A	13	28	46	May 6, 1988
	82-0-0	150 lbs/A	123	0	0	June 8, 1988

1. Planter placement 2" beside and 2" below row.

Soil

Soybeans-Kanaranzi (Typic Hapludolls, fine-loamy over sandy or sandy-skeletal, mixed, mesic) loam, 2 to 6 percent slope on 95 percent of the plot area. Fairhaven (Typic Hapludolls, fine-loamy over sandy or sandy-skeletal, mixed, mesic) loam, 0 to 2 percent slope on 5 percent of the plot area. Both soils are well drained.

Corn-Kanaranzi (Typic Hapludolls, fine-loamy over sandy or sandy-skeletal, mixed, mesic) loam, 2 to 6 percent slope on 90 percent of the plot area. Salida (Entic Hapludolls, sandy-skeletal, mixed, mesic) gravelly sandy loam, 3 to 6 percent slope on 10 percent of the plot area. Both soils are well drained.

Weed Control

Corn

1.5 qts/A (1.5 lbs/A) Lasso + 1.2 qts/A (2.4 lbs/A) Dual on May 6, 1988 with planter.

Soybeans

1.3 qts/A (1 lb/A) Roundup + 1 pt/A (.5 lb/A) 2,4-D applied to no till and ridge till treatments on May 6, 1988.

1 qt/A (1 lb/A) Lorox + 2 qts/A (2 lbs/A) Lasso applied with the planter for the ridge till system on May 12, 1988.

1 pt/A (.5 lb/A) Basagran + .5 pt/A (.125 lb/A) Blazer + 1 qt/A oil concentrate on May 31, 1988.

1 pt/A (.5 lb/A) Basagran + 1 pt/A (.188 lb/A) Poast + 1 qt/A Dash oil concentrate + 1 gal/A 28% on June 10, 1988.

Table 27. Effect of tillage on crop residue in Wright Co. 1988 on May 12, 1988, n=16.

	Soybean Residue in Corn					Corn Residue in Soybeans				
	Tillage					Tillage				
	No Till	Ridge	Chisel	Moldboard		No Till	Ridge	Chisel	Moldboard	
Location	--------	% cover	----------		Sig.	--------	% cover	----------		Sig.
In Row	57.3	7.8	22.3	4.5	.000	43.8	7.0	24.0	7.8	.000
Between Row	93.5	32.0	29.5	6.0	.000	57.0	35.0	23.8	7.8	.000

Table 28. Effect of tillage on corn and soybean early growth and population in Wright Co. on June 16, 1988.

	Crop											
	Corn						Soybean					
	Tillage						Tillage					
	No Till	Ridge	Chisel	Moldboard			No Till	Ridge	Chisel	Moldboard		
Variable	leaves/plant				Sig.	n	nodes/plant				Sig.	n
Growth Stage	8.3	8.1	8.4	8.9	.000	160	3.9	4.3	3.8	4.1	.042	80
	plants/A x 10^{-3}						plants/A x 10^{-3}					
Population	31.3	29.5	29.3	28.9	.214	32	231.0	179.2	258.8	256.3	.384[1]	16

1. The ridge till treatment was excluded from the statistical analysis for soybean stands.

Table 29. Effect of tillage on weed severity in corn at Wright Co. June 22, 1988, n=4.

	Tillage				
	No Till	Ridge	Chisel	Moldboard	
Weed	% cover				Sig.
Foxtail	0.5	0.3	1.6	5.5	.115
Volsoybean	0.0	0.0	0.1	0.0	
Quackgrass	1.5	0.5	0.6	0.3	.354
CanadaThis	0.0	0.0	0.0	0.0	
Milkweed	0.0	0.0	0.0	0.0	
Ragweed	0.0	0.0	0.0	0.0	
Buckwheat	0.3	0.0	0.0	0.0	

Table 30. Effect of tillage on weed severity in soybeans at Wright Co. on June 22, 1988, n=4.

	Tillage				
	No Till	Ridge	Chisel	Moldboard	
Weed	% cover				Sig.
Foxtail	21.3	0.8	20.0	19.5	.064
Milkweed	1.6	0.0	1.3	0.3	
Volcorn	1.3	0.5	8.8	7.8	.003
Lambsquart	1.0	0.0	0.8	1.0	
Pigweed	1.3	0.0	0.0	1.3	
Pennycress	0.3	0.0	0.0	0.0	
Curlydock	0.3	0.0	0.0	0.0	

Table 31. Effect of tillage on corn yield and final stand in Wright Co., on Sept. 28, 1988, n=16.

	Tillage				
	No Till	Ridge	Chisel	Moldboard	
Variable	tons/A				Sig.
Stover Yield	0.82	0.64	0.54	0.54	.001
	gram/plant				
Plant size	23.9	20.5	19.4	18.5	.008
	plants/A x 10^{-3}				
Final Stand	31.5	28.5	25.4	26.2	.025

Table 32. Effect of tillage and starter fertilizer on corn dry matter yield and plant size in Wright Co., Sept. 28, 1988[1].

	Tillage			
Variable	No till	Ridge	Chisel	Moldboard
Stover Yield	tons/A			
Starter[2]	0.82	0.59	0.56	0.53
No Starter	0.82	0.69	0.52	0.55
Plant size	gram/plant			
Starter	23.6	19.5	21.0	18.5
No Starter	24.3	21.5	17.7	18.5

1. The p value for the tillage by starter interaction is .415 and .098 for stover yield and plant size respectively, n=8.
2. Starter (9-20-33) was applied with the planter on May 6, 1988 at a rate of 140lb/A.

Table 33. Effect of tillage on soybean yield and moisture in Wright Co. Oct. 8, 1988, n=4.

	Tillage				
	No Till	Ridge	Chisel	Moldboard	
Variable	bu/A				Sig.
Yield	0.3	1.8	1.6	0.4	.306
	%				
Moisture	14.2	10.5	12.6	11.8	.120

The Effect of Tillage on Winter and Spring Wheat, Barley, and Soybean Production on a Lacustrine Soil in Northwestern Minnesota[1]

J.F. Moncrief, K.J. Pazdernik, and J.J. Kuznia[2]

Abstract: Three tillage systems are evaluated on a silty clay soil in a soybeans-barley-wheat rotation. There was little effect of tillage on spring wheat or barley yields if nitrogen was managed properly. Bighorn winter wheat showed higher winter losses when grown with plowing systems and had lower yields. No till grown soybeans had higher yields than those grown with moldboard and chisel plowing.

This is the third year of a three year project to evaluate the effect of tillage on the production of winter and spring wheat, barley and soybeans on a Vertic Haplaquoll soil in northwestern Minnesota. The crop rotation is barley-wheat-soybeans. Wheat plots are split with winter and spring wheat. Each crop is grown every year. For summaries the preceding two years refer to this publication in 1987 and 1988.

The spring soil test in 1988 revealed a tillage effect on nitrate nitrogen (2' samples). Following both barley and soybeans there was more nitrate nitrogen with moldboard plowing . The nitrogen rate for barley the preceding year applied April 24, 1987 was 100 lbs N/acre as drill applied diammonium phosphate (18 lbs N/acre) and broadcast urea (82 lbs N/acre). It is unlikely that there were denitrification losses in 1987. These differences probably reflect differences in mineralization of soil organic matter (4-5% OM) due to physical changes in the soil environment with tillage. Nitrogen rates for wheat following barley were adjusted based on soil tests for each tillage system. There were two nitrogen rates for barley following soybeans, zero and the recommended rate based on soil test nitrate.

Differences in soil test P and K probably reflect tillage effects on phytocycling of these two nutrients. This has been observed at other locations.

Cover by barley and soybean residue is shown in tables 3 to 8. The effect of no tillage on the amount of soil cover is similar for both barley and soybean residue. Chisel and moldboard plowing reduces the cover by soybean residue more than barley residue. The effect of secondary tillage in the spring is apparent when comparing the effect of plowing treatments on cover by barley residue in winter and spring wheat. There is also a small increase in cover over the row with all systems. This probably reflects the action of the double disc openers on the drill which was not very effective in removing residue from the row area.

There appeared to be a trend of tillage affecting winter wheat stand in the fall of 1987 (table 9). Less tillage resulted in higher stands. Bighorn went into the winter with a slightly higher stand than Roughrider.

The level of weeds that occurred in winter wheat closely followed winter stand loss (table 10 and 12). There were more weeds in chisel and moldboard plowing plots and generally more weeds in Bighorn plots (table 12). Stand losses are shown in table 19. No till winter wheat had fewer weeds for both varieties. There were very little weeds in spring wheat (tables 11 and 13).

Grain yields, moisture, and test weights are shown in table 14. These estimates were taken in areas of the plot where there was little stand loss of winter wheat with a small plot combine (4 foot head). The winter wheat yields reflect tillage differences independent of stand loss. Yields adjusted for stand loss are shown in table 15.

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1 This project is supported by the Soil Conservation Service. There support is greatly appreciated. Data collection was aided by Fred Kollman, the District Conservationist in Norman County.

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There was little difference in the yield for the winter and spring wheats with the exception of the Bighorn which suffered major stand losses with plowing systems. Tillage did not affect spring or winter wheat when stand losses were avoided in the yield sample.

When yields were adjusted for stand losses tillage had a significant effect on winter wheat yields (table 15). The spring wheat was not quite ready for combining on the July 25 sampling date. On August 18 they were sampled again with the growers combine. These data are shown in table 16. Again there was no effect of tillage on spring wheat yields although yields were slightly higher than the July 25 harvest.

Stand survival is shown in table 17. No till winter wheat had an 85% stand at harvest. The plowing systems resulted in about a 50% stand. Bighorn and Roughrider plots had 51% and 71% stands respectively at harvest.

Barley yields were not affected by tillage (table 18). This is consistent with the prior two years. Small grain planted into soybean stubble minimizes stand and nitrogen problems.

Check plot yields support the differences in soil nitrate that were measured in the spring (table 19). More tillage resulted in higher yields. When nitrogen was applied yield differences tended in a reverse direction.

Soybean yields were higher grown with no tillage (table 20). In the previous two years there were no difference in soybean yields due to tillage. The advantage of no till grown soybeans may have been due reduced runoff of the 5.38 inches of rain that fell in the last week of July and the first week of August.

NORMAN COUNTY

Table 1. Cultural practices at Norman County, MN. 1988.

Tillage

No Till
Fall Chisel Plowed
Fall Moldboard Plowed
The spring seeded chisel and moldboard plow treatments were field cultivated twice with a drag behind it before seeding.

Planting and Harvest Dates

A Haybuster No Till Disc Drill was used to plant all plots.

Crop	Planting Date	Planting Rate	Harvested
Winter wheat	Aug. 31, 1987	86 lbs/A	July 25, 1988
Spring wheat	April 22, 1988	100 lbs/A	July 25, 1988
			Aug. 18, 1988
Barley	April 22, 1988	90 lbs/A	July 25, 1988
Soybeans	May 10, 1988	94 lbs/A	Sept. 6, 1988

Cropping History

1985-Spring Wheat, 1986-87 three year (barley, wheat soybean) rotation.

1988 Crops

Winter wheat - Bighorn
- Roughrider

Spring wheat - Marshall
- Stoa

Barley - Robust

Soybeans - McCalls

Soil

Fargo silty clay, 0 to 1 percent slopes (Vertic Haplaquolls, fine, montmorillonitic, frigid) on 50 percent of the plot and Hegne (Typic Calciaquolls, fine, frigid)-Fargo (Vertic Haplaquolls, fine, montmorillonitic, frigid) silty clays on the rest of the plot. Both soils are poorly drained.

Weed Control

Spring Wheat

1 pt/A (.5 lb/A) Bronate (.25 lb/A Bromoxynil & .25 lb/A MCPA) applied on June 3, 1988.

Barley

1 pt/A (.5 lb/A) Bronate (.25 lb/A Bromoxynil & .25 lb/A MCPA) applied on June 3, 1988.

Soybeans

1.25 pts/A (.47 lb/A) Roundup applied to No Till plots on May 13, 1988.
1.25 pts/A Galaxy applied on June 6, 1988.
1 pt/A (.188 lb/A) Poast + 1 qt/A Dash applied on June 10, 1988.
1.5 pts/A (.375 lb/A) Blazer applied on June 25, 1988.

Fertilizer

Crop	Tillage	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied	Method of Application
				---	lb/A	----		
Winter wheat:	All	18-46-0	90 lb/A	16	41	0	Aug. 31, 1987	Drill
	No Till	46-0-0	152 lb/A	70	0	0	April 21, 1988	Broadcast
	Chisel	46-0-0	87 lb/A	40	0	0	April 21, 1988	Broadcast
	Moldboard	46-0-0	65 lb/A	30	0	0	April 21, 1988	Broadcast
Spring wheat:	All	18-46-0	95 lb/A	17	44	0	April 22, 1988	Drill
	No Till	46-0-0	152 lb/A	70	0	0	April 21, 1988	Broadcast
	Chisel	46-0-0	87 lb/A	40	0	0	April 21, 1988	Broadcast
	Moldboard	46-0-0	65 lb/A	30	0	0	April 21, 1988	Broadcast
Barley:	All	18-46-0	95 lb/A	17	44	0	April 22, 1988	Drill
	NoTill & Chisel	46-0-0	120 lb/A	55	0	0	April 21, 1988	Split barley plots
	Moldboard	46-0-0	65 lb/A	30	0	0	April 21, 1988	with broadcast urea

Soil Test

Table 2. Soil test results at Norman Co. for barley (previous crop soybeans) and winter and spring wheat (previous crop barley), nitrate nitrogen sampled to a depth of 2 feet, phosphorus and potassium sampled to a depth of 6 inches, sampled Spring 1988.

	Tillage															
	NoTil	Chisl	Moldbd		NoTil	Chisl	Moldbd		NoTil	Chisl	Moldbd		NoTil	Chisl	Moldbd	
	Nitrate Nitrogen				Phosphorus				Potassium				Organic Matter			
Previous Crop	-----	lbs/A[1]	-----	Avg	-----	lbs/A[2]	-----	Avg	-----	lbs/A[3]	-----	Avg	------	%[4]	------	Avg
Soybeans	53	55	75	61	36	36	24	32	600	575	520	565	4.8	4.5	3.9	4.4
Barley	43	71	99	71	38	21	25	28	643	583	627	618	4.0	3.8	3.6	3.8
Average	48	63	87	66	37	28	25	30	622	579	573	591	4.4	4.1	3.8	4.1

1. The p value for nitrate nitrogen for the main effect of previous crop, tillage, and tillage by previous crop interaction is .103 (n=9), .002 (n=6), .034 (n=3) respectively.
2. The p value for phosphorus for the main effect of previous crop, tillage, and tillage by previous crop interaction is .588 (n=9), .092 (n=6), .178 (n=3) respectively.
3. The p value for potassium for the main effect of previous crop, tillage, and tillage by previous crop interaction is .169 (n=9), .246 (n=6), .275 (n=3) respectively.
4. The p value for organic matter for the main effect of previous crop, tillage, and tillage by previous crop interaction is .008 (n=9), .254 (n=6), .760 (n=3) respectively.

Table 3. The effect of tillage on soil cover in and between the row by barley residue in winter wheat. Data was collected on August 31, 1987, n=12[1].

	IN-ROW RESIDUE				BETWEEN ROW RESIDUE			
	Tillage							
	No Till	Chisel	Moldboard		No Till	Chisel	Moldboard	
Crop-Variety	%							
Winter Wheat (Barley residue)				Avg.				Avg.
Bighorn	90.7	45.7	16.3	50.9	87.7	36.0	12.3	45.3
Roughrider	89.7	32.0	11.3	44.3	88.0	31.3	8.7	42.7

1. Tillage is significant < .100 in all cases.

Table 4. Effect of tillage on soil covered by barley residue in Winter wheat in Norman Co. on August 31, 1987[1].

	Tillage			
	No Till	Chisel	Moldboard	Average
Residue Location	% cover			
In Row	90.2	38.8	13.8	47.6
Between Row	87.8	33.7	10.5	44.0
Average	89.0	36.3	12.2	

1. The p value for residue for the main effect of location, tillage, and the tillage by residue location interaction is .036 (n=72), .000 (n=48), and .635 (n=24) respectively.

Table 5. The effect of tillage on soil cover in and between wheat rows on April 22, 1988.

	IN-ROW RESIDUE				BETWEEN ROW RESIDUE			
	Tillage							
	No Till	Chisel	Moldboard		No Till	Chisel	Moldboard	
Crop-Variety	%							
Winter Wheat[1] (Barley residue)				Average				Average
Bighorn	81.0	35.7	19.7	45.4	89.7	24.7	8.3	40.9
Roughrider	84.0	33.7	15.0	44.2	91.3	30.0	10.0	43.8
Average	82.5	34.7	17.3	44.8	90.5	27.3	9.2	42.3
Spring Wheat[2] (Barley Residue)								
Marshall	76.0	18.7	9.3	34.7	79.3	16.3	6.3	34.0
Stoa	77.7	25.0	7.0	36.6	79.7	18.0	5.7	34.4
Average	76.8	21.8	8.2	35.6	79.5	17.2	6.0	34.2
Barley (soybean Residue)								
Robust	78.0	11.5	2.3		80.3	8.5	2.3	

1. The p value for in-row residue for the main effect of winter wheat for variety, tillage, and tillage by variety interaction is .624 (n=36), .000 (n=24), .460 (n=12) respectively. The p value for between row residue for the main effect of winter wheat for variety, tillage, and tillage by variety interaction is .137 (n=36), .000 (n=24), .584 (n=12) respectively.
2. The p value for in-row residue for the main effect of spring wheat for variety, tillage, and tillage by variety interaction is .568 (n=36), .000 (n=24), .558 (n=12) respectively. The p value for between row residue for the main effect of spring wheat for variety, tillage, and tillage by variety interaction is .862 (n=36), .000 (n=24), .926 (n=12) respectively.

Table 6. The effect of tillage and wheat type on soil cover in and between wheat rows on April 22, 1988.

	IN-ROW RESIDUE				BETWEEN ROW RESIDUE			
	Tillage							
	No Till	Chisel	Moldboard		No Till	Chisel	Moldboard	
	%							
Crop[1]	(Barley residue)			Average				Average
Winter Wheat	82.5	34.7	17.3	44.8	90.5	27.3	9.2	42.3
Spring Wheat	76.8	21.8	8.2	35.6	79.5	17.2	6.0	34.2
Average	79.7	28.3	12.8	40.2	85.0	22.3	7.6	38.3

1. The p value of wheat in-row residue for the main effect of crop, tillage, and tillage by crop interaction is .003 (n=72), .000 (n=48), .238 (n=24) respectively. The p value of wheat between row residue for the main effect of crop, tillage, and tillage by crop interaction is .002 (n=72), .000 (n=48), .079 (n=24) respectively.

Table 7. Effect of tillage on soil covered by barley residue in wheat (Winter and Spring) in Norman Co. on April 22, 1988.

	Tillage			
	No Till	Chisel	Moldboard	Average
Residue Location	% cover			
In Row	79.7	28.3	12.8	40.2
Between Row	85.0	22.3	7.6	38.3
Average	82.3	25.3	10.2	

1. The p value of residue for the main effect of location, tillage, and the tillage by residue location interaction is .164 (n=144), .000 (n=96), and .024 (n=48) respectively.

Table 8. Effect of crop on soil covered by barley residue in wheat (Winter and Spring) in Norman Co. on April 22, 1988[1].

	Tillage			
	No Till	Chisel	Moldboard	Average
Crop	% cover			
Winter wheat	86.5	31.0	13.3	43.6
Spring wheat	78.2	19.5	7.1	34.9

1. The p value of residue for the main effect of location, tillage, and the tillage by residue location interaction is .000 (n=144) and .044 (n=48) respectively.

Table 9. The effect of tillage and wheat variety on population at Norman Co. on Oct. 1, 1987, n=18.

	Tillage			
Crop-Variety	No Till	Chisel	Moldboard	
Winter Wheat	plants/A x 10^{-3}			Average
Bighorn	793.8	697.0	759.9	750.3
Roughrider	779.3	726.1	605.0	703.5
Average	786.6	711.5	682.5	

1. The p value for the main effect of stand for variety, tillage, and the tillage by variety interaction is .389 (n=54), .337 (n=36), and .364 (n=18) respectively.

Table 10. The effect of tillage and variety on weeds in winter wheat on July 25, 1988, n=3.

	Bighorn Wheat				Roughrider Wheat			
	Tillage							
	No Till	Chisel	Moldboard		No Till	Chisel	Moldboard	
Weed	------- % cover ---------			Sig.	-------- % cover ---------			Sig.
Canada Thistle	2.7	0.0	0.0		1.7	0.0	0.0	
Wild Oat	5.0	23.3	0.0		0.0	16.7	6.7	
Lambsquarter	0.0	11.0	67.7		0.0	0.0	11.7	
Buckwheat	6.7	33.3	25.0	.486	8.3	50.0	16.7	.002
Foxtail	11.7	30.0	0.0		0.0	20.0	10.0	
G. Ragweed	0.7	1.7	0.0		0.0	3.3	0.0	

Table 11. The effect of tillage and variety on weeds in spring wheat on July 25, 1988, n=3.

	Marshall Wheat				Stoa Wheat			
	Tillage							
	No Till	Chisel	Moldboard		No Till	Chisel	Moldboard	
Weed	------- % cover ---------			Sig.	-------- % cover ---------			Sig.
Wild Oat	2.0	14.0	12.0	.358	3.0	5.3	7.7	.593
Foxtail	0.7	0.0	0.0		0.0	0.0	0.0	

Table 12. The effect of tillage, on cover by weeds in winter wheat on July 25, 1988.

	Tillage (n=6)				Variety (n=9)		
	No Till	Chisel	Moldboard		Bghn	Rrdr	
Weed	------- % cover --------			Sig.	- % cover -		Sig.
Canada Thist	2.2	0.0	0.0		0.9	0.6	.643
Wild Oat	2.5	20.0	3.3	.062	9.4	7.8	.828
Lambsquarter	0.0	5.5	39.7		26.2	3.9	.016
Buckwheat	7.5	41.7	20.8	.060	21.7	25.0	.737
Foxtail	5.8	25.0	5.0	.038	13.9	10.0	.679
G. Ragweed	0.3	2.5	0.0		0.8	1.1	.573

Table 13. The effect of tillage, on cover by weeds in spring wheat on July 25, 1988.

	Tillage (n=6)				Variety (n=9)		
	No Till	Chisel	Moldboard		Mrsl	Stoa	
Weed	------- % cover --------			Sig.	- % cover -		Sig.
Wild Oat	2.5	9.7	9.8	.302	9.3	5.3	.319
Foxtail	0.3	0.0	0.0		0.2	0.0	

Table 14. Effect of tillage and variety on wheat yield, moisture and test weight in Norman Co. in 1988. Harvest date was on July 25, 1988, n=3[1].

Crop-Variety	Tillage: No Till	Chisel	Moldboard		No Till	Chisel	Moldboard		No Till	Chisel	Moldboard	
	Grain Yield				Moisture				Test Weight			
Winter wheat	bu/A[2]			Avg.	%[3]			Avg.	lbs/bu[4]			Avg.
Bighorn	23.1	14.7	21.6	19.8	8.7	17.7	16.7	14.4	59.8	56.7	58.0	58.2
Roughrider	24.0	24.2	26.8	25.0	9.5	15.5	13.6	12.8	58.7	58.5	59.0	58.7
Average	23.6	19.4	24.2	22.4	9.1	16.6	15.1	13.6	59.3	57.6	58.5	58.4
Spring wheat												
Marshall	30.2	25.6	24.3	26.7	16.6	20.5	26.3	21.1	54.7	54.7	52.2	53.8
Stoa	25.4	25.2	22.7	24.4	16.0	19.3	22.7	19.3	53.5	54.3	53.3	53.7
Average	27.8	25.4	23.5	25.6	16.3	19.9	24.5	20.2	54.1	54.5	52.8	53.8

1. The yield estimates were made with a plot combine with a 4 foot head and 75 foot harvest length in areas where there was very little stand loss. This gives a yield estimate for winter and spring wheat independent of stand loss.
2. The p value for **winter wheat** yield for the main effect of variety, tillage, and tillage by variety interaction is .189 (n=9), .511 (n=6), .419 (n=3) respectively. The p value for **spring wheat** yield for the main effect of variety, tillage, and tillage by variety interaction is .314 (n=9), .716 (n=6), .758 (n=3) respectively.
3. The p value for **winter wheat** moisture for the main effect of variety, tillage, and tillage by variety interaction is .591 (n=9), .088 (n=6), .917 (n=3) respectively. The p value for **spring wheat** moisture for the main effect of variety, tillage, and tillage by variety interaction is .505 (n=9), .012 (n=6), .732 (n=3) respectively.
4. The p value for **winter wheat** test weight for the main effect of variety, tillage, and tillage by variety interaction is .959 (n=9), .563 (n=6), .896 (n=3) respectively. The p value for **spring wheat** test weight for the main effect of variety, tillage, and tillage by variety interaction is .488 (n=9), .601 (n=6), .325 (n=3) respectively.

Table 15. The effect of tillage and variety of wheat yield adjusted for stand loss at Norman Co. on July 25, 1988.[1]

Crop-Variety	Tillage: No Till	Chisel	Moldboard	
	Grain Yield			
Winter wheat[2]	bu/A			Average
Bighorn	18.9	6.5	6.6	10.7
Roughrider	21.3	13.3	19.2	17.9
Average	20.1	9.9	12.9	14.3
Spring wheat[3]				
Marshall	29.0	23.9	22.5	25.1
Stoa	24.4	24.3	21.4	23.4
Average	26.7	24.1	22.0	24.3

1. Yield estimates (75' x 4' sample size), in areas where there was little stand loss were multiplied times a visual estimate of the percent stand over the whole plot.
2. The p value for winter wheat yield for the main effect of variety, tillage, and tillage by variety interaction is .288 (n=9), .425 (n=6), .425 (n=3) respectively.
3. The p value for spring wheat yield for the main effect of variety, tillage, and tillage by variety interaction is .039 (n=9), .090 (n=6), .323 (n=3) respectively.

Table 16. The effect of tillage and variety on yield on spring wheat at Norman Co. on August 18, 1988.

Crop-Variety	Tillage: No Till	Chisel	Moldboard	
Spring Wheat	bu/A			Average
Marshall	25.9	26.5	25.6	26.0
Stoa	26.8	24.4	27.9	26.4
Average	26.3	25.4	26.8	26.2

1. These yield estimates were made with a production combine (20′ x 200′ sample size). The p value for spring wheat yield for the main effect of variety, tillage, and tillage by variety interaction is .853 (n=9), .923 (n=6), .648 (n=3) respectively.

Table 17. The effect of tillage and variety of wheat on percent stand at Norman Co. on July 25, 1988[1].

Crop-Variety	Tillage: No Till	Chisel	Moldboard	
	Percent Stand			
Winter wheat	%			Average
Bighorn	81.7	41.7	30.0	51.1
Roughrider	88.3	53.3	71.7	71.1
Average	85.0	47.5	50.8	61.1
Spring wheat				
Marshall	96.0	93.3	92.7	94.0
Stoa	95.0	96.7	93.3	95.0
Average	95.5	95.0	93.0	94.5

1. This is a visual estimate of the percent of the plot with a good stand of wheat. The p value for spring wheat percent stand for the main effect of variety, tillage, and tillage by variety interaction is .017 (n=9), .007 (n=6), .092 (n=3) respectively. The p value for winter wheat percent stand for the main effect of variety, tillage, and tillage by variety interaction is .592 (n=9), .549 (n=6), .621 (n=3) respectively.

Table 18. Effect of tillage on barley grain yield, moisture, and test weight in Norman Co. on July 25, 1988, n=6.

Variable	Tillage: No Till	Chisel	Moldboard	Sig.
	bu/A			
Grain Yield	56.7	56.7	56.4	.959
	%			
Moisture	9.1	10.2	11.6	.043
	lbs./bu			
Test Weight	44.6	43.2	42.9	.123

Table 19. Effect of tillage and nitrogen rate on barley yield, moisture, and test weight at Norman Co. on July 25, 1988.

Variable	Tillage[1]: No Till		Chisel		Moldboard		Average[2]	
	Nitrogen Rate lbs/A							
	55	0	55	0	30	0	N	No N
	bu/A							
Grain Yield	62.0	51.3	60.2	53.1	56.8	56.1	59.7	53.5
	%							
Moisture	9.2	9.0	10.9	9.5	11.3	11.8	10.5	10.1
	lbs/bu							
Test Weight	44.2	45.0	42.5	43.8	42.8	43.0	43.2	43.9

1. The p value of the tillage by nitrogen interaction for barley yield, moisture and test weight is .222, .128, .075; (n=3) respectively.
2. The p value of nitrogen for barley yield, moisture and test weight is .034, .282, .006; (n=9) respectively.

Table 20. The effect of tillage on soybean yield and moisture at Norman Co. on Sept. 6, 1988, n=3.

Variable	Tillage: No Till	Chisel	Moldboard	Sig.
	bu/A			
Grain Yield	29.6	22.2	24.6	.010
	%			
Moisture	8.9	9.8	9.4	.262

The Effect of Tillage on Crop Production in West Central Minnesota[1]

J.F. Moncrief and J.J. Kuznia[2]

Abstract: Although tillage affected the amount of weeds present in soybeans following spring wheat it did not affect grain yields. At another site barley following soybeans was not affected by tillage.

Douglas County

This is the third year of this study. The rotation is barley, wheat, and soybeans. In 1988 soybeans were grown. The soil at this site is a Barnes-Langhei loam and is well drained. There has been little effect of tillage on crop yields at this site.

There were very little weeds at this site but several species were significantly affected by tillage (table 2). There was more foxtail and canada thistle with the no till system. Quackgrass density was higher with the chisel and moldboard plowing systems. The no till system received an application of Roundup on May 3, 1988.

Plant stands were lower with chisel plowing. Soybean grain yields were not affected by tillage (table 3) and yield levels were high in light of the low rainfall early in the season (3.25 inches in June and July). Rainfall in July and August totaled 5.88 inches.

DOUGLAS COUNTY

Table 1. Cultural practices at Douglas County, MN. 1988

Tillage
- No Till
- Fall Chisel Plow-field cultivated twice in spring
- Fall Moldboard Plow-field cultivated twice in spring

Preceding Crop

1985-Soybeans, 1986-Barley,
1987-Spring Wheat-Pioneer 2369 and
Winter Wheat-Bighorn and Roughrider

1988 Crop

Soybeans-Pioneer 1082

Planting and Harvest Date

Planter was a Great Western with 6.75 inch row spacing.

	Planting		
Crop	Date	Rate	Harvested
Soybeans	May 13, 1988	225,000 plants/A	October 5, 1988

1 Support for this project in part was provided by the Soil Conservation Service which is greatly appreciated. Data collection was assisted by Lisa M. Axton, Lee R. Johnson, Larry J. Zilliox, and Dennis Q. Miller, Becker County Agricultural Extension Agent, Becker County District Conservationist, Douglas County Agricultural Extension Agent and Douglas County District Conservationist respectively. Without their help this study would not have been possible.

2 John F. Moncrief and Joe J. Kuznia are Associate Professor and Assistant Scientist respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN. 55108.

Fertilization History

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			---	lbs/A	---	
Winter Wheat	18-46-0[1]	100 lbs/A	18	46	0	September 29, 1986
	46-0-0[2]	217 lbs/A	100	0	0	May 29, 1987
Spring Wheat	18-46-0[1]	100 lbs/A	18	46	0	April 21, 1987
	46-0-0[2]	217 lbs/A	100	0	0	May 29, 1987

1. Drill applied with seed.
2. Urea was broadcast.

Soil

Complex of: Barnes (Udic Haploborolls, fine-loamy, mixed)-Langhei (Typic Udorthents, fine-loamy, mixed (calcareous) ,frigid) loams, 2 to 6 percent slopes, well-drained eroded. The Langhei occurs on eroded knobs and Barnes on uniform slopes and valleys.

Weed Control

No Till Plots:
1 qt/A (.75 lb/A) Roundup + .75 pt/A (.375 lb/A) 2,4-D applied May 3, 1988.

Chisel and Moldboard Plots:
1 qt/A (1 lb/A) Treflan applied May 13, 1988 just prior to planting and incorporated in with two passes with a field cultivator.

No Till Plots:
1.5 pts/A (.28 lb/A) Poast + 1 gal/A 9-18-9 applied July 7, 1988.

Chisel and Moldboard Plots:
1 pt/A (.5 lb/A) Basagran + 1 pt/A (.25 lb/A) Blazer + 1 gal/A 9-18-9 applied on July 8, 1988.

Table 2. Effect of tillage on weed severity in soybeans at Douglas Co. on October 5, 1988, n=3.

Weed	Tillage: No Till	Chisel	Moldboard	Sig.
		% cover		
Foxtail	5.3	3.0	3.3	.060
Quackgrass	1.3	2.0	3.3	.004
Ragweed	1.0	1.3	1.0	.444
Canada Thist	2.7	1.7	1.7	.005

Table 3. Effect of tillage on soybean yields, moisture, and population in Douglas Co. on Oct. 5, 1988, n=3.

Variable	Tillage: No Till	Chisel	Moldboard	Sig.
		bu/A		
Grain:Yield	39.5	39.6	40.7	.820
		%		
Moisture	11.8	12.3	12.2	.147
		plants/A x 10^{-3}		
Population	236.2	196.6	229.7	.068

Becker County

This is the third year of tillage demonstration at this site. The crop rotation is similar to the Douglas County site; wheat, soybeans, and barley. This is the barley year.

It is surprising that the soybeans in 1987 resulted in the soil cover (shown in table 5) when tillage was eliminated. Tillage did not affect barley yields however (table 6). It did have a small but statistically significant effect on test weight however. Barley following soybeans have not been affected by tillage in five site years that are available collectively from the Norman, Douglas, and Becker County studies.

BECKER COUNTY

Table 4. Cultural practices at Becker County, MN. 1988.

Tillage

No Till
Fall Chisel Plowed on October 26, 1988
Fall Moldboard Plowed on October 26, 1988
Spring tillage consisted of a pass with a Multi Weeder on April 18, 1988.

Cropping History

1985-Barley, 1986-Winter and Spring wheat
1987-Soybeans

1988 Crop

Barley-Robust

Planting and Harvest Dates

Planter was a Haybuster No Till Disc Drill.

	Planting		
Crop	Date	Rate	Harvested
Barley	April 12, 1988	2 bushel/A	July 26, 1988

Fertilization History

			Actual				
Crop	Material Analysis	Rate	N	P_2O_5	K_2O	Date Applied	Method of Application
			---	lbs/A	---		
Soybeans	18-46-0[1]	110 lbs/A	20	51	0	June 2, 1987	Drill

Fertilizer 1988

			Actual				
Crop	Material Analysis	Rate	N	P_2O_5	K_2O	Date Applied	Method of Application
			---	lbs/A	---		
Barley	9-23-30[1]	110 lbs/A	10	25	33	April 12, 1988	Drill
	46-0-0	130 lbs/A	60	0	0	April 18, 1988	Broadcast

Soil

Hamerly clay loam (Aeric Calciaquolls, fine-loamy, frigid)-Winger silty clay loam (Typic Calciaquolls, fine-silty, frigid) complex, 2 percent slope. Soil is somewhat poorly drained to moderately well drained soil.

Weed Control

12 lbs/A (1.2 lbs/A) Far-Go 10G granules applied on November 3, 1988.
.5 pt/A (.25 lb/A) 2,4-D applied on May 23, 1988.
.75 pt/A (.375 lb/A) 2,4-D applied on June 15, 1988.

Table 5. Effect of tillage on soil covered by soybean residue in barley at Becker Co. on April 21, 1988,[1].

	Tillage			
Residue Location	No Till	Chisel	Moldboard	Avg.
	--------	% cover	--------	
In Row	86.2	13.3	2.4	34.0
Between Row	89.8	8.2	0.9	33.0

1. Tillage was significant < .100 in all cases, n=18.

Table 6. Effect of tillage on barley yield, moisture and test weight in Becker Co. on July 26, 1988, n=6.

	Tillage			
Variable	No Till	Chisel	Moldboard	Sig.
	--------	bu/A	--------	
Grain:Yield	71.5	76.2	74.6	.224
	--------	%	--------	
Moisture	10.5	10.2	9.9	.009
	--------	lbs/A	--------	
Test Weight	45.5	45.7	45.3	.011

CORN-TILLAGE RESIDUE MANAGEMENT, LANCASTER, WI. 1988

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ABSTRACT: Severe drought conditions throughout the 1988 growing season drastically reduced corn grain yields, which ranged from 43 bu/A for conventional moldboard plow normal to 68 bu/A for no-tillage mulch treatments. Mulch increased grain yield 20 bu/A on conventional moldboard plow treatments, and in general yields were highest on mulch treatments for all tillage systems studied. A reversal of crop height occurred for high and low cover treatments between 70 to 95 days postplant; the reversal apparently corresponded to the earlier onset of drought stress on low cover treatments. Plant populations were not significantly different between treatments. The effect of in-row cover on grain moisture was more than twice as great as previously measured, again presumably due to water conservation and growth delay effects of the mulch. Surface mulch approximately doubled the infiltration rate on the moldboard plowed treatment but did not increase infiltration rates on the no-tillage treatment.

SUMMARY OF RESULTS FROM LANCASTER TILLAGE RESEARCH

Data from the corn tillage residue management research at Lancaster were used to develop a method to estimate corn growth, yield and grain moisture from air growing degree days (Swan et al., 1987 a). A simulation model was used to determine grain yields as a function of soil depth for specific probability levels based on simulated site-specific daily climatic values generated for a 100-year frequency (Swan et al., 1987 b). A model of the corn yield response to water stress, heat units, and management for the period 1972 through 1984 for the tillage-residue management research was developed, calibrated and validated (Staricka, 1984; Swan et al., 1989 a and b). The effect of tillage and residue management on seed depth, soil temperature, and corn growth was determined for the period 1984 through 1988 (Swan et al., 1988).

INTRODUCTION

The driftless soil area has the greatest county average estimated soil losses from cropland in Minnesota, ranging from 4.0 to 6.6 t/ac/yr in the six counties involved. Typical soils of the region such as Fayette-Dubuque, Seaton, and associated soils, are highly erodible, form dense crusts if unprotected from raindrop impact, and consequently, have low final infiltration rates and high runoff from the intense storm events common to the region. New and improved tillage practices are increasingly being relied upon to meet environmental goals under more intense cropping systems. These systems modify the soil and water losses as well as the kind and concentration of materials in the runoff. A more complete understanding of these tillage-residue management systems and of their effect on soil physical conditions will allow a more accurate prediction of their effect on the environment and will permit them to be more effectively incorporated into the overall farming systems of the region.

EXPERIMENTAL PROCEDURES

The experimental site is located on the Lancaster Agricultural Research Station. Four tillage treatments are replicated four times (Table 1), the first replicate is located on Palsgrove silt loam; the other three replicates are on Rozetta silt loam. Each treatment is split into normal and mulched subtreatments. On the no-till plots an additional subtreatment (bare) is established by removing all residue prior to planting; this residue is then placed on the adjacent no-till mulched plot. Corn residue additions are made after tillage but before planting to obtain approximately 60 to 80 percent surface cover. Plots are approximately 90 to 100 feet

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in width and 80 feet in length. Row width was 36 inches in 1988. Pioneer 3737 was planted May 4, 1988 at 31,000 plants per acre. The conventional (Moldboard) treatment was plowed about April 27 and crop residue applied on April 28. No-till and chisel plots were planted with a 4-row John Deere 7000 Max-Emerge planter equipped with fluted coulters on one side and "trash whip" units on the other side which removed residue from an 8 to 9 inch area over the row. Fluted coulters were used on all four rows on the conventional and Ro-till treatments.

Nitrogen (250 lb/A of N as 28% N) was broadcast April 12. Starter fertilizer at planting was 200 lb/A of 6-24-24. The insecticide was Counter at 10 lb/A. Pre-emergence herbicide was applied on May 4 following planting (2.5 Qt/A of Bladex 80W and 2.5 pt/A of Dual 8E). A tank mix of Buctril and Banvel was applied postemergence on May 24 at 1 pint/A and 0.5 pints/A, respectively.

Percent cover was determined from slides taken May 18. Planting depth, rate of emergence, and silking date measurements were made on designated portions of each plot. Crop height measurements were also recorded. Hourly soil temperatures, leaf number, soil moisture, bulk density, percent cover and thermal conductivity were measured on chisel, no-till, and Ro-till treatments in Rep 3 for mulch added, bare, and normal treatments. Soil temperature was measured at depths of 1, 5, 10, 15, and 50 cm. Yields for individual plots were determined by hand harvesting 60 foot of row (two subsamples each consisting of paired 15 ft lengths of row) in October.

Ten plot frames (45 3/4 x 45 3/4 inches) were emplaced May 5 before the surface was weathered by rainfall. Infiltration measurements were made on Ro-till mulch, no-till bare and mulch, and conventional normal and mulch treatments during the period May 16- may 19. Paired tensiometer measurements were made at three depths within the plot frame during the infiltration event.

RESULTS-CORN YIELDS AND CROP HEIGHT

Severe drought conditions were present throughout the 1988 growing season at Lancaster. Precipitation was 13.02 inches below normal for the April to October period and air GDD (degrees F) were 422 above normal for May through September (Table 2). Consequently corn yields ranged from 43.1 bu/A for conventional normal to 68.1 bu/A for no-till mulch treatments (Table 1). Grain yields of individual tillage, residue, and in-row residue management treatment were significantly different at the 5 percent level of significance. Plant population was not significantly different between treatments. A reversal of crop height for high and low cover treatments occurred between 70 and 95 days post-plant (Figures 1 and 2). For the first 70 to 80 days mulch treatments were 20 to 30 cm shorter than bare or normal treatments; however, by day 70 for the ro-till and day 85 for chisel and no-till, crop height of the mulch treatments exceeded crop height of bare and normal treatments. On the no-till bare treatment drought stress was observed by day 62 prior to pollen shed on day 68. On the no-till mulch treatment tasseling did not occur until after day 75. The earlier incidence of drought stress on bare and normal treatments and the delayed phenologic stage of growth on mulch treatments apparently both contributed to the observed reversal in crop height.

For each tillage treatment grain yields from mulch treatments equalled or exceeded those from normal or bare treatments; mulch increased grain yield 20 bu/A on the conventional tillage treatment. Average corn grain yields of the replicates ranged from 52.4 bu/A for rep. one to 64.6 bu/A in rep. three. As in 1983, 1984, 1985, and 1986, corn grain yield increased as soil depth increased; however, in 1981, 1982 and 1987 rep. average grain yields were not related to average soil depth. Thus the effect of rooting depth and available water holding capacity in the root zone on grain yields depends greatly on the climatic conditions in the individual year as well as on the crop grown (Table 3).

SEEDBED CONDITIONS AND CORN GROWTH

For the 12 treatments, the average planting depths were statistically different at the 0.01 level of significance; the average standard deviation of planting depths were not statistically different.

The trash whip attachment (TW) reduced in-row residue cover nearly one-half compared to the in-row cover resulting from the coulter unit (C) (Table 1). The equation

$$\text{Eq 1: \% cover TW} = 1.6 + 0.51\ (\text{\% cover C})$$

explained 98% of the variation in % cover of the TW treatments in 1988. The effect of increasing in-row residue cover (by mulch additions) was to increase the number of days required to reach 75% emergence (Table 4) and to delay the date of silking (Table 1). The equation

$$\text{Eq 2: Days to 75\% emergence} = 15.0 + 0.071(\text{\% in-row cover})$$

explained 86% of the variation in days to 75% emergence.
Percent in-row cover was closely related to grain moisture (GM) in 1988 and the increase in grain moisture per percent of cover was more double that measured in previous years.

$$\text{1985 Eq 3: \% G M} = 20.5 + 1.97 \times 10^{-2}\ (\text{\% in-row cover}); R^2 = 0.87$$
$$\text{1986 Eq 4: \% G M} = 19.1 + 0.69 \times 10^{-2}\ (\text{\% in-row cover}); R^2 = 0.47$$
$$\text{1987 Eq 5: \% G M} = 17.1 + 1.24 \times 10^{-2}\ (\text{\% in-row cover}); R^2 = 0.49$$
$$\text{1988 Eq 6: \% G M} = 14.3 + 5.39 \times 10^{-2}\ (\text{\% in-row cover}); R^2 = 0.80$$

The greater effect of in-row cover on grain moisture in 1988 is presumably due to both the delay in growth and to water conservation by the mulch which prolonged plant growth during the drought. Grain moisture of individual treatments was significantly different (0.01 level of significance).

Percent in-row cover was closely related to air growing degree days (GDD) measured from planting to 6-leaf in 1988 as in previous years; however, the change in air GDD per % of in-row cover was three times greater than that measured previously, apparently caused by the insulation effects of the higher mulch rate of approximately 7 tons/A applied in 1988. A similar effect was observed in 1981 when mulch rates of 7 or more tons/A were applied.

$$\text{1984 Eq 7: Air GDD(6-leaf)} = 285 + 0.53\ (\text{\% in-row cover}); R^2=0.96$$
$$\text{1985 Eq 8: Air GDD(6-leaf)} = 273 + 0.47\ (\text{\% in-row cover}); R^2=0.91$$
$$\text{1986 Eq 9: Air GDD(6-leaf)} = 296 + 0.54\ (\text{\% in-row cover}); R^2=0.84$$
$$\text{1987 Eq 10: Air GDD(6-leaf)} = 278 + 0.52\ (\text{\% in-row cover}); R^2=0.79$$
$$\text{1988 Eq 11: Air GDD(6-leaf)} = 274 + 1.49\ (\text{\% in-row cover}); R^2=0.91$$

The close agreement of the intercept at zero cover in 1988 (274) with that measured in previous years indicates that the corn growth relationship to Air GDD on low residue treatments in 1988 was similar to that measured in previous years in spite of the drought conditions.

The effect of in-row residue cover and tillage on soil temperature and corn growth was evaluated at Lancaster in 1983, 1984, 1985, 1986, 1987, and 1988. Hourly soil temperatures were recorded for 1, 6, 11, 16, 50, and 100 cm depths under the row on chisel normal and mulch, no-till bare and mulch, and paraplow normal and mulch treatments in 1984, 1985, and 1986. In 1987 the Ro-till treatment replaced the paraplow treatment. No-till normal (trash whip) was also measured in 1987 and 1988. Soil temperatures were measured using 4-couples in parallel for 16 cm and shallower depths. Leaf stage observations were taken periodically through 6-leaf stage. Equation 11 was developed using station air temperatures and leaf stage observations from rep 3.

Adjacent strips 15 feet long and 1 foot wide (centered over the row) were painted on May 6 on no-till bare and mulch treatments. Black paint increased to absorption of solar radiation increased soil temperatures on the no-till bare treatment sufficiently to reduce the air GDD to 6-leaf by 7.5 degrees C. However the black painted no-till mulch treatment required 32 additional air GDD to reach the 6-leaf stage apparently due to greater mulch depth and thus greater insulating properties on the painted treatment.

In 1988, large differences in "final" (50-60 minute average) infiltration rates were measured between treatments

(Tables 5 and 6). Final infiltration rates from conventional tillage mulch treatments were 43% greater than conventional tillage normal residue treatments (Table 7). For the eight year period of measurement, mulch has approximately doubled the infiltration rate on conventional tillage. Infiltration rates on the no-till mulch were between the rates measured on the conventional normal and mulch treatments. In 1988 there was little increase in infiltration rate due to mulch on the no-till treatment, and both treatments averaged approximately 0.8 in/hr. For the eight year period the final infiltration rates on the no-till mulch treatment averaged approximately the same as that measured with the conventional moldboard tillage without residue (normal). Large increases in final infiltration rates were measured on no-till mulch compared to other treatments when nitrogen injection immediately preceded planting. Increases were also measured following the use of the paraplow.

Measurements with tensiometers at 3, 7 and 16 inch depths inside the infiltration frames during the infiltration runs have shown the presence of a flow restricting layer below the plow layer on moldboard mulch treatments. Crust formation on the moldboard normal treatments is indicated by the negative matric potentials measured in the plow layer. The surface crust formed by raindrop impact on the bare surface of the moldboard normal treatment restricts the flow rate sufficiently so that flow restriction from the layer below the plow layer is not observed during the infiltration run. Similar results have been observed in some but not all of the previous years when tensiometer measurements were made. Even though water was applied for more than 60 minutes, infiltrating water did not penetrate to the 3-inch tensiometer depth on the no till bare treatment in 4 out of 6 measurements.

The results again illustrate the requirement for rapid infiltration of 1) a porous surface layer with high saturated conductivity, 2) a protective mulch cover, 3) absence of flow restricting layers within the depth of infiltration. Residue cover alone is not sufficient to produce a high infiltration rate when significant restriction to flow occurs within the infiltrating profile.

SUMMARY

Five year yield results (1979-1983) with continuous corn at Lancaster show nearly equal yields from conventional (moldboard) tillage, ridge till, and chisel treatments. Nine year yield results (1979-1988) show nearly equal yields for conventional, chisel and no-till treatments (Table 8). In 1986, 1987, and 1988 no-till was the highest yielding treatment. Thus farmers in the driftless soil area can choose between a variety of tillage options which have yields comparable to conventional tillage, but which are superior in soil and water conservation and offer savings in time, labor, and fuel compared to the conventional moldboard plow tillage method.

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FIG 1 CROP HEIGHT VS TIME FOR NO-TILLAGE TREATMENTS

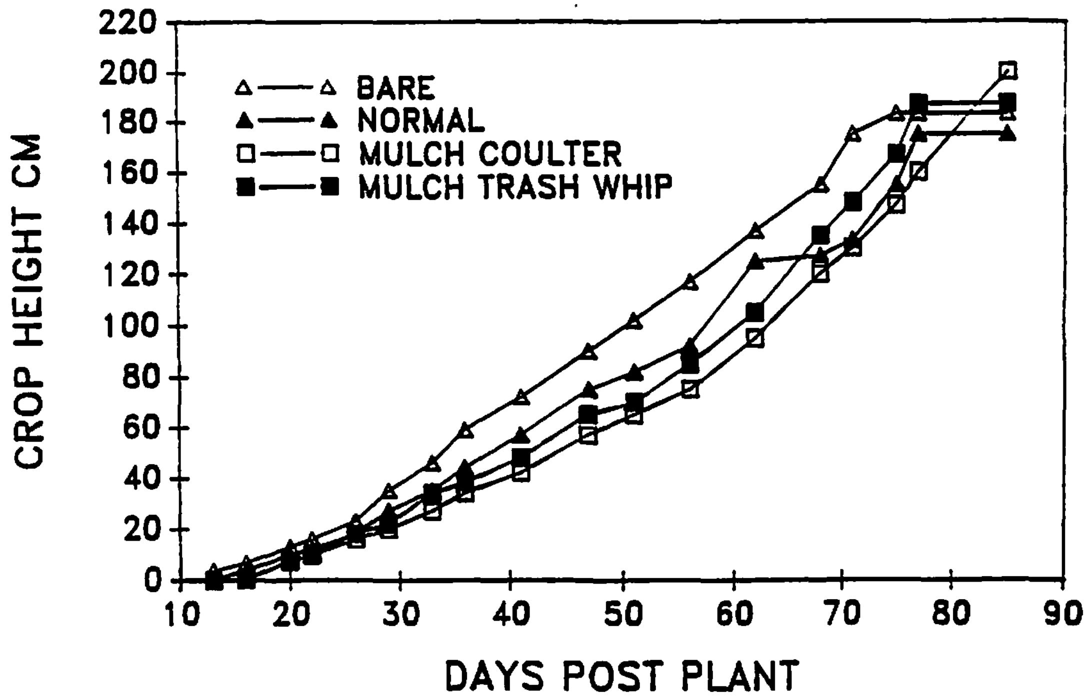

FIG 2 CROP HEIGHT VS TIME FOR CHISEL AND RO-TILL TREATMENTS

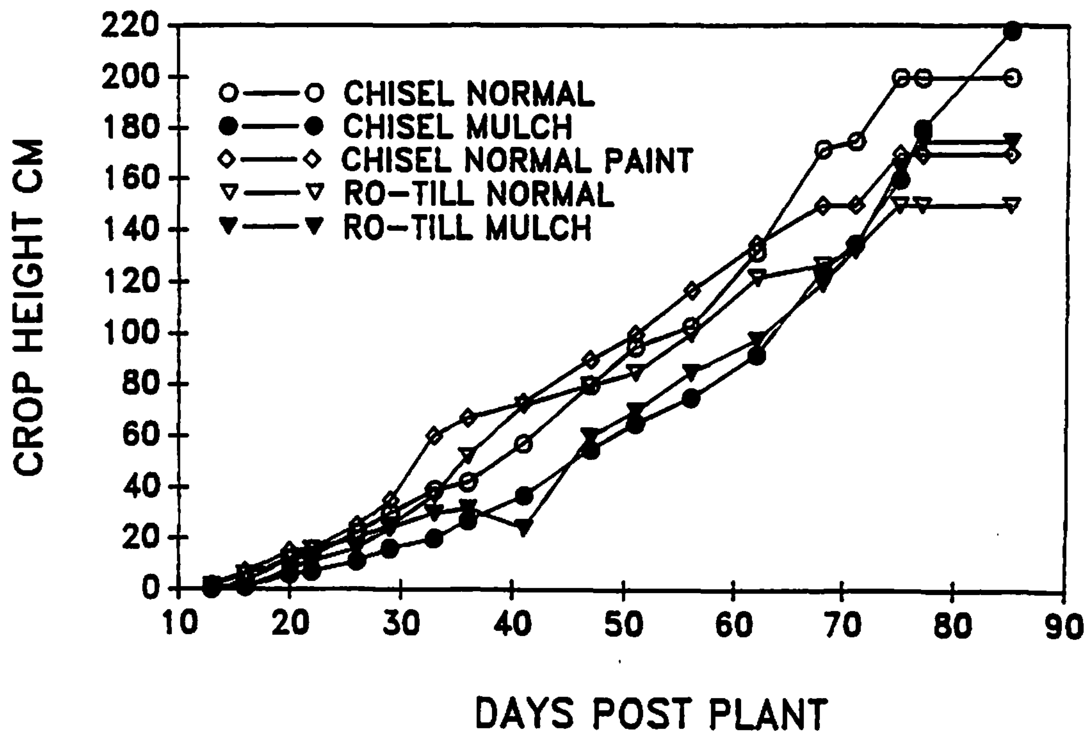

Table 1. Effect of Tillage and Mulch Treatments on Percent Cover, Planting Depth, Emergence, Silking Date, Population and Grain Yield-1988-Lancaster, WI.

Treatments: Tillage	Treatments: Residue	In-Row Residue MGT	Percent Cover: In Row	Percent Cover: Entire Area	Planting Depth: Avg. mm	Planting Depth: S.D. mm	Days Post Plant to 75% Emergence	Date 50% Silked July	Avg. Poplin at Harvest PL/A	Ave. Grain Yield Bu/Ac	Avg. Grain Moisture %
NoTill	Normal	C	43	70	26.5	7.4	18	17	26320	58.8	16.7
	(N)	TW	24	41	34.1	5.4			27950	62.3	16.1
	Bare	C	7	6	28.4	7.6	15	14	25770	58.1	13.8
	(0)	TW	5	6	37.0	6.1			27410	56.9	15.0
	Mulch	C	92	95	35.4	10.0	19.5	20	25530	66.4	18.9
	(2X)	TW	52	66	38.8	6.6			26620	68.1	18.5
Bush Hog	Normal (N)	C	12	29	35.1	7.0	16.5	15.5	26920	54.2	14.6
	Mulch (2X)	C	75	88	33.5	8.4	21	21	25650	67.6	19.8
Chisel	Normal (N)	C	7	13	35.9	6.6	16.5	14.5	26320	56.5	14.5
		TW	5	8	42.0	7.2			25650	55.5	14.5
	Mulch (1X)	C	91	97	38.6	7.3	21	20.5	26860	60.8	19.0
		TW	44	58	34.4	6.1			25170	56.3	17.9
Conv	Normal (N)	C	2	3	42.4	6.2	14	13.5	24380	43.1	13.4
	Mulch (1X)	C	93	96	43.5	7.0	23.5	21	24320	63.3	17.3
	Significance Level								NS	0.05	0.01

Table 2. 1988 Weather Summary Lancaster, WI Agricultural Research Station

Month	Precipitation inches: Total	Precipitation inches: Departure	Growing Degree Days: 1988	Growing Degree Days: Departure	Air Temperatures: Average Max	Air Temperatures: Average Min	Air Temperatures: Average Daily	Air Temperatures: Departure
	- - - inches - - -		- - - - - - - -	- - - - - - - -	- - - - of - - - -	- - - -	- - - -	- - - -
April	1.16	-1.87	--	--	59.0	34.7	46.8	-0.2
May	0.87	-1.58	375	+ 71	76.5	47.6	62.0	+3.9
June	0.42	-3.99	613	+ 93	86.0	56.4	71.2	+4.0
July	1.80	-2.40	721	+ 58	89.7	61.5	75.6	+3.9
August	2.92	-1.51	712	+119	86.8	63.4	75.1	+6.1
September	3.96	+0.40	439	+ 81	76.0	51.3	63.6	+2.6
October	1.27	-1.07	--	--	54.6	32.5	43.6	-6.4
Total Growing Season	12.40	-13.02	2860	+422				

Last day in spring with minimum temperature: 32° or less 4/27 (32°F)
28° or less 4/21 (17°F)

First day in fall with minimum temperature: 32° or less 10/4 (31oF)
28° or less 10/5 (28°F)

Table 3. Average Yields and Depth to Clay Residuum by Replicate and Monthly precipitation for 1981 through 1988, Lancaster, WI.

	Replicate Number				Monthly Precipitation			
	1	2	3	4	May	June	July	August
Year	Bu/Ac				inches			
1981	146.8	146.7	142.1	147.1	0.85	4.28	2.91	11.35
1982	150.0	143.4	142.8	147.3	5.46	3.45	5.29	4.06
1983	72.8	85.2	96.4	111.2	5.18	3.28	3.34*	3.12*
1984	107.3	110.4	118.0	120.1	3.92	7.77	2.57**	1.37**
1985	118.5	121.1	129.6	130.6	4.95	1.32***	2.11***	3.34
1986	159.5	162.4	168.6	164.8	3.90	5.47	1.85	3.65
1987	168.3	167.7	170.9	168.0	3.78	4.15	6.71	6.78
1988	52.4	56.9	64.6	62.6	0.87	0.42	1.80	2.92
Avg. Depth to Clay Residuum inches	29	41	46	62				

1981 - Subplots with population < 17,000 omitted.
1982 - Missing values estimated for 8 plots out of a total or 48 plots.
1983 - Subplots with population < 18,000 omitted Rep. II, III, IV.
*1983 - 1.13 inches precipitation from July 3 to Aug. 25 (53 days).
**1984 - 1.52 inches precipitation from July 18 t Aug. 31 (45 days.
***1985 - 1.59 inches precipiation from May 28 to July 25 (57 days). Largest rain was 0.36 inches.

Table 4. Influence of tillage method and residue management on rate of emergence - 1988 Lancaster, WI.

Treatment		Coulter or trash	Percent Emergence						
			Days Post Plant						
Tillage	Residue	whip unit	13	15	17	21	23	27	30
No-Till	Normal	C	4	17	67	96	99	100	-
	Bare	C	44	76	90	99	100	-	-
	Mulch	C	1	6	43	89	97	98	100
Bush Hog	Normal	C	10	31	84	97	98	99	100
Ro-Till	Mulch	C	1	3	16	77	79	97	100
Chisel	Normal	C	13	40	82	97	100	-	-
	Mulch	C	0	1	18	75	88	98	100
Conventional	Normal	C	61	85	88	98	99	100	-
	Mulch	C	1	10	34	68	73	94	100
Air Growing Degree Days from planting		'F	151.5	173.	204.	269.5	295	377.5	445.0
(including plant date May 4)		'C	84.2	96.1	113.3	149.7	163.9	209.7	247.0

All treatments reached 100% emerged by Day 30.
May 4 = Day 1

Table 5. 1988 Lancaster, WI Infiltration Rate Measurement.

Tillage	Residue	Rep.	Application rate	Water applied before runoff	Infiltration rate X min. after runoff commences - in/hr. 2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5
			in/hr	inches	- - - - - -						- inches/hour -					- - -
No Till	Bare	E	4.32	0.36	1.92	0.96	1.20	0.48	0.24	0.24	0.24	0.24	0.24	0.48	0.72	0.72
		W	4.32	0.50	1.44	1.20	1.44	0.48	0	0.48	0.48	0	0	0.48	0.96	0.96
	Mulch	E	4.32	0.40	3.48	2.52	1.92	1.44	1.20	0.96	0.72	0.24	0.96	0.48	0.72	0.72
		W	4.40	0.59	3.20	2.12	2.00	1.88	1.76	1.04	1.04	0.56	1.04	0.80	0.80	1.04
Conv.	Normal	E	5.04	1.64	4.20	3.48	2.88	2.88	2.40	2.40	1.80	1.32	1.44	2.16	1.68	2.16
		W	4.80	1.84	3.96	3.48	3.00	2.76	2.40	2.28	1.32	1.44	1.44	1.44	1.68	1.68
	Mulch	E	4.80	1.92	-	0.96	0.72	0.72	0.96	1.68	1.44	1.20	1.56	1.56	1.80	2.04
		W	4.56	3.19	4.08	3.48	3.36	3.36	3.48	3.36	3.36	3.36	3.36	3.36	3.36	3.12
Bush Hog	Mulch	E	4.24	1.06	2.08	1.84	1.84	1.84	1.60	1.36	1.60	1.36	1.12	1.84	1.84	2.32
Ro-Till		W	4.16	1.11	3.68	2.24	2.00	2.24	2.00	1.76	1.76	1.28	1.52	1.52	1.52	2.00

Table 6. Infiltration rate 55 minutes after runoff begins (paired observations).

Tillage	Treatment Residue	1981	1982	1983	1984	1985	1986	1987	1988	Avg.
		------------				inches/hour				------------
No Till	Bare	--	--	--	1.68	1.00	1.24	1.26	0.84	
	Mulch	1.46	1.10	3.53*	0.60	3.02	2.10	1.22	0.82	1.47+
Conventional	Bare	0.97	1.52	0.54	1.70	1.40**	1.83	1.15	1.80	1.36
	Mulch	2.72	2.34	1.49	2.90	2.14**	2.25	4.81	2.58	2.65
	------------				Ratio					------------
Conv. Bare/Conv. Mulch		0.36	0.65	0.36	0.58	0.65	0.81	0.24	0.70	0.51
No Till Mulch/Conv. Bare		1.51	0.72	6.53	0.35	2.16	1.15	1.06	0.46	1.00+

* Soil disturbed prior to planting by anhydrous ammonia injection.

** 1 observation only.

\+ omit 1983

Table 7. Relationship of infiltration rates (Avg. 40 to 60 min. after runoff starts) to matric potential - 1988 Lancaster.

Treatment			Infilt	cm soil depth						
				7.5	17.5	40	7.5	7.5	17.5	40
Tillage	Residue	Rep.	in./hr	cm H_2O						
No-Till	Bare	E	0.54	-202	- 87	- 75	-33	-113	-	-
		W	0.64	-160	-107	+ 9	-10	- 12	-40	-
	Mulch	E	0.72	- 36	- 49			- 24	+24	-
		W	0.92	- 6	- 32	- 95		- 30	-	+ 12
Conven.	Normal	E	1.86	- 12	- 6	- 85		+ 3	- 5	-219
		W	1.56	- 10	- 4	-240		+ 4	- 5	- 1
	Mulch	E	1.74	+ 8	+ 9	+ 35	+12	+ 8	-10	-
		W	3.30	+ 6	+ 7	- 33	+22	+ 13	+ 9	+ 28
Ro-Till	Mulch	E	1.78	+ 2	- 31	+ 2		+ 3	+ 2	
		W	1.64	- 58	+ 12	- 3		- 19	-39	

Table 8. 1979-1988 Continuous corn tillage yield results, Lancaster, WI.

Tillage Treatment with normal residue	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	79-83	79-88
	bu/A											
Ridge plant	162	157	157	147	100	---	---	---	---		145	---
No-Till (slot plant)	163	146	151	141	85	108	120	165	177	59	137	132
Chisel	160	150	167	154	95	115	125	159	168	57	145	135
Conventional	169	159	168	151	89	121	133	164	168	43	147	137
Paraplow*	---	---	---	---	---	106	125	162	---	---	---	---
Ro-Till	---	---	---	---	---	---	---	---	172	54	---	---

*Fall 1983 and Fall 1984

APPENDIX

Directory to information by crop or production influencing factor

Page

WEATHER

CORN

SOYBEANS

WHEAT

BARLEY

RYE

SUGARBEET

POTATO

RED CLOVER

LUPIN

ROTATION

FERTILIZER PLACEMENT

NITROGEN

PHOSPHORUS

POTASSIUM

SULFUR

ENVIRONMENTAL CONCERNS